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6. AUTHOR(S)

DR. I. EDWARD BLOCK

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

SIAM
3600 UNIVERSITY CITY SCIENCE CENTER
PHILADELPHIA, PA 19104-2688

8. PERFORMING ORGANIZATION REPORT NUMBER

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A SIAM Conference on Optimization was held on May 11-13, 1992 in Chicago. Over three hundred papers were presented at the 75 sessions.

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Final Report
Fourth SIAM Conference on Optimization
May 11-13, 1992
Chicago

The Fourth SIAM Optimization conference gave further evidence of the continuing growth and interest in optimization.. As evidence of this observation we note that there were 262 papers presented at the 1989 conference, but 301 papers at this conference.

The conference themes, invited speakers, and minisymposia of the conference were chosen around three main areas:

- Large scale optimization problem
- Optimization applications
- Optimization problems in control

This was done because the organizers felt that optimization research will lead to significant advances in scientific computing by addressing important applications problems. Of special interest were the following minisymposia on optimization problems in applications:

- Global and local optimization methods for molecular chemistry problems
- Optimal design of engineering systems
- Optimization problems in chemical engineering
- Problems "off-the-shelf" Newton methods won't solve
- Protein Folding – A challenging optimization problem

Interaction between optimization researchers and application scientists was fostered by organizing sessions along optimization areas. As a result, attendance at sessions was increased. The main complaint was that there were too many interesting talks; never that there were no interesting talks at a given time.

We also tried to attract application scientists to the conference by arranging for a preconference tutorial centered on optimization software. The tutorial was quite successful with 93 attendees. Attendees of the tutorial praised, in particular, the presentations, and the software guide that was part of the program. A copy of the software guide is enclosed.

We also tried to increase interaction between attendees by scheduling the social sessions together with the poster sessions. This resulted in well attended poster sessions, and considerable discussion between the attendees.

Complaints centered around the large number of presentations. In order to accommodate the large number of presentations, and keep the number of parallel sessions to a reasonable number (6), many of the talks were shifted to poster sessions. This decision was not entirely popular. Possible methods for dealing with this problem are scheduling a four day conference, and being more selective in the acceptance of papers. Each of these solutions has obvious drawbacks. A more imaginative use of poster sessions may be a better solution. At this conference we tried to increase the status of poster sessions by awarding a prize for best poster. This had some success.

The general feeling was that the conference was highly successful, and that there was a definite need for SIAM Conferences on Optimization. The technical program, the SIAM staff, and the choice of city and site, were singled out as noteworthy by the attendees. The enclosed program contains additional details of the meeting. In particular, the program overview is on page 3.

Jorge Moré (co-chair)
Argonne National Laboratory

Jorge Nocedal (co-chair)
Northwestern University

Jane Cullum
IBM Thomas J. Watson Research Center

Donald Goldfarb
Columbia University

Society for Industrial and Applied Mathematics
3600 University City Science Center
e-mail: siam@siam.org
Philadelphia, PA 19104-2688
Fax: (215) 386-7999
Telephone (215) 382-9800
Telex: 446 715

40th ANNIVERSARY
1952 · 1992

LIST OF ATTENDEES

CONFERENCE OF OPTIMIZATION

MAY 11-13, 1992

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Mehiddin, Al-Baali
University of Calabria
Department of Systems
87036 Rende-Cosenza
Cosenza, Calabria 87036
Italy
0984-493209

Natalia, Alexandrov
Rice University
Department of Math Sciences
P O Box 1892
Houston TX 77251-1892
natalia@rice.edu

Abdulrahim, Alghamdi
Apt # 201
16 W 465 Mockingbird Lane
Hinsdale IL 60521
(708) 986-8303

Farid, Alizadeh-Dehkharghani
4
1235 Cortez Dr
Sunnyvale CA 94086-5651
alizadeh@icsi.berkeley.edu (404) 894-3037

Faiz, Al-Khayyal
Georgia Inst of Technology
School Industrial & Syst Engr
Atlanta GA 30332-0205
(312) 988-8889
falkhayy@gtri01.gatech.edu

J Ray, Alley
Board of Trade
821 W Broadmoor
Pedria IL 61614

Deborah F, Allinger
Draper Laboratories
Department ES
555 Technology Square
Cambridge MA 02139-3539
(617) 258-2269

Juergen, Amendinger
Univ of Southern California
Dept of Applied Mathematics
1154 W 30th Street
Los Angeles CA 90007

Paul B, Anderson
3521 Launcelot Way
Annandale VA 22003-1

Kurt M, Anstreicher
University of Iowa
Dept of Management Science
Iowa City IA 52242
(319) 335-0859

Shawki, Areibi
University of Waterloo
Dept of Elec & Comp Engr
Waterloo N2L 3G1
Ontario, Canada

Jasbir, Arora
University of Iowa
College of Engineering
1129 Engineering Bldg
Iowa City IA 52242

Miroslav D, Asic
Ohio State University
Department of Mathematics
University Drive
Newark OH 43055
(614) 366-9418
masic@magnus.acs.ohio-state.edu

David S, Atkinson
273 Altgeld Hall
1409 W Green St
Urbana IL 61801-2917
(217) 333-1809

Giles, Auchmuty
University of Houston
Department of Mathematics
Houston TX 77204-34
(713) 749-2124
auch@uh.edu

Brett M, Averack
Bldg 221
9700 South Cass Ave
Argonne IL 60439-4806
(708) 252-6529
averick@mis.anl.gov (914) 945-1298

Francisco, Barahona
IBM Corporation
T J Watson Research Center
PO Box 218
Yorktown Hgts NY 10598-0218
barlow@cs.psu.edu
barahon@ibm.com

Jesse L, Barlow
Penn State University
Department of Computer Scie
University Park PA 16802
(814) 863-1705

Pablo, Barrera-Sanchez
av de la Luz 61
col San Simon
Mexico 13 DF
cp 03660
Mexico

Tamer, Basar
University of Illinois
Coordinated Science Lab
1101 W Springfield Avenue
Urbana IL 61801-3082
(217) 333-3607
tbasar@markov.csl.uiuc.edu

James C, Bean
University of Michigan
Dept of Indu & Oper Engr
1205 Beal
Ann Arbor MI 48109-21

Thomas, Beergrehn
Case Western Reserve Univ
Dept of Systems Engineering
10900 Euclid Avenue
Cleveland OH 44106

William J, Behrman
116 F Escondido Village
Stanford CA 94305-7480
(415) 497-6104
behrman@na-net.stanford.edu (814) 863-2115

Ashok D, Belegundu
Pennsylvania State Univ
Mechanical Eng Dept
University Park PA 16802

A, Benchakroun
Universite de Sherbrooke
Department of Math Info
Sherbrooke J1K 2R1
Quebec, Canada
(819) 821-7034

Aharon, Ben-Tal
Technion Israel Institute of Technology
Facutly of Ind Eng & Managemnt
Haifa 32000
Israel
04 294444
ierbt99@technion.bitnet

Dimitris, Bertsimas
Massachusetts Inst of Tech
Sloan School of Management
E53-359
Cambridge MA 02139
dbertsim@math.mit.edu

Lorenz T, Biegler
Carnegie Mellon University
Dept of Chemical Engineering
Pittsburgh PA 15213

Christian H, Bischof
Argonne National Labs
Math & Comp Sci Div, Bldg 221
9700 S Cass Avenue
Argonne IL 60439-4806
(708) 252-8875
bischof@mcs.anl.gov

E R, Bishop
Acadia University
Department of Mathematics
Wolfville
B0P 1X0 Nova Scotia
Nova Scotia, Canada

Johannes J, Bisschop
Westerhoutpark 28
20 JN Haarlem
Netherlands

Maria L, Blanton
Univ of North Carolina
601 S College Road
Wilmington NC 28403

Paul T, Boggs
Nat'l Inst of Standards & Te
Building 225, Room A-151
Gaithersburg MD 20899
(301) 975-3800
boggs@cam.nist.gov

Ingrid, Bongartz
IBM Corporation
Dept of Math Sciences
PO Box 218, TJ Watson Res Cntr
Yorktown Hghts NY 10598

Joseph Frederik, Bonnans
INRIA
Domaine de Voluceau
BP 105 Rocquencourt
78153 Le Chesnay Cedex
France

Robert, Bosch
Oberlin College
Department of Mathematics
Oberlin OH 44074

Ali, Bouaricha
Apt C2-G
2031 Grandview Ave
Boulder CO 80302-6552

M, Bouhtou
INRIA
Domaine de Voluceou
Rocquencourt BP 105
78153 Le Chesnay Cedex
France

Stephen, Boyd
Stanford University
Dept of ISL & EE
111 Durand
Stanford CA 94305
(415) 723-0002
boyd@isl.stanford.edu

Gordon H, Bradley
Naval Postgraduate School
Dept of Operations Research
Monterey CA 93943
(408) 646-2359

Jerome G, Braunstein
604 Gretchen Road
Chula Vista CA 91910
(619) 534-7494
jerome@ucsd.edu brenan@aerospace.aero.org

Kathryn E, Brenan
5324 W 135th St
Hawthorne CA 90250-49
(213) 336-4503

Dennis L, Bricker
University of Iowa
Dept of Industrial Engr
4110 Engineering Blvd
Iowa City IA 52242

Albert G, Buckley
Royal Roads Military College
Department of Mathematics
FMO Victoria V0S 1B0
British Columbia, Canada
604-363-4594
buckley@agb.royalroads.ca dsbunch@ucdavis(.edu or.bitnet)

David S, Bunch
Univ of California, Davis
Graduate School of Manageme
308 Voorhies
Davis CA 95616
(916) 752-2248

Hermann G, Burchard
Oklahoma State University
Department of Mathematics
Stillwater OK 74078
(405) 744-5690
burchard@nemo.math.okstate.edu (206) 543-6183

James V, Burke
University of Washington
Dept. of Mathematics
GN-50
Seattle WA 98195

burke@math.wasington.edu

John A, Burns
Virginia Polytechnic Instit
and State University
Department of Mathematics
Blacksburg VA 24061

Cheri, Bush
University of Cincinnati
Dept of Civil Engineering
M L 71
Cincinnati OH 45221

Richard H, Byrd
University of Colorado
Department of Computer Science
Campus Box 430
Boulder CO 80309

Paul H, Calamai
University of Waterloo
Dept of Systems Design Eng
Waterloo N2L 3G1
Ontario, Canada
phcalamai@watfun.waterloo.ec

Gale F, Capps
Sherwin-Williams Company
Automotive Tech Center
10909 S Cottage Grove Avenue
Chicago IL 60628
(312) 821-2152

Alan, Carle
Rice University
Cntr for Resc on Parallel Comp
PO Box 1892
Houston TX 77251
(713) 285-5368
carle@rice.edu

Celso, Carnieri
Univ of Illinois @ Urbana
Department of forestry
Urbana IL 61801
(217) 384-5526

Richard G, Carter
Argonne National Lab
MCS Division
Argonne IL 60439
(708) 252-5431
carter@mcs.anl.gov

Lori, Case
University of Waterloo
Dept of Computer Science
Waterloo N2L 3G1
Ontario, Canada
France

Cavalli
Enseeiht
Dept de Electronique
2 Rue C Camichel
Toulouse 31071

Mark E, Cawood
Apt# 13
813 College Ave
Clemson SC 29631-1045
(803) 656-5196
mcawood@clemson.bitnet

S S, Chadha
University of Wisconsin
Department of Mathematics
Eau Claire WI 54702
(715) 836-2835

Veena, Chadha
Univ of Wisconsin
Department of Mathematics
Eauclaire WI 54701

Vira, Chankong
Case Western Reserve Univ
Dept of Systems Engineering
10900 Euclid Avenue
Cleveland OH 44106-7070

Wai, Chan
Digital Equipment Co
AETI-2/7
6 Tech Drive
Andover MA 01810-2434
( ) 474-6402

George Hong-Gang, Chen
604 150th Place SW
Lynnwood WA 98037
chen@amath.washington.edu

Jen-Ming, Chen
Penn State University
Dept of Industrial Engr
207 Hammond Bldg
State College PA 16801

Mei-Qui, Chen
The Citadel
Department of Mathematics
And Computer Science
Charleston SC 29409-0255
(803) 792-9868
chenm@citadel.bitnet lu@jupiter.eecs.nwu.edu

Peihuang Lu, Chen
Northwestern University
Dept of Indu Engr & Mgmt Sc
197-B Brittany Dr
Streamwood IL 60107
(708) 491-7263

Shaohua, Chen
McMaster University
Dept of Elec & Comp Engr
1280 Main West
Hamilton L8S 4L7
Ontario, Canada

Daniel C, Chin
Johns Hopkins University
Applied Physics Laboratory
Johns Hopkins Road
Laurel MD 20723-6099

Hern, Chin
Aspen Technology
251 Vassar Street
Cambridge MA 02139

Paulina, Chin
University of Waterloo
Department of Electrical &
Computer Engineering
Waterloo N2L 3G1
Ontario, Canada
pchin@watfun.waterloo.edu

Eugene Inseok, Chong
Northwestern University
Dept of Computer Science
Evanston IL 60201
(708) 475-8124
woosh@rice.edu

Pang-Chieh, Chou
Rice University
Dept of Math Sciences
PO Box 1892
Houston TX 77251
(713) 527-8750 X2750

Bock Jin, Chun
University of Wisconsin
704 Eagle Heights
Madison WI 53705

Anne W, Clark
1320 Knollwood Drive
Arlington Hghts IL 60004
(708) 632-5544
clarka@mot.cid Cambridge MA 02139-3758

Shepard A, Clough
Atmospheric & Environmental
Research Inc
840 Memorial Drive

William J, Clover Jr
412 S 7th Ave
Maywood IL 60153-1505
(312) 642-8273

Thomas F, Coleman
Cornell University
Department of Computer Science
Upson Hall
Ithaca NY 14853-7501
(607) 255-9203
coleman@guax.is.cornell.edu

Michael D, Collins
101
4508 Commons Drive
Annandale VA 22003
(202) 767-9037
collins5@ccf.nrl.navy.mil

Domenico, Conforti
Universita della Callabria
Dipartimento di Sistemi
Rende Cosenza 87036
Italy
(984) 493 209
2101gra@icsuniv.bitnet

Andrew R, Conn
IBM, Thomas J Watson Res Ctr
PO Box 218
Yorktown Hgts NY 10598-0218
(914) 945-1589
arconn@yktvmz.bitnet conroy@super.org

John M, Conroy
Supercomputing Research Cent
17100 Science Dr
Bowie MD 20715-437
(301) 805-7425

Martha P,Contreras
University of California
Department of Mathematics
Riverside CA 92521
(714) 787-3114
martha@ucrmath.ucr.edu (713) 527-8101 X3776

Debora, Cores
Rice University
Dept of Mathematical Sciences
PO Box 1892
Houston TX 77251-1892
georgec@boris.mscs.mu.edu
cores@rice.edu

George F, Corliss
Marquette University
Department of Mathematics
Milwaukee WI 53233
(414) 288-6599

Richard W, Cottle
Stanford University
Department of Operations
Research
Stanford CA 94305-4022
(415) 725-0557
cottle@sierra.stanford.edu

Charles R, Crawford
39 Mac Pherson Avenue
Toronto M5R 1W7
Ontario, Canada
(416) 922-7997

Jane K, Cullum
14 Ridgeview Ln # 2
Yorktown Hgts NY 10598-104
(914) 945-2227
cullumj@watson.ibm.com

Norman D, Curet
UCLA
6220 Anderson Graduate School
of Management, 405 Hilgard Ave
Los Angeles CA 90024-1481

Joseph J, Czyzyk Jr
1109 Garnett Place
Evanston IL 60201-3107
czyzyk@iems.nwu.edu University Park PA 16802

Thomas, D'Alfonso
Penn State University
Dept of Industrial Engineeri

Edward J, Dean
University of Houston
Department of Mathematics
4800 Calhoun Road
Houston TX 77204-3476
(713) 749-2124

Kalyanmoy, Deb
Univ of Ill/Urbana-Champaign
Dept of Engr,104 S Mathews Ave
117 Transportation Building
Urbana IL 61801

E, De Klerk
University of Pretoria
Dept of Mechanical Engr
Pretoria 0001 RSA
Republic of South Africa

Jose L, De La Fuente
Iberdrola
Hermosilla 3
28001 Madrid
Spain

Renato, De Leone
University of Wisconsin
Department of Computer Science
1210 W Dayton
Madison WI 53705
(608) 262-5083
deleone@cs.wisc.edu

Robert W, Deming
SUNY College-Oswego
Department of Mathematics
Oswego NY 13126
(315) 341-2736

J E, Dennis Jr
Rice University
Dept of Mathematical Sciences
P O Box 1892
Houston TX 77251-1892
(713) 527-4094
dennis@rice.edu (0192) 39-7915

Alvaro R, De Pierro
Universidade Estadual Campinas
Inst Matematica Estatistica e
Ciencia da Computacao, CP 6065
13081 Campinas SP
Brazil
db@math.fundp.ac.be
alvaror@bruc.ansp.br

Burton, Didier
F U N D P
Department of Mathematics
Rempart de la Vierge 8
B-5000 Namur
Belgium

Garry, Didinsky
University of Illinois
Coordinated Science Lab
1101 W Springfield Avenue
Urbana IL 61801

Raymond S, Di Esposti
6439 Hardwick Street
Lakewood CA 90713
(213) 336-8404
diespos@aerospace.aero.org Russia

I I, Dikin
Siberian Energy Institute
130 Lermontov Street
Irkutsk 664 033

Jiu, Ding
Univ of Southern Mississippi
Department of Mathematics
Southern Station, Box 5045
Hattiesburg MS 39406
(601) 266-4292
ding@usmcp6.bitnet

Gianni, Di Pillo
University of Rome
Dept of Information & Systems
Via Eudossiana 18
00184 Rome
Italy
domich@bldr.nist.gov

Paul D, Domich
National Inst of Standards &
Technology 881
325 Broadway
Boulder CO 80303-332
(303) 497-5112

R A, Donnelly
Auburn University
Department of Chemistry
Auburn AL 36849

Asen L, Contchev
Mathematical Reviews
416 4th St
Ann Arbor MI 48107
(313) 996-5270
ald.achilles.mr.ams.com

Robin, Duquette
1800 Montee Ste-Julie
Varennes J3X 1S1
Quebec, Canada
(514) 652-8239

Jean Pierre, Dussault
Université de Sherbrooke
Departement de Math & Info
Sherbrooke J1K 2R1
British Columbia, Canada
(819) 565-3548

Jonathan, Eckstein
Thinking Machines Corporation
245 1st St
Cambridge MA 02142-1264
(617) 234-2866
eckstein@think.com edsberg@nada.kth.se

Lennart, Edsberg
KTH Stockholm
NADA, Kth
S-100 44 Stockholm
Sweden

Mahmoud M, El-Alem
University of Texas
Dept Math & Computer Science
San Antonio TX 78249-0600

Amr Saad, El-Bakry
Rice University
Dept of Mathematical Sciences
PO Box 1892
Houston TX 77251-1892
(713) 527-8750 X3824
elbakry@rice.edu

Sam, Eldersveld
4323 170 Pl S E
Issaquah WA 98027-900

Moe, El-Khadiri
Argonne National Labs
Dept of Math & Computer Sci
9700 S Cass Ave
Argonne IL 60439

Gary, Elsring
Upjohn Company
9164-36-1
Dept of Bis-Statistics
Kalamazoo MI 49007

Steve F, Elston
Mobil Rsch & Development ,Cor
PO Box 819047
Dallas TX 75381-904

Ramin S, Esfandiari
California State University
Dept of Mechanical Engineering
1250 Bellflower Blvd
Long Beach CA 90840

Elizabeth A, Eskow
University of Colorado
Dept of Computer Science
Campus Box 430
Boulder CO 80309
(303) 492-8157

Francisco, Facchinei
Univ of Rome "La Sapienza"
Dipt di Informatica e Sistem
Via Buonarroti 12
00185 Roma
Italy
39-6-487 3676
facchinei@irmiasi.bitnet

Guangxiong, Fang
Daniel Webster College
Dept of Engr Math & Science
20 University Dr
Nashua NH 03063

Mao, Fang
University of Cincinnati
Dept of Civil Engineering
M L 71
Cincinnati OH 45221

Ko Hui M, Fan
2691 Smoketree Way NE
Atlanta GA 30345-9156

Joel E, Farrand
6159 Pritchett Drive
Suite 500
100 Northcreek
Powder Springs GA 30073
(404) 261-5256

Mary C, Fenelon
C Plex Optimization Inc
1601 Ashbury Pl
Eagan MN 55122-1223
(612) 683-9934

Dan, Feng
University of Colorado
Department of Computer Scien
Campus Box 430
Boulder CO 80309
(303) 492-4463
feng@cs.colorado.edu

Peter A, Fenyes
2324 Buckingham Avenue
Birmingham MI 48009-5869
(313) 986-0460
fenyes@gmr.com Ames IA 50011

David F, Fernandez-Baca
Iowa State University
Department of Computer Science
209 Computer Science Bldg
Madrid 28006
(515) 294-2168

Jose L, Fernandez
Red Electrica de Espana
Estudios de Red
Paseo de la Castellana 95

Spain

Luis M, Fernandes
Escola Superior De Tecnologia
De Tomar
Av Candido Madureira 13
2300 Tomar
Portugal
351-49-321500

Michael C, Ferris
University of Wisconsin
Department of Computer Science
1210 W Dayton Street
Madison WI 53711
(608) 262-4281
ferris@cs.wisc.edu

Sharon K, Filipowski
Cornell University
ETC 206 / ORIE
Ithaca NY 14853
(607) 255-9139
sharon@orie.cornell.edu

Roger, Fletcher
University of Dundee
Department of Mathematics &
Computer Science
Dundee DD1 4HN
Scotland
0382-23181 ex 4490

Christodoulos A, Floudas
Princeton University
Dept Of Chemical Engineering
Princeton NJ 08544-5263
(609) 258-4595
floudas@zeus.princeton.edu

Anders L, Forsgren
K T H
Department of Mathematics
S-100 44 Stockholm
Sweden

David, Fournier
Otter Research Limited
PO Box 625
Station A
Namaimo V9R 5K9
British Columbia, Canada
(604) 756-0956

Robert, Fourer
Northwestern University
Dept of Industrial Engineering
Evanston IL 60208-3119
(312) 491-3151
4er@iems.nwu.edu (206) 283-8802

Christina, Fraley
Statistical Sciences Inc
Suite 500
1700 Westlake Ave North
Seattle WA 98119

fraley@stat.washington.edu

Paul D, Frank
1850 3rd St
Kirkland WA 98033-4917
(203) 865-3592
frank@atc.boeing.com Cambridge MA 02139

Robert M, Freund
MIT E53-361
Sloan School of Management
50 Memorial Drive
Murray Hill NJ 07974
(617) 253-8997
rfreund@sloan.mit.edu

Roland W, Freund
AT&T Bell Laboratories
Room 2C-420
600 Mountain Road

freund@research.att.com

Efim A, Galperin
Universite Quebec a Montreal
Department Mathematics & Info
CP 8888, Succ A
Montreal H3C 3P8
Quebec, Canada

Fatima, Garcia
Telefonica Ltd
Planificacion De Redes
c/ Emilio Vargas 6
28043 Madrid
Spain

Ubaldo M, Garcia-Palomares
Universidad Simon Bolivar
Dept Procesos y Sistemas
Apartado 89000
Caracas 1086-A
Venezuela

David G, Garrett
10543 Xylon Rd S
Bloomington MN 55438-1922
(612) 456-2222

David M, Gay
35 Livingston Ave
New Providence NJ 07974-2219
(908) 582-5623
dmg@research.att.com

David, Gedeon
46922 S Canaan Rd
Athens OH 45701-946
(614) 592-5166

Jurgen, Gerlach
Radford University
Dept of Math & statistics
Radford VA 24142-5772
(703) 831-5437
jgerlach@ruacad.ac.runet.edu

Omar N, Ghattas
Carnegie Mellon University
Dept of Civil Engineering
Pittsburgh PA 15213

Jean Charles, Gilbert
I N R I A
Domaine de Voluceau
B P 105 78153
Le Chesnay
France

Philip E, Gill
Univ of California-San Diego
Department of Mathematics
9500 Gilman Drive
La Jolla CA 92093-0112
(619) 534-4879
peg@optimal.ucsd.edu

Paul A, Gilmore
7128 Turner Creek Rd
Apex NC 27502-8520

Robert, Ginns
#3B
425 E 84th Street
New York NY 10028
(212) 249-5469

Isidoro, Gitler
Centro de Investigacion y Esta
Avanzados del IPN
Department de Mathematica
Zacatenco 07300 - Mexico City
Mexico

Neal, Glassman
1 Paddock Ct
Potomac MD 20854-2328

William K, Glunt
F210 Shawneetown
Lexington KY 40503
(606) 258-8864

Jean Louis, Goffin
McGill University
Faculty Management
1001 Sherbrooke St West
Montreal H3A 1G5
Quebec, Canada

Beila S, Goldman
17A
1445 N State Parkway
Chicago IL 60610

Donald, Goldfarb
Columbia University
IE & OR Dept
New York NY 10027
(212) 280-8011

Susana, Gomez
IIMAS - UNAM
Department Numerical Analysis
Apdo Postal 20-726
Mexico DF 10200
Mexico

Raghu, Gompa
Indiana University
Department of Mathematics
P O Box 9003
Kokomo IN 46902
(317) 455-9267

Clovis C, Gonzaga
COPPE - UFRJ
Caixa Postal 68511
21945 Rio De Janeiro
Brazil
gonzaga@brlncc.bitnet

Maria D, Gonzalez-Lima
Rice University
Dept of Mathematical Sciences
PO Box 1892
Houston TX 77251-1892
(713) 527-8101 X3817
mgl@rice.edu

Rudy, Gonzalez
3938 N Kedzie
Chicago IL 60618

Franco, Gori
Universita di Firenze
Matematica Applicata
Via Montebello m 7
Firenze 50123
Italy

Nicholas I M, Gould
Numerical Algorithms Group
Rutherford Appleton Lab
Oxford OX2 8DR
Great Britain

Donald W, Grace
Francis Marion College
Dept of Math & Comp Science
Florence SC 29501
(803) 661-1589

Thomas A, Grandine
The Boeing Company
5011 120th Ave SE
Bellevue WA 98006-282

Andreas, Griewank
708 Buell Avenue
Joliet IL 60435
(708) 252-6722
griewank@mcs.anl.gov New Brunswick NJ 08903

Michael D, Grigoriadis
Rutgers University
Department of Computer Science
Hill Center
00184 Roma
(201) 932-2898
grigoriadis@cs.rutgers.edu (39)-6-4873676

Luigi, Grippo
Univ di Roma "La Sapienza"
Dep Informatica e Sistemistic
Via Eudossiana 18

Italy

Osman, Guler
5704 S Harper Avenue #204
Chicago IL 60637
(312) 363-8928
ext_guler@gsbvax.uchigago.edu

James D, Guptill
Apt 103
14830 Bagley Rd
Cleveland OH 44130-5503

Milton M, Gutterman
5049 Lee St
Skokie IL 60077-233
(312) 856-7101

Jean-Pierre A, Haeberly
Fordham University
Department of Mathematics
Bronx NY 10458-5165
(212) 579-2356
haeberly@fordmurh (309) 677-2446

Mahmood, Haghighi
Bradley University
Dept of Computer Sciences
Main Street
Peoria IL 61624

Jane N, Hagstrom
823 S Racine Ave # D
Chicago IL 60607-4123
(312) 996-5335
u22043@uicvm.uic.edu

Salim, Haidar
Northern Michigan University
Dept of Math & Comp Science
Marquette MI 49855

Jianxiu, Hao
GTE Laboratories
40 Sylvan Road
Waltham MA 02254
(617) 466-2353
jhao@gte.com

Andrew W, Harrell
3000 Drummond Street
Vicksburg MS 39180
(601) 634-3382
h3gm0rh0@wes.army.mil

Wolfgang, Hartmann
SAS Institute Inc
SAS Campus Drive
J 465
Cary NC 27513

Thomas L, Hayden
University of Kentucky
Department of Mathematics
Lexington KY 40506
(606) 257-6810
hayden@ms.uky.edu

Teresa, Head-Gordon
A T & T Bell Labs
600 Mountain Avenue
1A-365
Murray Hill NJ 07974

Geraldine M, Hemmer
Northeastern Illinois Univ
Department of Mathematics
5500 N St Louis Ave
Chicago IL 60625-4699
(312) 794-2637

Ken, Hickey
University of Cincinnati
Dept of Civil Engineering
M L 71
Cincinnati OH 45221

Karen A, High
Oklahoma State University
School of Chemical Engineer
Stillwater OK 74078

Alexander L, Hipolito
University of Florida
Dept ISE
303 Weil Hall
Gainesville FL 32611-2083
(904) 392-6757
hipolito@ise.upl.edu

Dorit, Hochbaum
University of California
School Business Administration
350 Barrows Hall
Berkeley CA 94720
dorit@hochbaum.berkeley.edu

Charles A, Holly
804 W Vermont
Urbana IL 61801
(217) 244-1663
holly@symcom.math.uiuc.edu

John N, Holt
University of Queensland
Department of Mathematics
St Lucia Qld 4067
Australia

Mary Elizabeth, Hribar
Northwestern University
Dept of Computer Science
2145 Sheridan Rd
Evanston IL 60208
marybeth@jupiter.eecs.nwu.edu

Michelle, Hribar
Northwestern University
Dept of Computer Science
2145 Sheridan Rd
Evanston IL 60208
michelle@jupiter.eecs.nwu.edu

Arthur, Hsu
Northwestern University
Dept of Indus Engr & Mgmt Aci
Evanston IL 60201

Juergen L, Huschens
Bleischmelzc 13
55 Trier-Quint
Germany

Chenyi, Hu
University of Houston/Downtc
Dept of Appl Math Sciences
One Main Street
Houston TX 77002-101
(713) 221-8414
ams17@menudo.uh.edu

George, Isac
College Miltaire Royal
Department of Mathematics
St Jean J0J 1R0
Quebec, Canada
(514)-346-2131 X3713

B, Jansen
T U Delft
Fac T W I / S S O R
Mekelweg 4
2628 C D Delft
Netherlands

Florian, Jarre
Universitat Wurzburg
Am Hubland
Institut Ang Mathematik
W-8700 Wurzburg
Germany

Debra, Jelinek
University of Wisconsin
Dept of Computer Science
1210 W Dayton Street
Madison WI 53715
(608) 262-6607

Jun, Ji
438 Hawkeye Ct
Iowa City IA 52246-2809

Prasanna, Jog
DePaul University
Department of Computer Scien
243 S Wabash Ave
Chicago IL 60604
(312) 362-5325
jog@depaul.edu

George W, Johnson
University South Carolina
Department of Mathematics
Columbia SC 29208-0001
(803) 777-3781
johnson@thor.math.scarolina.edu

Christopher V, Jones
Simon Fraser University
Faculty of Business
Burnaby V5A 1S6
British Columbia, Canada

Donald R, Jones
GM Research Labs and
Environmental Staff
Department OS-30
Warren MI 48090-905
(313) 986-1358
djones@cmsa.gmr.com

John, Jones Jr
2101 Matrena Dr
Dayton OH 45431-3114

Stefan, Karisch
University of Waterloo
Dept of Combinatorics and
Optimization
Waterloo N2L 3G1
Ontario, Canada

Keith, Kastella
Paramax Systems Corp
Dept of Com & Control Sys En
PO Box 64525 - M S U1N28
St Paul MN 55164-052

Edwin H, Kaufman Jr
Central Michigan University
Department of Mathematics
Mt Pleasant MI 48859

Linda C, Kaufman
AT&T Bell Labs
Room 2C 461
600 Mountain Avenue
Murray Hill NJ 07974-2010
(201) 582-6429
attcom!research!lck

Anthony J, Kearsley
Rice University
Dept Of Math Sciences
Houston TX 77251-189
(713) 527-8101 X2458
kearsley@rice.edu

Frederick C, Keihn
249 S Pugh Street
State College PA 16801

Carl T, Kelley
North Carolina State Univ
Department of Mathematics
Box 8205
Raleigh NC 27695-8205
(919) 515-7163
na.kelley@na-net.ornl.gov

Kenneth R, Kelly
231 Hazel Blvd
Tulsa OK 74114-3925

Diane, Kennedy
University of Waterloo
Dept of Elect & Comp Engr
Waterloo N2L 3G1
Ontario, Canada

Erich M, Klein
3218 Cedartree Crescent
Mississauga L4Y 3G4
Ontario, Canada
(416) 231-4111 x6101

Karl E, Knapp
Numerical Algorithms Group
Suite 200
1400 Opus Place
Downers Grove IL 60515-5702
(708) 971-2337
knapp@mcs.anl.gov

Masakazu, Kojima
Tokyo Institute of Technology
Dept of Information Sciences
Oh-Okayama, Meguro
Tokko 152
Japan

Michael M, Kostreva
Clemson University
Dept of Math Sciences
Clemson SC 29634
(803) 656-2616
flstgla@clemson.bitnet (814) 867-0629

Nainan, Kovoor
Pennsylvania State Universi
Department of Computer Scie
333 Whitmore Laboratory
University Park PA 16802361

kovoor@omega.cs.psu.edu

Brenda, Kroschel
SBCIOC Service
141 W Jackson
Chicago IL 60604

Donna M, Kuklinski
R & D Associates
PO Box 9377
Albuquerque NM 87119-9377
(505) 842-8911

P R, Kumar
University of Illinois
CSL
1101 W Springfield
Urbana IL 61801530
(217) 333-7476
prkumar@markov.csl.uiuc.edu

Frank-Stephan, Kupfer
Paulinstrasse 122
D-5500 Trier
Germany
kupfer%uni-trier.dbp.de@relay.cs.net (708) 491-7263

Marucha, Lalee
Northwestern University
Dept IE/MS
Evanston IL 60201
lalee@jupiter.eecs.nwu.edu (512) 471-9433

Leon, Lasdon
University of Texas
School of Business
Department of MSIS
Austin TX 78712

Susan, Lash
700
1800 Sherman Ave
Evanston IL 60201-3792
(708) 492-3620

Jeffery J, Leader
433 Belden Street
Monterey CA 93940

Robert H, Leary
San Diego Supercomputer Cent
User Services
P O Box 85608
San Diego CA 92138
(619) 534-5123
leary@sds.sdsc.edu

David M, Levine
Argonne National Laboratory
Math & Computer Science Div
9700 Cass Avenue South
Argonne IL 60439-4806
(708) 972-6735
levine@mcs.anl.gov buckaroo@rice.edu

Robert M, Lewis
Rice University
Dept of Mathematical Sciences
P O Box 1892
Houston TX 77251-1892
(713) 527-8101 X2595

Li-zhi, Liao
Cornell University
Advanced Computing Res Inst
702 Cornell Theory Center
Ithaca NY 14853
liliao@cs.cornell.edu

Thilo, Liebig
Univ of Southern California
Dept of Applied Mathematics
1154 W 30th Street
Los Angeles CA 90007

James W, Lindsay
Northwestern University
Vogelback Computing Center
2129 Sheridan Road
Evanston IL 60201-5502
(708) 491-4051
jlindsay@nwu.edu

Jianguo, Liu
Cornell University
ACRI
716 Theory Center Bldg
Ithaca NY 14853
(607) 254-8837

Guangye, Li
Rice University
CRPC
P O Box 1892
Houston TX 77251-1892
(713) 285-5183
gli@rice.edu

Wu, Li
Old Dominion University
Dept Of Math & Statistics
Norfolk VA 23529-0077
(804) 683-3918
li@xanth.cs.odu.edu yong@cs.psu.edu

Yong, Li
Penn State University
Department of Compuer Scienc
University Park PA 16802
(814) 863-7325

Zhi-Quan, Luo
McMaster University
Dept of Elect/Comp Engineering
Room CRL/225
Hamilton L8S 4K1
Ontario, Canada
416-525-9140
luozq@sscvax.cis.mcmaster.ca

Irvin J, Lustig
Princeton University
Dept of Civil Engineering
& Operations Research
Princeton NJ 08544
(609) 258-4614
irv@basie.princeton.edu maciel@rice.edu

Maria Cristina, Maciel
Rice University
Dept of Mathematical Science
PO Box 1892
Houston TX 77251-189
(713) 527-8101 X3824

Humberto, Madrid
Av Mexico 977-1
Col Latinoamericana
Saltillo Coah. 25270
Mexico

Kaj, Madsen
The Technical Univ of Denmark
Inst for Numerical Analysis
Building 305
DK-2800 Lyngby
Denmark

Thomas, Magnanti
Mass Institute of Technology
Sloan School of Management
Room E53-351
Cambridge MA 02139
(617) 253-6604
magnanti@sloan

Philippe, Mahey
Lab ARTEMIS / IMAG
B P 53X
38041 Grenoble
France
mahey@flagada.imag.fr (608) 262-1204

Olvi L, Mangasarian
University of Wisconsin
Dept of Computer Sciences
1210 W Dayton Street
Madison WI 53706-1685
Quebec, Canada
olvi@cs.wisc.edu

A, Mansouri
Universite de Sherbrooke
Dept de Mathe et Informatiqu
2500 Bd Universite
Sherbrooke J1K 2R1

Angel G, Marin
E T S Ingens Aeronauticos
Matem Aplicada Department
Plaza Cardenal Cisneros 3
Madrid
Spain
3412444700 235

Jose Mario, Martinez
IMECC-UNICAMP
Dept of Mathematic Application
C P 6065
13081 Campinas SP
Brazil
55-192-423857
martinez@ccvak.unicamp.ansp.br

Geraldo Robson, Mateus
Inst de Ciencias Exatas UFMG
Departamento C Computacao
Caixa Postal 702
30161 Belo Horizonte-MG
Brazil

Frank H, Mathis
Baylor University
Department of Mathematics
PO Box 97328
Waco TX 76798-7328

Robert L, Matlosz
5413 Peggy Circle
Virginia Beach VA 23464

Robert M, Mattheyses
G E Research & Dev Center
PO Box 8
Schenectady NY 12301-000

S Thomas, McCormick
University of British Columbia
Faculty of Commerce
2053 Main Mall
Vancouver V6T 1Y8
British Columbia, Canada
604-224-8426
tom_mccormick@mtsg.ubc.ca

Catherine C, McGeoch
Amherst College
Department of Mathematics
and Computer Science
Amherst MA 01002
(413) 542-7913

Richard S, McGowan
Haskins Laboratories
270 Crown St
New Haven CT 06511-669
(203) 865-6163

Frederick Martin, Medak
2103 Stony Run Circle
Broadview Hgts OH 44147-2566
(216) 546-0835

Sanjay, Mehrotra
Northwestern University
McCormick School ofEngineering
Dept Industrial Eng & Mgmt Sci
Evanston IL 60208
(708) 491-3155
mehrotra@iems.nwu.edu

Sanjay, Melkote
Northwestern University
Dept of Indu Engr & Mgmt Sci
Sheridan Road
Evanston IL 60208

Aharon, Melman
Israel Institute of Technology
Dept of Industrial Engineering
Technion
Haifa 32000
Israel
melman@ie.technion.ac.il

S, Meusel
Oregon State University
West Hall #209
Corvallis OR 97331-1801

Robert, Meyer
University of Wisconsin
Department of Computer Scien
1210 W Dayton Street
Madison WI 53706-161
(608) 262-7870

Juan C, Meza
Sandia National Labs
Division 8210
P O Box 969
Livermore CA 94551-0969

John E, Mitchell
Rensselaer Polytechnic Inst
Dept of Mathematical Sciences
Troy NY 12180
(518) 276-6915
mitchell@turing.cs.rpi.edu Japan

Shinji, Mizuno
Inst of Statistical Math
4-6-7 Minami - Azabu
Minato-ku
Tokyo 106

45-622-8575
mizuno@ime.titech. ac.jp

Regina H, Mladineo
Rider College
2083 Lawrenceville Rd
Lawrenceville NJ 08648-3099
(609) 895-5554
mladineo@rider.bitnet

Kelly B, Mohrmann
U S Military Academy
Dept of Math Sciences
West Point NY 10996-1786

France

Marcel, Mongeau
INRIA
Projet Promath, Bat 12
Rocquencourt BP 105
78153 LeChesnay

Brian L, Monteiro
807
1915 Maple Avenue
Evanston IL 60201
d50monte@gandalf.tech.nwu.edu Tucson AZ 85721

Renato D C, Monteiro
University of Arizona
College of Engr & Mines
Dept of Syst & Indus Engr
(602) 621-5087
renu@sie.arizona.edu

James T, Moore
6611 Deer Knolls Drive
Huber Heights OH 45424
(513) 255-3362

Jose L, Morales-Perez
Imperial College of Science
Centre for Process Systems
London SW7 2BY
Great Britain

Jorge J, More
Argonne National Lab
Mathematics and Computer
Science Division
Argonne IL 60439-4803

Steven, Morley
Anderson Consulting
Department C Star
100 South Wacker
Chicago IL 60606
(312) 507-9368

A M, Morshedi
DOT Products Inc
Dept of Research & Development
1613 Karankawas Ct
Deer Park TX 77536

John M, Mulvey
Princeton University
School of Engineering &
Applied Science
Princeton NJ 08544

Katta G, Murty
University of Michigan
IOE
1205 Beal Avenue
Ann Arbor MI 48109-21
(313) 764-9407

B, Narendran
Univ of Wisconsin / Madison
Dept of Computer Science
1210 W Dayton Street
Madison WI 53706
(608) 286-1721

John C, Nash
1975 Bel Air Drive
Ottawa K2C 0X1
Ontario, Canada
(613) 564-6825
jxnhg@acadvm1.uottawa.ca (703) 764-6046

Stephen G, Nash
George Mason University
Dept of Operations Research
& Applied Statistics
Fairfax VA 22030

snash@gmuvax.gmu.edu

John Larry, Nazareth
Washington State University
Dept Of Pure & Applied Math
Pullman WA 99164-3113
(509) 335-3127
nazareth@wsumath.bitnet

Thomas K, Neuberger
605 Upland Pl
Alexandria VA 22301-2743
(703) 824-2273

Van Hien, Nguyen
Facultes Univ de Namur
Dept of Mathematics
8 Rempart De La Vierge
Belgium
32 0 81 724938

vhnguyen@bnandp51.bitnet

Peh H, Ng
Univ of Minnesota / Morris
Department of Mathematics
Morris MN 56267

Ronald H, Nickel
Center for Naval Analysis
PO Box 16268
Alexandria VA 22302-8268
(703) 824-2463

Soren S, Nielson
358 Dupont Street
Philadelphia PA 19128
(215) 898-5715
nielson@wharton.upenn.edu

Jorge, Nocedal
Northwestern University
Dept of Electrical Engineering
and Computer Science
Evanston IL 60208
(708) 491-5038
nocedal@eecs.nwu.edu

Gautham, Nookala
Kessler Asher Group
Suite 500
111 W Jackson Blvd
Chicago IL 60604

Lawrence Sean, Norris
Apt 98
5650 N Sheridan Road
Chicago IL 60660-482
(708) 491-5635
lnorris@nwu.edu

James I, Northrup
Colby College
Department of Mathematics
Waterville ME 04901
(207) 872-3114
jinorthr@colby.edu (717) 675-9255

M, Nouri-Moghadam
Penn State University
Department of Mathematics
P O Box PSU
Lehman PA 18627-0217

MNMI@PSUVM

Kimberly, Oates
John Hopkins University
Applied Physics Lab
John Hopkins Road
Laurel MD 20723-609

Francis J, O'Brien Jr
Naval Underwater Systems Ctr
Code 2211, B 1171-1
Newport RI 02841

Aurelio Ribeiro L, Oliveira
Rice University
Dept of Math Sciences
PO Box 1892
Houston TX 77251-1892

Rick, Olson
Loyola University of Chicago
Dept of Mgmt Science
820 N Michigan Ave
Chicago IL 60611

James B, Orlin
Massachusetts Institute of
Technology
E53-357
Cambridge MA 02139
(617) 253-6606
jorlin@eagle.mit.edu

Brian, Ostrow
SBC/OC Services LP
141 W Jackson Blvd
Chicago IL 60604

Michael L, Overton
Courant Institute
251 Mercer St
New York NY 10012-118
(212) 998-3121
overton@cs.nyu.edu

Robert W, Owens
Lewis & Clark College
Dept of Mathematical Sciences
Portland OR 97219

Laura, Palagi
La Sapienza of Rome
Dept of Informatica e Sistems
Via Buonarroti 12
Rome 00185
Italy

Jong-Shi, Pang
The Johns Hopkins University
Dept of Mathematical Science
Baltimore MD 21218

Shao Wei, Pan
Univ of Wisconsin @ Madison
Dept of Electrical & Comp Sci
1415 Johnson Dr
Madison WI 53705
(608) 262-9205
pan@ece.wisc.edu

Panos M, Pardalos
University of Florida
Dept of Industrial Engineering
303 Weil Hall
Gainesville FL 32611

Teresa A, Parks
3401 Rice Blvd
Houston TX 77005-293

Joao M, Patricio
University De Coimbra
Apartado 3008
3000 Coimbra
Portugal
351-39-28097
fcmtjmmp@civcz.uc.rccn.pt

Terpolilli, Peppino
ELF Aquitaine
Av Larribau
Pau 64018 cedux
France
33 5983 4547

Andrew T, Phillips
838 Southern Hills Ct
Arnold MD 21012-261
(301) 267-2798

Jane E, Pierce
SAS Institute
SAS Campus Drive
Bldg J-4
Cary NC 27513
(919) 677-8000 X7636

George, Pitts
Virginia Polytechnic Inst
Department of Mathematics
461 McBryde Hall
Blacksburg VA 24060

Frank, Plab
University of Edinburgh
Parallel Computing Centre
James Clerk Maxwell Bldg
Mayfield Rd Edinburgh EH9 3
Great Britain

Todd D, Plantenga
724 Mulford Street
Evanston IL 60202

Paul E, Plassmann
Argonne National Laboratory
Division of Math & Comp Sci
Argonne IL 60439

Louis J, Podrazik
Supercomputing Research Cen
17100 Science Dr
Bowie MD 20715-43

Polyar
IBM-T J Watson Research Center
Department of Mathematics
PO box 218
Yorktown Hghts NY 10598

Florian A, Potra
University of Iowa
Department of Mathematics
Iowa City IA 52242-0001
(319) 335-0776
fpotra@umaxa.weeg.uiowa.edu Great Britain

M J D, Powell
University of Cambridge
Department D A M T P
Silver Street
Cambridge, CB3 9EW

0223-337889
mjdp@amtp.cam.ac.uk

David T, Price
611 E Prairie Ave
Wheaton IL 60187-3824

Malcolm C, Pullan
University of Cambridge
Inst of Mgmt Studies
Mill Lane
Cambridge CB2 1RX
Great Britain

Maijian, Qian
University of Washington
Department of Mathematics
GN-50
Seattle WA 98195
(206) 543-1150
qian@math.washington.edu

Abdur, Rais
Purdue University
Dept of Industrial Engr
Grissom Hall
West Lafayette IN 47907
(317) 494-8522
rais@ecn.purdue.edu

Joanna, Rakowska
Virginia Polytechnic Inst &
State University
Department of Mathematics
Blacksburg VA 24061

danny@cs.cornell.edu

Daniel, Ralph
Cornell University
Department of Computer Scien
Upson Hall
Ithaca NY 14853-750
(607) 254-8863

Motakuri V, Ramana
Johns Hopkins University
Dept of Mathematical Sciences
Baltimore MD 21218

Marcos, Raydan
University of Kentucky
Dept of Mathematics
Patterson Office Tower 735
Lexington KY 40506-0027

David, Reiner
O'Connor & Associates
Quantitative Research Dept
141 West Jackson Boulevard
Chicago IL 60604-290
(312) 322-7171

James M, Renegar
Cornell University
School Oper Res & Ind Eng
Upson Hall
Ithaca NY 14853-7501
(607) 255-9142
renegar@orie.cornell.edu

Jeffrey G, Renfro
Dyna Optim Tech Product
Dept of Research Development
1613 Karankawas Ct
Deer Park TX 77536
mgcr@research.att.com

Mauricio G C, Resende
AT&T Bell Laboratories
Room 2D-152
600 Mountain Avenue
Murray Hill NJ 07974-201
(908) 582-2118

Ulf T, Ringertz
Aeronautical Research
Institute of Sweden
Box 11021
S-161 11 Bromma
Sweden
46 8 7591204
na.ringertz@na-net.ornl.gov

Stephen M, Robinson
University of Wisconsin
Department Industrial Engineer
1513 University Avenue
Madison WI 53706-1512
(608) 263-6862

Phillip, Rogaway
I B M
11400 Burnet Road
Austin TX 78758-3965

Janet E, Rogers
484 Golden Lane
Longmont CO 80501

Janet E, Rogers
Nat'l Inst of Stand & Tech
Dept of Appl & Comp Math 881
325 Broadway
Boulder CO 80303-3328

Jack W, Rogers Jr
Auburn University
Division of Mathematics
218 Parker Hall
Auburn Univs'ty AL 36849

Cornelis, Roos
Delft University of Technology
Dept of Math & Informatics
P O Box 356
2600 AJ Delft
Netherlands
3115-782530
wioro12@hdetud1.tudelft.nl(bitnet)

J Ben, Rosen
University of Minnesota
Department of Computer Science
200 Union St SE
Minneapolis MN 55455-0154

Norma, Rueda
Merrimack College
Dept of Math and Comp Sci
North Andover MA 01845
(508) 837-5000 X4262
rueda@merrimack.edu

I Bert, Russak
Naval Postgraduate School
Code 53RU
Monterey CA 93940
(408) 646-2293

Bert W, Rust
Nat'l Inst of Standards & Tech
Bldg 225, Room A-151
Gaithersburg MD 20899
(301) 975-3811
bwr@vax.cam.nist.gov Germany

Ekkehard W, Sachs
University of Trier
FB IV Mathematik
Postfach 3825
5500 Trier

0651/201-2858
sachs@uni-trier.dbp.de

Ibraham, Sadek
University of North Carolina
Department of Mathematics
Wilmington NC 28401

Nikolaos V, Sahinidis
University of Illinois
Dept Industrial & Mech Eng
1206 W Green Street
Urbana IL 61801
(217) 244-1304
sahinidi@uxh.cso.uiuc.edu

Peter, Salamon
S D S U
Department of Mathematical
Sciences
San Diego CA 92182
(619) 594-7204

Matthew J, Saltzman
Clemson University
Dept of Mathematical Sciences
Clemson SC 29634

L Michael, Santi
Christian Brothers University
650 E Parkway S
Campus Box S-359
Memphis TN 38104
(901) 722-0572

Roger W H, Sargent
Imperial College
Ctr Process System Engineer
Prince Consort Road
London SW7 2BY
Great Britain
071 228 8100

A, Sartenaer
Fac Univ N-D de la Paix
Department of Mathematics
61 rue de Bruxelles
Namur 5000
Belgium

Michael A, Saunders
Stanford University
Dept Operations Research
4022 Terman
Stanford CA 94305-4022
(415) 723-1875
na.saunders@na-net.stanford.edu

Wolfgang, Scheerer
Univ of Southern California
Dept of Applied Mathematics
1154 W 30th Street
Los Angeles CA 90007

Bruce G, Schinelli
University of North Carolina
Dept of Operations Research
CB #3180 - Smith Building
Chapel Hill NC 27599-3180

Rina P, Schneur
IBM-T J Watson Research Center
Room 33-218, PO Box 218
Department of Mathematics
Yorktown Hghts NY 10598

Robert B, Schnabel
University of Colorado
Department of Computer Scie
Campus Box 430
Boulder CO 80309-04
(303) 492-7554
bobby@boulder.colorado.edu

Andrei L, Schor
Charles Stark Draper Lab
Department E S C
555 Technology Sq / MS-4E
Cambridge MA 02139

Linus, Schrage
1101 E 58th St
Chicago IL 60637-1511
(312) 702-7449

Richard S, Segall
#11
View Points Apartments
2702 Paoli Pike
New Albany IN 47150

Elena, Senigaglia
University of Venice
Dept de Mathematica App & Info
Ca Dolfin Dorsoduro Venezia
Venezia 30122
Italy

David, Shalloway
Cornell University
Biochem Molec & Cell Biology
Biotechnology Bldg, Rm 265
Ithaca NY 14853
(607) 254-4896

Joseph, Shinnerl
3735C Miramar Street
La Jolla CA 92037-13

Christine A, Shoemaker
Cornell University
Civil & Environmental Eng
Rm 210, Hollister Hall
Ithaca NY 14853-3501
(607) 255-9233

John, Sibert
Otter Research Ltd
Box 267
N Animo V9R 5K9
British Columbia, Canada

Dirk, Siegel
Cambridge University
Dept of Appl Math & Physics
Silver Street
Cambridge CB3 9EW
Great Britain

Vasile, Sima
Institute for Informatics
Research Division
Bd Republicii #35, Sector 2
70332 Bucuresti
Romania

Amar, Singh
University of Waterloo
Dept of Systems Design Engr
University Avenue
Waterloo N2L 3G1
Ontario, Canada

Kerstin, Singer
Oregon State University
Department of Mathematics
402 West Hall
Corvallis OR 97331-418

Joseph A, Smith
U S Coast Guard
Marine Systems
Avery Point
Groton CT 06340
(203) 441-2656

Stuart H, Smith
Purdue University
Krannert School of Mgmt
West Lafyette IN 47907
(317) 494-4441
shsmith@midas.mgmt.purdue.edu

Ariela, Sofer
George Mason University
Department ORAS
4400 University Drive
Fairfax VA 22030-44
(703) 323-2728
asofer@gmuvax.bitnet

Mikhail V, Solodov
Univ of Wisconsin / Madison
Dept of Computer Science
1210 West Dayton Street
Madison WI 53706

Trond, Steihaug
University of Bergen
Department of Informatics
Hoyteknologisenteret
N-5020 Bergen
Norway
47-5-544169
trond@eik.ii.vib.no

Julio Michael, Stern
213 N Tioga
P O Box J
Ithaca NY 14850
(607) 257-8138
jstern@cs.cornell.edu

Richard Evan, Stone
Northwest Airlines Inc
Department E 3100
5101 Northwest Dr
St Paul MN 55111-3034

Virgnia L, Stonick
Carnegie Mellon University
Department of Electrical &
Computer Engineering
Pittsburgh PA 15213-3890
(412) 268-6636
ginny@ece.cmu.edu

Rob, Stubbs
Northwestern University
Dept of Indu Engr & Mgmt Sc
Evanston IL 60208

Brian, Sumner
234 Needle Leaf Lane
Sugar Land TX 77479-5038
(713) 954-6235

Jie, Sun
Northwestern University
Dept of Industrial Engineering
and Management Sciences
Evanston IL 60208
(708) 491-7008
SUN@IEMS.NWU.EDU

William W, Symes
7807 Chinon Cir
Houston TX 77071-337
(713) 527-4805
symes@rice.edu

Toshihiko, Takahashi
Kajima Corporation
Information Processing Center
2-7 Motoakasaka 1-Chome
Minato-ku, Tokyo 107
Japan

Hitoshi, Takehara
MTB Investment Tech Inst
Department of Research
Nihon Bldg 2-6-2 Ohtemachi
Chiyodaku Tokyo 100
Japan

Masayoshi, Tamura
756 California Avenue
Palo Alto CA 94306

Rhenzhong, Tan
University of Cincinnati
Dept of Civil Engineering
M L 71
Cincinnati OH 45221

Richard A, Tapia
Rice University
Dept of Mathematical Sciences
Box 1892
Houston TX 77251-1892
(713) 527-4049
rat@rice.edu p.tarazaga@rumac.upr.clu.edu

Pablo, Tarazaga
University of Puerto Rico
Department of Mathematics
P O Box 5000
Mayaguez PR 00709-50
(809) 265-3848 X3257

Marc, Teboulle
University of Maryland
Baltimore County Campus
Department of Mathematics
Baltimore MD 21228
(301) 455-2435

Andre L, Tits
University of Maryland
Dept of Electrical Engineering
Systems Research Center
College Park MD 20742
(301) 405-3669

Michael J, Todd
Cornell University
Sch of Oper Rsch & Indust Er
Upson Hall Etc Bldg
Ithaca NY 14853-38
(607) 255-9135

teboulle@umbc(bitnet) andre@cacse.src.umd.edu miketodd@orie.cornell.edu

Philippe L, Toint
Fac Univ Notre Dame de la Paix
Department of Mathematics
61 Rue de Bruxelles
B-5000 Namur
Belgium
(32) 81-229 061
pht@math.fundp.ac.be

Jon W, Tolle
University of North Carolina
Department of Mathematics
CB#3250
Chapel Hill NC 27599

d53330@jpnkudpc.bitnet

Kaoru, Tone
Saitama University
Grad School of Policy Scien
Urawa
Saitama 338
Japan
81-48-852-2111

Virginia J, Torczon
Rice University
Dept Of Mathematical Sciences
Houston TX 77251-1892
(713) 285-5176
va@rice.edu

Jay S, Treiman
Western Michigan University
Dept of Math & Statistics
Kalamazoo MI 49008

Michael W, Trosset
PO Box 40993
Tucson AZ 85717-309
(602) 327-2704
trosset@ccit.arizona.edu

Paul Y, Tseng
University of Washington
Department of Mathematics
GN-50
Seattle WA 98195
(206) 543-1177
tseng@math.washington.edu

Takashi, Tsuchiya
Institute of Statistical Math
4-6-7 Minami-Azabu
Minato-ku
Tokyo 106
Japan

Levent, Tuncel
Cornell University
Sch Of Oper Rsch & Indust Er
Ithaca NY 14853-38
(607) 255-1270
tuncel@cs.cornell.edu

Kathryn L, Turner
Utah State University
Department Of Mathemtics
Logan UT 84322-3900
(801) 750-2817
kturner@math.usu.edu Belgium

Daniel, Tuyttens
Faculte Polytechnique de Mons
Dept of Math & Oper Research
9 Rue de Houdain
B-7000 Mons
(513) 556-3643
daniel@pip.umh.ac.be juber@uceng.uc.edu

James G, Uber
University of Cincinnati
Dept Civil/Environmental Eng
ML #71
Cincinnati OH 45221-007

George, Vairaktarakis
University of Florida
Dept of Indu & Systems Engr
303 Weil Hall
Gainesville FL 32611

Russ, Vander Wiel
University of Illinois
Dept of Mech & Indus Engr
1206 W Green Street
Urbana IL 61801

R J, Vanderbei
AT&T Bell Laboratories
Room 2C-124
600 Mountain Avenue
Murray Hill NJ 07974-201
(201) 582-7589

Nguyen, Van Hien
FNDP Namur
Department of Mathematics
8 Rempart De La Vierge
Namur B-5000
Belgium
32-81-229061 ext2436

Avi, Vardi
Drexel University
Department of Mathematics
& Computer Science
Philadelphia PA 19104
(215) 895-6824
vardi@duvm vavasis@cs.cornell.edu

Stephen A, Vavasis
Cornell University
Department of Computer Scien
Upson Hall
Ithaca NY 14853-750
(607) 255-9213

James, Vegeais
5256 Lynd Ave
Lyndhurst OH 44124-1031
(216) 581-5493
vegeaisj@rcwcl1.dnet.bp.com

Geraldo, Veiga
Apt 215
2000 Durant Ave
Berkeley CA 94704-1501

Jose A, Ventura
Penn State University
207 Hammond Bldg
University Park PA 16802

orge R, Vera
ornell University
Dept of Operations Research
319 Upson Hall
Ithaca NY 14853
(607) 255-1270
vera@orie.cornell.edu

Jean-Phillippe, Vial
University of Geneva
2 Rue De Candolle
CH-1211
Geneva 4
Switzerland
lfcnv@ciucz.uc.rccn.pt

Luis Nunes, Vicente
Universidade de Coimbra
Departamento de Matematica
3000 Coimbra
Portugal
(351) 39-28097

Ole, Vignes
Norsk Hydro
PO Box 4313
Nygardstangen
N-5028 Bergen
Norway

John A, Volmer
612 N Elm St
Hinsdale IL 60521-3504
(708) 789-1524
632831@achilles.ctd.anl.gov

Gregory M, Vydra
Z S Associates
1800 Sherman Avenue
Evanston IL 60201

Don, Wagner
O N R
Dept of Math Sciences
800 N Quincy St
Arlington VA 22217

Jen-Shan, Wang
Northwestern University
Department of IE / MS
Evanston IL 60208

Jiasong, Wang
Nanjing University
Department of Mathematics
22 Han Kou Road
Nanjing, Jiangsu 210 008
People's Republic of China

Tao, Wang
Johns Hopkins University
Dept of Mathematical Sciences
Baltimore MD 21218

Layne T, Watson
VPI & SU
Dept of Computer Science
562 McBryde Hall
Blacksburg VA 24061-4094
(703) 231-7540
ltw@vtopus.cs.vt.edu 46 0 15439

Per Ake, Wedin
University of Umea
Institute of Information
Processing
S-90187 Umea
Sweden

Clark, Wells
University of Kentucky
Department of Mathematics
7th Fl Patterson Office Tower
Lexington KY 40506

Norman Daniel, Whitmore Jr
Amoco Production Company
Department of Research
PO Box 3385
Tulsa OK 74102

J Ernest, Wilkins Jr
Clark Atlanta University
PO Box J
Atlanta GA 30314
(404) 880-8834

Karen A, Williamson
Rice University
Dept of Mathematical Sciences
P O Box 1892
Houston TX 77251-1892
(713) 285-5178
kaw@rice.edu (519) 888-4597

Henry, Wolkowicz
University of Waterloo
Department of Combinatorics
and Optimization
Waterloo N2L 3G1
Ontario, Canada

Robert S, Womersley
University of New South Wale
School of Mathematics
PO Box 1
Kensington, NSW 2033
Australia

61-2-697 2998
hwolkowicz@orion.uwaterloo.ca vsw@hydra.maths.unsw.oz.au

Margaret H, Wright
AT&T Bell Laboratories
Room 2C-462
600 Mountain Avenue
Murray Hill NJ 07974-2010
(201) 582-3498
mhw@research.att.com

Stephen J, Wright
Argonne National Laboratory
MCS Division
Argonne IL 60439

Chih-Hang, Wu
Penn State University
Dept of Indus & Mgmt Syst Er
513 Linden Road
State College PA 16801

Zhijun, Wu
Cornell University
Dept of Computer Science
721 Theory Center
Ithaca NY 14853

Guo-Liang, Xue
Army High Performance
Computing Research Center
1100 South Washington Avenue
Minneapolis MN 55415

Hiroshi, Yabe
Science Univ of Tokyo
Faculty of Engineering
1-3 Kagurazaka, Shinjuku-ku
162 Tokyo
Japan
03-3260-4271 Ex 3560

Jonathan, Yackel
Univ of Wisconsin/Madison
Dept of Computer Science
1210 West Dayton Street
Madison WI 53706-1685

Hiroshi, Yamashita
Mathematical Systems Institute
Bldg 6F
2-5-3 Shinjuku
Shinjuku-ku Tokyo 160-00
Japan

Wing K, Yeung
The Aerospace Corporation
Software Support Office
2350 E El Segundo Blvd
El Segundo CA 90245

Yinyu, Ye
University of Iowa
Dept of Management Sciences
Iowa City IA 52242
(319) 335-1947

Wei, Yuan
Cornell University
Advanced Computing Res Inst
714, Theory Center Building
Ithaca NY 14853-3801
(607) 254-8836
yuan@cs.cornell.edu

Stavros A, Zenios
University of Pennsylvania
The Wharton School
Decision Sciences Departmen
Philadelphia PA 19104-63

Yin, Zhang
Univ of Maryland Baltimore Cty
Dept of Math & Statistics
Baltimore MD 21228
(301) 455-3298
zhang@math12.math.umbc.edu

Yongmin, Zhang
University of Chicago
Department of Mathematics
5734 S University
Chicago IL 60637

Changqing, Zhen
University of Cincinnati
Dept of Civil Engineering
M L 71
Cincinnati OH 45221

Jian, Zhou
University of Maryland
Systems Research Center
A V Williams Bldg 115
College Park MD 20742
(301) 454-4178

Hao, Zhu
University of Cincinnati
Department of Civil Engr
M L 71
Cincinnati OH 45221

Qing Zhoa
University of Waterloo
Department of Combinatorics and Optimization
Waterloo, Ontario N2L 3G1
Canada

Fourth SIAM Conference on

Final
Program

Sponsored by SIAM
Activity Group on
Optimization

And Tutorial on Numerical Optimization and Software May 10, 1992

May 11-13, 1992 Hyatt Regency Hotel Chicago, Illinois

CONFERENCE THEMES

Large-Scale Optimization
Interior-Point Methods
Algorithms for Optimization
Problems in Control
Network Optimization Methods
Parallel Algorithms for
Optimization Problems

SOCIETY FOR INDUSTRIAL
AND APPLIED MATHEMATICS

SCIENCE AND INDUSTRY
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Contents

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Jorge Moré (Co-chair)
Mathematics and Computer
Science Division
Argonne National Laboratory

Jorge Nocedal (Co-chair)
Department of Electrical Engineering and Computer Science
Northwestern University

Jane K. Cullum
IBM Thomas J. Watson
Research Center

Donald Goldfarb
Department of Operations Research
and Industrial Engineering
Columbia University

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Tutorial

Tutorial on Numerical Optimization and Software
May 10, 1992
Hyatt Regency Hotel
Chicago, Illinois

Tutorial Description and Objectives

The use of optimization in industrial applications and in other areas of applied mathematics could be greatly widened and enhanced if potential users were made aware of the capabilities of existing algorithms and the availability of software which implements these algorithms. In this course, the lecturers aim to provide information about algorithms and software to enable workers in academia and industry to make use of modern numerical optimization techniques.

The course will cover four main problem areas. These are nonlinear equations and nonlinear least squares, unconstrained optimization, constrained optimization, and global optimization.

Who Should Attend?

Academics, industrialists, and government researchers in science, engineering and economics, who have found that optimization problems arise in their work. Employees of companies who create and distribute numerical software, and wish to learn more about the state of the software market.

Recommended Background

A basic knowledge of computational linear algebra (Gaussian elimination, Cholesky decomposition, QR decomposition, eigenvalues and eigenvectors of symmetric matrices), and calculus for functions of several variables (Derivatives, Taylor's theorem, and Lagrange's theorem for minimization problems with constraints).

Lecturers

Jorge J. Moré and Stephen J. Wright, MCS Division, Argonne National Laboratory.

Jorge J. Moré played a lead role in the development of MINPACK, a collection of high-quality optimization subroutines distributed worldwide. He is currently working on an expanded version of this collection, with a focus on large-scale optimization.

Stephen J. Wright is known for his contributions to optimization and parallel numerical methods. His recent work has been on algorithms for constrained and nonsmooth optimization, and on parallel methods for ordinary differential equations.

Information will be provided about the availability of software for different classes of optimization problems. This will be of immediate benefit to the applications community.

PROGRAM

9:00 AM	**Nonlinear Equations and Nonlinear Least Squares** Jorge J. Moré and Stephen J. Wright
10:30 AM	Coffee
11:00 AM	**Unconstrained Optimization** Jorge J. Moré and Stephen J. Wright
12:30 PM	Lunch
2:00 PM	**Linear Programming** Stephen J. Wright
3:00 PM	Coffee
3:30 PM	**Nonlinear Programming** Jorge J. Moré and Stephen J. Wright
4:30 PM	**Global Optimization** Jorge J. Moré
5:00 PM	Discussion
5:30 PM	Adjourn

The tutorial will take place in Regency C, coffee in Regency Foyer and luncheon (tutorial only) in Regency D rooms of the hotel.

OPTIMIZATION

Program Overview

Following are subject classifications for the sessions. The codes in parentheses designate session type and number. The session types are: Invited (IP), Minisymposium (MS), Contributed (CP), and Poster (P).

Advanced Environments for Optimization Software

- Advanced Environments for Optimization Software (MS10, page 10)
- ADIFOR--Automatic Differentiation in Fortran and Applications to Optimization (MS17, page 13)
- Cheap Gradients and Beyond: The Promise of Automatic Differentiation in Optimization (IP6, page 11)

Algorithms for Optimization Problems in Control

- Control Problems I (CP7, page 9; P1, page 9)
- Control Problems II (CP28, page 18)
- Convex Optimization Problems Arising in Controller Design (IP4, page 10)
- Optimal Control of Flexible Systems (MS25, page 17)
- Optimization in Control and Differential Equations (MS15, page 12)
- Scheduling of Manufacturing Systems (IP5, page 10)
- Stochastic Problems (P1, page 9)

Global Optimization

- Computational Global Optimization (MS16, page 13)
- Genetic Algorithms in Function Optimization (MS23, page 17)
- Global Optimization (CP8, page 9; P2, page 14)
- Simulated Annealing (CP5, page 8)

Interior Point Methods

- Finite Termination and Basis Recovery Using Interior Point Methods for LP (MS22, page 16)
- Interior Methods for Large-Scale Nonlinear Optimization Problems (IP2, page 6)
- Linear Programming: Analysis and Theory I (CP17, page 13; P1, page 9)
- Linear Programming: Analysis and Theory II (CP27, page 17)
- Linear Programming: Computational Issues I (CP10, page 11)
- Linear Programming: Computational Issues II (CP20, page 15)
- Recent Computational Advances in Interior Methods (MS1, page 6)
- Recent Developments in Interior Point Methods for Linear Programming (IP8, page 15)
- Recent Theoretical Advances in Interior Point Methods (MS7, page 8)

Large-Scale Optimization

- Algorithms for Solving Large Nonlinear Optimization Problems (IP7, page 15)
- Bound Constrained Problems I (CP3, page 7)
- Bound Constrained Problems II (CP22, page 16)
- Development of Codes for Large-Scale LP, QP and NLP (IP1, page 6)
- Large-Scale Nonlinear Optimization (MS19, page 15)
- Large-Scale Constrained Optimization I (CP1, page 6)
- Large-Scale Constrained Optimization II (CP11, page 11)
- Parallel Algorithms in Optimization (MS18, page 15)
- Robust Optimization: Models and Solution Strategies (MS8, page 8)
- Quadratic Programming (CP13, page 11)
- Sparse Matrix Problems (CP6, page 8)

Network Optimization Methods

- Large-Scale Network Optimization: An Assessment (IP9, page 16)
- Network Flow Algorithm (MS12, page 11)
- Network Optimization: Five Decades of Applications (IP3, page 7)
- Network Optimization I (CP4, page 8; P1, page 9)
- Network Optimization II (CP24, page 16)

Optimization Algorithms and Software

- Advances in Operator/Matrix Splitting Methods (CP14, page 12)
- Advances in Proximal Point Methods (MS6, page 7)
- Combinatorial Optimization (MS2, page 6; CP23, page 16; P1, page 10)
- Constrained Nonlinear Optimization (MS4, page 7)
- Constrained Optimization I (CP9, page 9; P1, page 9; P2, page 14)
- Constrained Optimization II (CP14, page 12; P1, page 9; P2, page 14)
- Constrained Optimization III (CP29, page 18; P1, page 9; P2, page 14)
- Convex Programming (CP16, page 12; P1, page 9; P2, page 14)
- Linear Complimentarity (CP19, page 13)
- Optimization Problems Involving Eigenvalues - Part 1 (MS9, page 8)
- Optimization Problems Involving Eigenvalues - Part 2 (MS24, page 17)
- Optimization Problems Over Matrices (CP26, page 17)
- Optimization Algorithms and Software (P1, page 10; P2, page 14)
- Unconstrained Optimization (P2, page 13)

Optimization Problems in Applications

- Global and Local Optimization Methods for Molecular Chemistry Problems (MS21, page 16)
- Optimal Design of Engineering Systems (MS11, page 10)
- Optimization Problems in Chemical Engineering (MS3, page 6)
- Problems "Off-the-Shelf" Newton Methods Won't Solve (MS 5, page 7)
- Protein Folding—A Challenging Optimization Problem (MS13, page 12)

Parameter Estimation and Data Fitting Problems

- Data Fitting Problems I (CP2, page 7; P2, page 14)
- Data Fitting Problems II (CP12, page 11)
- Data Fitting Problems III (CP21, page 15)
- Minimax Problems (CP25, page 17)
- Nonlinear Least Squares (CP18, page 13)

Get-Togethers

SIAM Welcoming Reception
7:00 PM - 9:00 PM
Sunday, May 10, 1992
Regency D
Cash Bar and assorted mini hors d'oeuvres.

Poster Session 1
6:00 PM - 7:30 PM
Monday, May 11, 1992
Regency Ballroom
Come and join your colleagues in the exchange of ideas with the presenters and others who have interest in their work. During the session, complimentary beer, assorted sodas, chips and dips will be available.

Poster Session 2
6:00 PM - 7:30 PM
Tuesday, May 12, 1992
Regency Ballroom
Once again you are invited to join your colleagues in the exchange of ideas generated by the poster presentations. There will be a cash bar during the session. Chips and dips will be complimentary.

Business Meeting
SIAM Activity Group on Optimization
7:30 PM
Tuesday, May 12, 1992
Belmont Room
ALL ARE WELCOME TO ATTEND!

Program-At-A-Glance

Saturday, May 9

6:00 PM-8:00 PM
Registration for Tutorial opens
Regency Ballroom Foyer

Sunday, May 10

8:00 AM-4:00 PM
Registration for Tutorial opens
Regency Ballroom Foyer

9:00 AM-5:30 PM
Tutorial
Regency C

6:30 PM-9:00 PM
Registration for Conference opens
Regency Ballroom Foyer

7:00 PM-9:00 PM
Welcoming Reception
Regency D

Monday, May 11

7:00		**Registration for Conference opens** Regency Ballroom Foyer
8:15		**Opening Remarks** **Jorge Moré** Regency A/B
8:30	**IP1**	**Development of Codes for Large-Scale LP, QP and NLP** *Roger Fletcher* Regency A/B
9:15	**IP2**	**Interior Methods for Large-Scale Nonlinear Optimization Problems** *Margaret H. Wright* Regency A/B
10:00		**Coffee and Exhibits** Regency D
10:30-11:50		**Concurrent Sessions (Minisymposia and Contributed)**
	MS1	**Recent Computational Advances in Interior Point Methods** *Organizer: Sanjay Mehrotra* Regency A/B
	MS2	**Combinatorial Optimization** *Organizer: Francisco Barahona* Water Tower Room
	MS3	**Optimization Problems in Chemical Engineering** *Organizer: Lorenz T. Biegler* Toronto Room
	CP1	**Large-Scale Constrained Optimization I** Belmont Room
	CP2	**Data Fitting Problems I** Gold Coast Room
	CP3	**Bound Constrained Problems I** Acapulco Room
12:00		**Lunch**
1:30	**IP3**	**Network Optimization: Five Decades of Applications** *Thomas L. Magnanti* Regency A/B
2:30		**Concurrent Sessions (Minisymposia and Contributed)**
	MS4	**Constrained Nonlinear Optimization** *Organizer: Richard H. Byrd* Regency A/B
	MS5	**Problems "Off-the-Shelf" Newton Methods Won't Solve** *Organizer: Virginia Torczon* Belmont Room
	MS6	**Advances in Proximal Point Methods** *Organizers: James V. Burke and Paul Tseng* Water Tower Room
	CP4	**Network Optimization I** Toronto Room
	CP5	**Simulated Annealing** Acapulco Room
	CP6	**Sparse Matrix Problems** Gold Coast Room
3:50		**Coffee and Exhibits** Regency D
4:20		**Concurrent Sessions (Minisymposia and Contributed**
	MS7	**Recent Theoretical Advances in Interior Point Methods** *Organizer: Kurt M. Anstreicher* Belmont Room
	MS8	**Robust Optimization: Models and Solution Strategies** *Organizer: John M. Mulvey* Toronto Room
	MS9	**Optimization Problems Involving Eigenvalues - Part 1 of 2** *Organizer: Michael L. Overton* New Orleans Room
	CP7	**Control Problems I** Acapulco Room
	CP8	**Global Optimization** Gold Coast Room
	CP9	**Constrained Optimization I** *Water Tower Room*
6:00		**Poster Session I** Regency A/B

Program-At-A-Glance

Tuesday, May 12

7:30 **Registration Opens**
Regency Ballroom Foyer

8:30 IP4 **Convex Optimization Problems Arising in Controller Design**
Stephen Boyd
Regency A/B

9:15 IP5 **Scheduling of Manufacturing Systems**
P. R. Kumar
Regency A/B

10:00 **Coffee and Exhibits** Regency D

10:30 **Concurrent Sessions (Minisymposia and Contributed)**

MS10 **Advanced Environments for Optimization Software**
Organizer: Robert Fourer
Water Tower Room

MS11 **Optimal Design of Engineering Systems**
Organizer: Omar N. Ghattas
Regency A/B

CP10 **Linear Programming Computational Issues I**
Belmont Room

CP11 **Large-Scale Constrained Optimization II**
Toronto Room

CP12 **Data Fitting Problems II**
Gold Coast Room

CP13 **Quadratic Programming**
Acapulco Room

12:00 **Lunch**

1:30 IP6 **Cheap Gradients and Beyond: The Promise of Automatic Differentiation in Optimization**
Andreas Griewank
Regency A/B

2:30 **Concurrent Sessions (Minisymposia and Contributed)**

MS12 **Network Flow Algorithm**
James B. Orlin
Belmont Room

MS13 **Protein Folding--A Challenging Optimization Problem**
Organizers: David M. Gay and Margaret H. Wright
Regency A/B

MS14 **Advances in Operator/Matrix Splitting Methods**
Organizers: Paul Tseng and James V. Burke
Toronto Room

CP14 **Constrained Optimization II**
Acapulco Room

CP15 **Unconstrained Minimization**
Water Tower Room

CP16 **Convex Programming**
Gold Coast Room

3:50 **Coffee and Exhibits** Regency D

4:20 **Concurrent Sessions (Minisymposia and Contributed)**

MS15 **Optimization in Control and Differential Equations'**
Organizer: Carl T. Kelley
Belmont Room

MS16 **Computational Global Optimization**
Organizer: J.B. Rosen
New Orleans Room

MS17 **ADIFOR--Automatic Differentiation in Fortran and Applications to Optimization**
Organizers: Christian Bischof and George Corliss
Acapulco Room

CP17 **Linear Programming Analysis and Theory I**
Toronto Room

CP18 **Nonlinear Least Squares**
Water Tower Room

CP19 **Linear Complementarity**
Gold Coast Room

6:00 **Poster Session II**
Regency A/B

7:30 **Business Meeting**
SIAM Activity Group on Optimization
Belmont Room

Wednesday, May 13

7:30 **Registration opens**
Regency Ballroom Foyer

8:30 IP7 **Algorithms for Solving Large Nonlinear Optimization Problems**
Nicholas I.M. Gould
Regency A/B

9:15 IP8 **Recent Developments in Interior Point Methods for Linear Programming**
Michael J. Todd
Regency A/B

10:00 **Coffee and Exhibits** Regency D

10:30 **Concurrent Sessions (Minisymposia and Contributed)**

MS18 **Parallel Algorithms in Optimization**
Organizer: Stephen J. Wright
Regency A/B

MS19 **Large-Scale Nonlinear Optimization**
Organizer: Philip E. Gill
Toronto Room

MS20 **Complexity Issues in Numerical Optimization**
Organizer: Stephen A. Vavasis
Acapulco Room

CP20 **Linear Programming: Computational Issues II**
Belmont Room

CP21 **Data Fitting Problems III**
Water Tower Room

CP22 **Bound Constrained Problems II**
Gold Coast Room

12:00 **Lunch**

1:30 IP9 **Large-Scale Network Optimization: An Assessment**
Michael D. Grigoriadis
Regency A/B

2:30 **Concurrent Sessions (Minisymposia and Contributed)**

MS21 **Global and Local Optimization Methods for Molecular Chemistry Problems**
Organizer: Robert B. Schnabel
Belmont Room

MS22 **Finite Termination and Basis Recovery Using Interior-Point Methods for LP**
Organizer: Amr S. El-Bakry
Regency A/B

CP23 **Combinatorial Optimization**
Water Tower Room

CP24 **Network Optimization II**
Toronto Room

CP25 **Minimax Problems**
Acapulco Room

CP26 **Optimization Problems over Matrices**
Gold Coast Room

3:50 **Coffee and Exhibits** Regency D

4:20 **Concurrent Sessions (Minisymposia and Contributed)**

MS23 **Genetic Algorithms in Function Optimization**
Organizer: David Levine
Acapulco Room

MS24 **Optimization Problems Involving Eigenvalues - Part 2 of 2**
Organizer: Michael L. Overton
Belmont Room

MS25 **Optimal Control of Flexible Systems**
Organizer: M.R. Nouri-Moghadam
Water Tower Room

CP27 **Linear Programming: Analysis and Theory II**
Regency A/B

CP28 **Control Problems II**
Gold Coast Room

CP29 **Constrained Optimization III**
Toronto Room

6:00 **Conference Adjourns**

7:00/Regency Ballroom Foyer
Registration opens

8:15/Regency A/B
Opening Remarks
Jorge Moré, Argonne National Laboratory

8:30/Regency A/B
IP1/Chair: Michael J.D. Powell, Cambridge
University, United Kingdom
Development of Codes for Large-Scale LP, QP and NLP

Large-scale LP and QP problems arise directly, and as subproblems in the solution of Mixed Integer Programming and Nonlinear Programming problems. In such applications it is of particular importance that the algorithms are 100% reliable, because there is no scope for user intervention. Obtaining reliablity in the presence of degeneracy, ill-conditioning and round-off error has been a main feature of research. Another important issue has been the use of generalised elimination schemes in QP and NLP which allow the effective use of sparse matrix methods. In these schemes second order information is handled through a dense representation of the reduced Hessian matrix and global convergence is assured by the use of an l-1 line search with second order corrections using a trust region framework. The speaker will discuss various aspects of the implementation of such a scheme.

Roger Fletcher
Department of Mathematics and Computer Science
University of Dundee, Scotland

9:15/Regency A/B
IP2/Chair: Michael J.D. Powell, Cambridge
University, United Kingdom
Interior Methods for Large-Scale Nonlinear Optimization Problems

Since 1984, substantial attention has been lavished on interior methods for constrained optimization, with increasing focus on nonlinear problems. Interior methods are closely related to classical barrier techniques of the 1960's which fell from favor because of their apparent inefficiency compared to approaches such as sequential quadratic programming methods. Interior methods can become a viable solution alternative for nonlinear problems only after resolution of several generic issues of algorithmic structure and convergence. Their application to large-scale problems necessarily involves sparse linear algebraic procedures that can overcome the inherent ill-conditioning associated with the barrier Hessian. The speaker will describe several promising strategies in interior methods for large-scale nonlinear problems.

Margaret H. Wright
AT&T Bell Laboratories

10:00/Regency D
Coffee

10:30-11:50
Concurrent Sessions (Minisymposia and Contributed)

MS1/Regency A/B
Recent Computational Advances in Interior Point Methods

The speakers in this minisymposium will present recent developments on the implementational aspects of interior point methods for linear and nonlinear optimization problems. They will discuss new algorithms and linear algebra techniques developed due to implementational needs of these methods. The algorithms and techniques include predictor-corrector methods, the use of conjugate gradient methods, matrix factorization schemes for symmetric indefinite matrices, and crossing over to simplex method from interior solutions.

Organizer: Sanjay Mehrotra
Northwestern University

10:30 **Interior Point Methods for Large Scale Quadratic Programming**
David Shanno, Rutgers University and Tami Carpenter, Princeton University

10:50 **Primal-Dual Symmetric Formulations of the Predictor-Corrector Method for QP**
R.J. Vanderbei, Princeton University

11:10 **Solving Symmetric Indefinite Systems in Interior Point Methods**
Sanjay Mehrotra, organizer and Robert Fourer, Northwestern University

11:30 **Switching from Interior to Vertex Solutions in OSL**
J.A. Tomlin, IBM Almaden Research Center and J.J.H. Forrest, IBM Thomas J. Watson Research Center

MS2/Water Tower Room
Combinatorial Optimization

The speakers will address algorithmic and polyhedral aspects of several combinatorial problems. They will discuss finding maximum weighted forest with degree constraints and related problems, delta-wye transformations of planar graphs as a reduction technique for combinatorial problems, a polynomial algorithm for minimum weighted bases of vector spaces, and the 2-connected subgraph problem.

Organizer: Francisco Barahona
IBM Thomas J. Watson
Research Center

10:30 **The Degree Constrained Forest Problem**
Bruce Gamble, Northwestern University

10:50 **Delta-Wye-Delta Reducibility of Three Terminal Planar Graphs**
Isidoro Gitler, University of Waterloo, Canada

11:10 **Minimum Weight Bases for Vector Spaces**
David Hartvigsen, Northwestern University

11:30 **Algorithmic and Polyhedral Results for the 2-Connected Steiner Subgraph Problem**
Abdur Rais, Purdue University

MS3/Toronto Room
Optimization Problems in Chemical Engineering

Chemical engineering applications have long been a rich source of complex and challenging optimization problems. Applications include the analysis of laboratory and plant data, design of chemical processes, process control and operation, and planning and scheduling tasks. The engineering models consist of sets of nonlinear algebraic and differential equations that may include several thousand variables and in many cases involve nonsmooth and discontinuous relations and discrete decisions.

The speakers in this minisymposium will provide an overview of process optimization problems by industrial practitioners. They will discuss problems from reactor optimization, overall process optimization, and incorporation of process dynamics into the problem formulation. The speakers will emphasize the unique features of each application and describe current methods used in their solution.

Organizer: Lorenz T. Biegler
Carnegie Mellon University

10:30 **A Concise Overview of Chemical Engineering Optimization Applications**
Lorenz T. Biegler, organizer

10:50 **Theoretical Modeling of Amoco's Gas-Phase Horizontal Stirred-Bed Reactor for the Manufacturing of Polypropylene Resins**
Michael Caracotsios, Amoco Chemical Company

11:10 **Optimization Using Process Simulators**
Hern-shan Chen and Thomas P. Kisala, Aspen Technology, Inc., Cambridge, MA

11:30 **Large-Scale Process Optimization with Differential Equations**
A.M. Morshedi, DOT Products, Inc.

CP1/Belmont Room
Large-Scale Optimization I
Chair: Gianni Di Pillo, Universitá di Roma
"La Sapienza", Italy

10:30 **Recursive Components in Large Optimization Models**
Arne Stolbjerg Drud, ARKI Consulting and Development A/S, Denmark

10:50 **Numerical Experience with LANCELOT (Release A) in Large Scale Nonlinear Programming**
A. Conn, IBM Thomas J. Watson Research Center; N. Gould, Rutherford Appleton Laboratory, United Kingdom; and *Phillippe Toint*, Facultes Universitaires Notre Dame de la Paix, Belgium

11:10 **Singularities in Large-Scale Structural Optimization**
James D. Guptill; Surya N. Patnaik and Laszlo Berke, NASA Lewis Research Center

11:30 **The Design of a Large-Scale NLP Code for Trajectory Optimization Problems**
K. Brenan, W. Hallman and W. Yeung, The Aerospace Corporation

CP2/Gold Coast Room

Data Fitting Problems I

Chair: C. Lemarechal, INRIA, France

10:30 **POSM - A Nonlinear Optimization Program Suitable for Engineering**
Shao Wei Pan and Yu Hen Hu, University of Wisconsin, Madison

10:50 **A Comparison of Some Methods for Estimating Rate Constants in Chemical Kinetics**
Per-Ake Wedin, University of Umea, Sweden and Lennart Edsberg, Royal Institute of Technology, Sweden

11:10 **On the EM Algorithm and a Generalization of the Proximal Point Method**
Alvaro Rodolfo de Pierro, Universidade Estadual de Campinas, Brazil

11:30 **Experimental Data Integration in Large Scale System Analysis**
L. Michael Santi, Christian Brothers University and John P. Butas, NASA, George C. Marshall Space Flight Center

CP3/Acapulco Room

Bound Constrained Problems I

Chair: Panos Pardalos, University of Florida

10:30 **Bounded Least Squares for PET**
Linda Kaufman, AT&T Bell Laboratories

10:50 **Data Parallel Quadratic Programming with Box-Constrained Problems**
Jill Mesirov and Mike McKenna, Thinking Machines Corporation and *Stavros A. Zenios*, University of Pennsylvania

11:10 **Massively Parallel Solution of Quadratic Programs via Successive Overrelaxation**
Renato De Leone and Mary A. Tork Roth, University of Wisconsin, Madison

11:30 **On the Effects of Scaling on Projected Gradient Methods for Solving Bound Constrained Quadratic Programming Problems**
Jesse L. Barlow, Pennsylvania State University and *Gerardo Toraldo*, Universitá della Basilicata, Italy

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12:00-1:30

Lunch

1:30/Regency A/B

IP3/Chair: Jorge Nocedal,
Northwestern University

Network Optimization: Five Decades of Applications

Evolving in the best tradition of applied mathematics, network optimization is a subject that is grounded in theory and arises in a remarkably wide variety of problem domains. It poses considerable challenges for modeling, algorithm development, and efficient computation. Drawing upon almost 200 applications from a textbook (in press) on network flows co-authored by R. Ahuja, J. Orlin and T.L. Magnanti, the speaker will provide an overview of a variety of fields, including computer and communications systems, distribution and transportation systems, engineering, management science, manufacturing, production and inventory planning, the medical sciences, and the social sciences and public policy.

Thomas L. Magnanti
Sloan School of Management and Operations Research Center
Massachusetts Institute of Technology

2:30-3:50

Concurrent Sessions (Minisymposia and Contributed)

MS4/Regency A/B

Constrained Nonlinear Optimization

The speakers in the minisymposium will discuss new algorithms for solving nonlinearly constrained optimization problems. These optimization problems occur in applications such as engineering design, industrial process control, data fitting and trajectory control. For small to medium size problems with exact data, the method of choice has come to be some version of successive quadratic programming (SQP), but for large or noisy problems other approaches must be developed. The speakers in the minisymposium will present some extensions of SQP and discuss some totally different approaches.

Organizer: Richard Byrd
University of Colorado

2:30 **A Truncated SQP Algorithm for Large-Scale Nonlinear Programming Problems**
Paul Boggs, National Institute of Standards and Technology and Jon W. Tolle, University of North Carolina, Chapel Hill

2:50 **A Direct Search Method that Employs Quadratic Model Functions**
M.J.D. Powell, Cambridge University, United Kingdom

3:10 **An Interior Point Algorithm for Nonlinearly Constrained Problems**
Leon Lasdon and Gang-Yu University of Texas, Austin, and John C. Plummer, Southwest Texas State University

3:30 **Constrained Optimization Algorithms Using Limited Memory Methods**
Richard Byrd, organizer and Jorge Nocedal, Northwestern University

MS5/Belmont Room

Problems "Off-the-Shelf" Newton Methods Won't Solve

There are important optimization problems from a variety of applications areas, for which standard "off-the-shelf" quasi-Newton methods do not work and in fact, usually perform quite badly. These problems arise in such areas as biotechnology, control, electrical engineering, and geophysics. All the problems share certain features. First, the function evaluation routines are expensive to compute. Second, analytic expressions for the derivatives are difficult to obtain and finite-difference gradients are not trustworthy. Third, the underlying function may not even be differentiable. Fourth, while local solutions are often of interest, the global solution is usually desired.

The speakers will present some of these problems and describe their efforts to solve them. They will discuss alternate optimization methods that, in certain instances, are more appropriate for some of the problems under consideration.

Organizer: Virginia Torczon
Rice University

2:30 **Control System Radii and Nonstandard Optimization Problems**
John A. Burns and Kimberly Oates, Virginia Polytechnic Institute and State University and Gunter Peichl, Universitat Graz, Austria

2:50 **An Algorithm for Optimizing MESFET Design**
Paul A. Gilmore and C.T. Kelley, North Carolina State University

3:10 **Optimization Techniques for Molecular Structure Determination**
Michael E. Colvin, Richard S. Judson and *Juan Meza*, Sandia National Laboratories

3:30 **Velocity Estimation: A Difficult Nonlinear Optimization Problem from Seismology**
William W. Symes, Rice University

MS6/Water Tower Room

Advances in Proximal Point Methods

The proximal point method constitutes one of the most powerful and versatile tools available for optimization and, in general, for solving monotone operator equations. Applications of this method give rise to numerous well known techniques for convex and convex-concave programming, such as powerful splitting techniques, thus making it potentially well suited for large-scale program decomposition and massively parallel computation.

The speakers in this minisymposium will present some of their recent results with a focus on new algorithms using the proximal point method and new implementations. Recent advances in the convergence analysis of these algorithms, including techniques for accelerating convergence, will also be discussed.

Organizers: James V. Burke and Paul Tseng
University of Washington

2:30 **Newton-like Proximal Point Method: Convergence and Application**
Maijian Quian, University of Washington

2:50 **Some Recent Results on Proximal-Like Methods in Convex Optimization**
Marc Teboulle, University of Maryland, Baltimore County

3:10 **Convergence Rates of Proximal Point Algorithms for Convex Minimization**
Osman Guler, Delft University of Technology, The Netherlands

3:30 **Partial Proximal Algorithms and Partial Methods of Multipliers: The Quadratic and Entropy Cases**
Dimitri Bertsekas, Massachusetts Institute of Technology and Paul Tseng, Organizer

CP4/Toronto Room

Network Optimization I

Chair: Gordon H. Bradley,
Naval Postgraduate School

2:30 **A Generic Auction Algorithm for the Minimum Cost Network Flow Problem**
Dimitri P. Bertsekas, Massachusetts Institute of Technology and David A. Castanon, Boston University

2:50 **An Efficient Implementation of a Network Interior Point Method**
Mauricio G.C. Resende, AT&T Bell Laboratories and Geraldo Veiga, University of California, Berkeley

3:10 **LSNNO, a FORTRAN Subroutine for Solving Large-scale Nonlinear Network Optimization Problems**
Daniel Tuyttens, Faculte Polytechnique de Mons, Belgium

3:30 **A Class of Trust Region Algorithms for Optimization Using Inexact Projections on Convex Constraints: Application to the Nonlinear Network Problem**
Annick Sartenaer, Facultes Universitaires Notre Dame de la Paix, Belgium

CP5/Acapulco Room

Simulated Annealing

Chair: Robert Schnabel,
University of Colorado, Boulder

2:30 **Classification Tree Optimization by Simulated Annealing**
Richard S. Bucy, University of Southern California and The Aerospace Corporation and *Raymond S. DiEsposti*, The Aerospace Corporation

2:50 **Ensemble Simulated Annealing for Parallel Architectures**
Peter Salamon, Luqing Wang, *Andrew Klinger* and Yaghout Nourani, San Diego State University

3:10 **The Demon Algorithm**
Theo Zimmermann and *Peter Salamon*, San Diego State University

3:30 **Beamforming with Simulated Annealing**
Michael D. Collins and W.A. Kuperman, Naval Research Laboratory, Washington, DC

CP6/Gold Coast Room

Sparse Matrix Problems

Chair: Linda Kaufman,
AT&T Bell Laboratories

2:30 **A Sparse Updating Approach to Problems in Column Block Angular Form**
Julio M. Stern, University of Sao Paulo, Brazil and *Stephen A. Vavasis*, Cornell University

2:50 **A New Iterative Method for Solving Symmetric Indefinite Linear Systems Arising in Optimization**
Roland W. Freund, NASA Ames Research Center and Hongyuan Zha, Stanford University

3:10 **Preconditioned Iterative Techniques for Sparse Linear Algebra Problems Arising in Circuit Simulation**
William D. McQuain, Calvin J. Ribbens and *Layne T. Watson*, Virginia Polytechnic Institute and State University and Robert C. Melville, AT&T Bell Laboratories

3:30 **Graph Coloring and the Estimation of Sparse Jacobian Matrices Using Row and Column Partitioning**
Trond Steihaug and A.K.M. Shahadat Hossain, University of Bergen, Norway

3:50/Regency D

Coffee

4:20-5:40

Concurrent Sessions (Minisymposia and Contributed)

MS7/Belmont Room

Recent Theoretical Advances in Interior Point Methods

The last two years have seen considerable progress in the theoretical analysis of interior point methods for linear and nonlinear programming and complementarity problems. Some highlights of this work include the development of long step path following algorithms for linear and nonlinear programming, the determination of general conditions for convergence in primal-dual algorithms for LCP, new, stopping criteria for linear programming that apply to degenerate problems, and the unification of global and local convergence theory for primal-dual methods. Continued progress on the theory of interior point methods promises to both improve the theoretical complexity of algorithms and contribute to the development of methods with improved practical performance.

Organizer: Kurt M. Anstreicher
University of Iowa

4:20 **Toward Probabilistic Analysis of Interior-Point Algorithms for Linear Progamming—Part 1 of 2**
Yinyu Ye, University of Iowa

4:40 **An Artificial Self-Dual Linear Program**
Masakazu Kojima, Tokyo Institute of Technology, Japan; Nimrod Megiddo, IBM Almaden Research Center; Shinjo Mizuno, The Institute of Statistical Mathematics, Japan; and Akiko Yoshise, University of Tsukuba, Japan

5:00 **On the Convergence of the Iteration Sequence in Primal-Dual Interior-Point Methods**
Richard Tapia, Rice University

5:20 **Ellipsoidal Trust Regions and Prox Functions for Linearly Constrained Nonlinear Programs**
Clovis C. Gonzaga, Federal University of Rio de Janeiro, Brazil

MS8/Toronto Room

Robust Optimization: Models and Solution Strategies

This minisymposium takes up the theme that solutions to optimization problems ought to be robust in the face of imprecise data. The motivation for this theme is the observation that real-world empirical data possess unavoidable degrees of noise.

The speakers in this minisymposium will discuss robust models, solution strategies using parallel/distributed computers, and generalized sensitivity analysis. They will emphasize practical procedures.

Organizer: John M. Mulvey
Princeton University

4:20 **General Modeling Framework for Robust Optimization**
John M. Mulvey, organizer

4:40 **Decomposition and Robust Optimization**
Bock Jin Chun and Stephen M. Robinson, University of Wisconsin, Madison

5:00 **Robust Optimization: Massively Parallel Solution Methodologies**
Stavros A. Zenios, University of Pennsylvania

5:20 **Robust Optimization: Interior Point Solution Methodologies**
Robert J. Vanderbei, Princeton University

MS9/New Orleans Room

Optimization Problems Involving Eigenvalues – Part 1 of 2

Optimization problems involving eigenvalues arise in a wide variety of applications. These problems are interesting for several reasons, one being that the eigenvalues of a matrix are not smooth functions of the matrix elements at points in parameter space where multiple eigenvalues occur. Nonetheless these problems have a rich structure and nonsmooth optimization techniques can be applied very fruitfully.

The speakers in this minisymposium will discuss a number of different classes of such problems which arise in diverse application areas.

Organizer: Michael L. Overton
Courant Institute of Mathematical Sciences, New York University

4:20 **Semi-definite Programming : Duality Theory, Eigenvalue Optimization and Combinatorial Applications**
Farid Alizadeh, University of Minnesota

4:40 **Measures for Symmetric Rank-one Updates**
Henry Wolkowicz, University of Waterloo, Canada

5:00 **Shape Optimizing Eigenvalues of the Laplacian**
Jean-Pierre Haeberly, Fordham University

5:20 **Bounds for Eigenvalues and Singular Values of Matrix Completions**
Hugo Woerdeman, College of William and Mary

CP7/Acapulco Room

Control Problems I

Chair: William Hager, University of Florida

4:20 **Advantages of Differential Dynamic Programming Over Stage-wise Newton's Method for Optimal Control Problem**
Christine A. Shoemaker and Li-Zhi Liao, Cornell University

4:40 **Applications of Structured Secant Approaches in Hilbert Space**
J. Huschens, Universität Trier, Germany

5:00 **Solution of a Nonlinear Boundary Control Problem by Reduced SQP**
F.-S. Kupfer and E.W. Sachs, Universität Trier, Germany

5:20 **A New Homotopy Method for Solving the H^2 Optimal Model Reduction Problem**
Yuzhen Ge and *Layne T. Watson*, Virginia Polytechnic Institute and State University and Emmanuel G. Collins, Jr., Harris Corporation, Melbourne, FL

CP8/Gold Coast Room

Global Optimization

Chair: Regina Hunter Mladineo, Rider College

4:20 **An Application of Semiinfinite Programming Methods to Nonlinear Approximation Problems**
Miroslav D. Asic, Ohio State University and Vera V. Kovacevic-Vujcic, University of Belgrade, Yugoslavia

4:40 **New Method of a Global Optimization**
Alexander A. Bolonkin, Courant Institute of Mathematical Sciences, New York University

5:00 **Efficient Hybrid Techniques for Solving Some Global Optimization Problems**
Luis N. Vicente and Joaquim J. Judice, Universidade de Coimbra, Portugal

5:20 **Potential Transformation Methods for Global Optimization**
Jack W. Rogers, Jr. and Robert A. Donnelly, Auburn University

CP9/Water Tower Room

Constrained Optimization I

Chair: Paul Boggs, National Institute of Standards and Technology

4:20 **A Global Convergence Theory for a Trust Region Algorithm for Constrained Optimization**
J. E. Dennis, Jr. and *Maria Cristina Maciel*, Rice University

4:40 **An Implicit Trust Region Algorithm for Constrained Optimization**
Frederic Bonnans and Genevieve Launay, INRIA, France

5:00 **Numerical Experience with a Merit Function for Inequality Constraints**
Anthony J. Kearsley, Rice University

5:20 **Another Look at Direction Finding Methods**
Mark Cawood and Michael Kostreva, Clemson University

6:00/Regency A/F

Poster Session 1

(During the session, complimentary beer, assorted sodas, chips and dips will be available.)

LINEAR PROGRAMMING

Parallel Extreme Point Algorithms for Linear Programming
Mohan Sodhi and John Mamer, University of California, Los Angeles

An Algorithm for a Class of Continuous Linear Programs
Malcolm Craig Pullan, Judge Institute of Management Studies, Cambridge, United Kingdom

New Directions for Progress in Linear and Nonlinear Programming
Victor Pan, Lehman College, City University of New York, Bronx

Perturbation Analysis of Hoffman's Bound for Linear Systems
Zhi-Quan Luo, McMaster University, Canada and *Paul Tseng*, University of Washington, Seattle

Stability of the Optimal Solution of a Linear Program to Simultaneous Perturbations of All Data
Jiri Rohn, Charles University, Czechoslovakia

Interval Methods for Degenerate Linear Programs
Frank Plab, University of Edinburgh, Scotland

Optimization of Large Structural Systems by Using Karmarkar's Method
S. Hernandez, J. Mata, and J. Doria, University of Zaragoza, Spain

A Modified Termination Rule for Karmarkar's Algorithm
J.N. Singh, College of Business Management, India and D. Singh, Indian Institute of Technology, India

Applications of Linear Programming to Medical Diagnosis
Xu Shu Rong, Zhongshan University, China

Projective Interior Point Methods with O(sqrt(n)L) Step Complexity
Donald Goldfarb, Columbia University and Dong Shaw, Rider College

CONSTRAINED OPTIMIZATION

Barrier Methods for Large-Scale Nonlinear Programming
Stephen Nash and *Ariela Sofer*, George Mason University

Image Reconstruction from Noisy Projections: A Regularized Dual-Based Iterative Method
Alfredo Noel Iusem, Instituto de Matemática Pura e Aplicada, Brazil

Numerical Experience with the Modified Barrier Functions Method for Linear-Constrained Optimization Problems
David Jensen, Roman Polyak and Rina R. Schneur, IBM Thomas J. Watson Research Center

The Nonconvex Separable Resource Allocation Problem with Continuous Variables
Emile Haddad, Virginia Polytechnic Institute and State University

CONTROL PROBLEMS

Optimization of Interactions in an Interconnected System
Ronald A. Perez, University of Wisconsin, Milwaukee

Hierarchical Controls in Stochastic Manufacturing Systems with Convex Costs
S. Sethi, Q. Zhang, and *X.Y. Zhou*, University of Toronto, Canada

Methods of Solution of Boundary Value Problem of Optimal Theory
Alexander A. Bolonkin, Courant Institute of Mathematical Sciences, New York University

On Certain Optimization Problems in Banach Spaces with Nonsmooth Equality Constraints
Urszula Ledzewicz-Kowalewska, Southern Illinois University, Edwardsville and Stanislaw Walczak, University of Lodz, Poland

STOCHASTIC PROBLEMS

Comparative Study of Stochastic Approximation Algorithms in the Multivariate Kiefer-Wolfowitz Setting
Daniel C. Chin, Johns Hopkins University

NETWORK OPTIMIZATION

Comparison of Approximate and Exact Solution Methods for Network Location Problems
Geraldo R. Mateus, Universidade Federal de Minas Gerais, Mexico and *Jean-Michel Thizy*, University of Ottawa, Canada

Sensitivity of the Time Bounds for Network Flow Path Searches when Critical Nodes are Altered
Andrew W. Harrell, U.S. Army Waterways Experiment Station

An Implementation of a Parallel Interior Point Method for Multicommodity Flow Problems
Guangye Li, Rice University and Irvin J. Lustig, Princeton University

A General Overshipment Solution to Transportation Problem of Three Dimensions
Nabih N. Mikhail, Liberty University

An Algorithm for Solving the Cost Optimization Problem in Precedence Diagram Network
Miklos Hajdu, Technical University of Budapest, Hungary

Redistribution Transport Means the Traffic in the Area of Subway is Shut
Aleksander Mishenco, Plekhanov Academy of National Economy, Russia

Algorithms for the Production and Vehicle Routing Problems with Deadlines
M. A. Forbes, J. N. Holt, P. J. Kilby, and A. M. Watts, University of Queensland, Australia

COMBINATORIAL OPTIMIZATION

A Primal-Dual Interior Point Method with Cutting Planes for the Linear Ordering Problem
John E. Mitchell and Brian Borchers, Rensselaer Polytechnic Institute

Three Approximation Algorithms that Minimize the Rectilinear Steiner Tree on a Hypercube Network
Tao Zhou and Dionysios Kountanis, Western Michigan University

Alternating Sequences Relative to Maximum Independent Sets of Independence Systems
Tao Wang, John's Hopkins University

Maximizing the Visibility Area from a Point Moving on a Curved Segment
Lambros Piskopos and Dionysios Kountanis, Western Michigan University

Practical Heuristics for Scheduling Precedence Graphs onto Multiprocessor Architectures
Kiran Bhutani and Abdella Battou, Catholic University of America

Minimizing Communication in Domain Decomposition via Minimum-Perimeter Tiling
Jonathan Yackel and Robert R. Meyer, University of Wisconsin, Madison

Transfer Method for Optimization on Non-Transitive Binary Relations
Jianxin Zhou, Texas A&M University, College Station

Integer Search Method
Wu Xingbao, Wuhan College of Metallurgic Management Cadre, People's Republic of China

OPTIMIZATION ALGORITHMS AND SOFTWARE

Newton Modified Barrier Function Complexity for Quadratic Programming Problems
Aharon Melman, California Institute of Technology and Roman Polyak, IBM Thomas J. Watson Research Center

Interior Point Algorithms and Dynamic Systems
Zai-yun Diao, Shandong University, People's Republic of China

Modelling of an Economic Incentive Approach in Environmental Protection
A. D. Rikun, Water Problems Institute of the USSR Academy of Sciences Sadovo-Cherniogriazskaya, Russia

The Optimization with Formally-Undefined Criterion
Mikhael Aron Alexandrov, Moscow Geological-Prospecting Institute, Russia

Optimization Modeling for Neural Networks and Mathematical Biology
Richard S. Segall, Eastern Kentucky University

Optimal Regularity of Equilibria and Material Instabilities
Salim M. Haidar, Northern Michigan University

Functions with Unstable Images: Cracks
Guangxiong Fang, Daniel Webster College and Jack Warga, Northeastern University

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7:30/Ballroom Foyer

Registration opens

8:30/Regency A/B
IP4/Chair: Jane K. Cullum, IBM Thomas J. Watson Research Center

Convex Optimization Problems Arising in Controller Design

Many problems in control system design and analysis can be cast as convex nondifferentiable optimization problems. In many cases these problems come far closer to the "real" engineering design or analysis problem than any problem for which an "analytic" solution is known. The cost, of course, is that solving such a problem requires more computation than solving a problem that has an "analytic" solution. However, great advances in computer power and the development of powerful specialized algorithms for convex nondifferentiable optimization problems mean that these problems will have great practical relevance in the future. Indeed, in some cases these problems can be solved so quickly that the engineer can manipulate the problem parameters (design specifications) and view the resulting solution (design) in real time.

Several methods have been successfully applied to these problems. The ellipsoid algorithm of Shor, Yudin, and Nemirovsky has proved reliable, and interior point methods recently developed by Nesterov and Nemirovsky and others show great promise.

Stephen Boyd
Information Systems Laboratory
Department of Electrical Engineering
Stanford University

9:15/Regency A/B
IP5/Chair: Jane K. Cullum, IBM Thomas J. Watson Research Center

Scheduling of Manufacturing Systems

Manufacturing systems consist of several machines producing several types of parts. Machines are subject to various disruptions such as random failures, yield losses, and processing time and demand changes. Nevertheless, it is important to dynamically schedule them in real-time to produce all parts in the required numbers, at close to their due dates, while keeping work-in-process and manufactuing lead times small. In this presentation, the speaker will address some of the issues involved in efficiently running manufacturing systems, with a special focus on problems from the semiconductor industry.

P.R. Kumar
Department of Electrical and Computer Engineering, and Coordinated Science Laboratory
University of Illinois, Urbana-Champaign

10:00/Regency D

Coffee

10:30-11:50

Concurrent Sessions (Minisymposia and Contributed)

MS10/Water Tower Room

Advanced Environments for Optimization Software

Successful optimization methods must be more than fast and reliable. Users increasingly expect an advanced algorithm to be made available in an advanced computing environment. The speakers will present an introduction to diverse environments that have been designed to help mathematical programming users specify and manage their models, data, and results. The presentations will be of direct interest to conference participants who develop applications of linear programming, nonlinear programming or combinatorial optimization. The session will also be of interest to algorithm developers, because of its implications for interface design and its relevance to issues in the creation and maintenance of test problems.

Organizer: Robert Fourer
Northwestern University

10:30 **Optimization Model Management**
David S. Hirshfeld, MathPro Incorporated, Washington, DC

10:50 **Graph-Grammars for Network Flow Modeling**
Christopher V. Jones, Simon Fraser University, Canada

11:10 **AIMS: An Environment for Advanced Integrated Modeling Support**
Johannes J. Bisschop, Technical University of Twente, The Netherlands

11:30 **An Introduction to ASCEND: Its Language and Interactive Environment**
Ramayya Krishnan and Peter Piela, and Arthur Westerberg, Carnegie Mellon University

MS11/Regency A/B

Optimal Design of Engineering Systems

The speakers in this minisymposium will address optimization problems in engineering design, in particular structural and shape optimization problems that arise in the geometric design of civil, mechanical, and aerospace systems. The increasing complexity of the engineering systems (requiring larger numbers of design variables to describe them) and resolution requirements of the governing partial differential equations (leading to larger numbers of state variables when discretized) mean that these problems are of larger scale. The speakers will discuss efficient gradient computation and sensitivity analysis, automated meshing, design/analysis integration and algorithms for large-scale problems and advanced-architecture computers. The presentations collectively span formulations, structure, algorithms and difficulties encountered in some optimal engineering design problems.

Organizer: Omar N. Ghattas
Carnegie Mellon University

10:30 **Design/Analysis Process Integration for Shape Optimization of Mechanical Parts**
Srinivas Kodiyalam, General Electric Co.

10:50 **Conjugate Directions Methods for Large-Scale Optimization**
Jasbir S. Arora and Guangyao Li, University of Iowa

11:10 **Optimization Methods in Curve and Surface Design**
Thomas A. Grandine, The Boeing Company

11:30 **Data-Parallel Optimal Shape Design of Airfoils**
Omar N. Ghattas, organizer and Carlos E. Orozco, Carnegie-Mellon University

CP10/Belmont Room

Linear Programming: Computational Issues I

Chair: Irvin J. Lustig, Princeton University

10:30 **Computational Issues in the Interior Point Methods**
Geraldine M. Hemmer, Northeastern Illinois University

10:50 **More on Dual Ellipsoids and Degeneracy in Interior Algorithms for Linear Programming**
Kurt M. Anstreicher and Jun Ji, University of Iowa

11:10 **A Long-Step Inverse Barrier Hybrid Algorithm for Linear Programming**
Alexander Hipolito, University of Florida, Gainesville

11:30 **Decomposition in LP Based on Modified Barrier Function**
David Jensen and *Roman Polyak*, IBM Thomas J. Watson Research Center

CP11/Toronto Room

Large-Scale Constrained Optimization II

Chair: Arne Stolbjerg Drud, ARKI Consulting and Development A/S, Denmark

10:30 **Finding Optimal Orthotropic Composites**
Rob Lipton, Worcester Polytechnic Institute and *James Northrup*, Colby College

10:50 **Using Barrier Methods for Solving Large-Scale Crystallographic Problems**
Paul B. Anderson, PRC Inc.; Stephen G. Nash and Ariela Sofer, George Mason University

11:10 **Optimal Design of Trusses by Smooth and Nonsmooth Methods**
Aharon Ben-Tal, Technion. Israel Institute of Technology, Israel

11:30 **On-line Optimal Control of a Large-Scale Water System**
R. Grino, *Gabriela Cembrano*, Institut de Cibernetica (UPC-CSIC), Spain

CP12/Gold Coast Room

Data Fitting Problems II

Chair: Per-Ake Wedin,
University of Umea, Sweden

10:30 **A Continuation Method for Linear L1 Estimation**
Kaj Madsen and Hans Bruun Nielsen, The Technical University of Denmark, Lyngby, Denmark

10:50 **An Algorithm for Non-negative Least Error Minimal Norm Solutions**
Panagiotis Nikolopoulos and Christos Nikolopoulos, Bradley University

11:10 **On the Sensitivity of Paired Comparisons**
Trond Steihaug and Lars-Magnus Nordeide, University of Bergen, Norway

11:30 **Shape Matching via Piecewise Linear Approximation**
Jose A. Ventura and Jen-Ming Chen, Pennsylvania State University

CP13/Acapulco Room

Quadratic Programming

Chair: Andrew Conn, IBM Thomas J. Watson Research Center

10:30 **Numerical Experiments with an Interior Point Method for Large Sparse Convex Quadratic Programming**
J.L. Morales-Perez and R.W.H. Sargent, Imperial College, United Kingdom

10:50 **A New Modified Newton Method for Large-Scale Quadratic Programming**
Thomas F. Coleman and Jianguo Liu, Cornell University

11:10 **A Robust Algorithm for Special Quadratic Programming**
Guangye Li, J. E. Dennis, and Karen A. Williamson, Rice University

11:30 **Implementation of a Schur-Complement Method for Large-Scale Quadratic Programming**
Paul Frank and John Betts, Boeing Computer Services

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12.00-1:30

Lunch

1:30/Regency A/B

IP6/Chair: Philippe Toint, Facultes Universitaires Notre Dame de la Paix, Belgium

Cheap Gradients and Beyond: The Promise of Automatic Differentiation in Optimization

The numerical solution of most nonlinear optimization problems requires the evaluation of objective gradients and constraint Jacobians as well as the approximation of the Hessians of the Lagrangian, or at least its product with several vectors. Currently, first derivatives are either evaluated by user supplied code or estimated by divided differences, and second derivatives are often approximated sequentially by secant updating. For various reasons this is unsatisfactory for obtaining derivative information, especially on large-scale problems.

Automatic differentiation software produces extended object code that evaluates first and second derivatives as well as error estimates for the underlying functions themselves. The numerical calculations are based on the chain rule, and the derivative values are therefore exact up to round-off. The integration of automatic differentiation into optimization packages greatly enhances user friendliness, ensures maximal solution accuracy, and facilitates faster convergence through the use of higher order methods.

The speaker will give an overview of automatic differentiation and discuss its advantages in optimization problems.

Andreas Griewank
Mathematics and Computer Science Division
Argonne National Laboratory

2:30-3.50

Concurrent Sessions (Minisymposia and Contributed)

MS12/Belmont Room

Network Flow Algorithms

An important special case of linear programming is the network flow problem, both because of its wide applicabilty and because of the existence of special purpose algorithms that solve minimum cost flow problems orders of magnitude faster than other linear programs.

The speakers in this minisymposium will discuss an implementation of an algorithm for solving a stochastic network optimization problem on the (massively parallel) connection machine, the results of the DIMAC's challenge, (an experimental study on implementations of network flow algorithms on sequential and parallel machines), an improved algorithm for the minimum cut problem, and improved algorithms for providing useful feedback to the modeler of a minimum cost flow problem when the formulation has no feasible flow.

Organizer: James B. Orlin
Massachusetts Institute of Technology

2:30 **Proximal Minimizations with D-functions and the Massively Parallel Solution of Stochastic Networks**
Stavros Zenios and Soren S. Nielsen, The University of Pennsylvania

2:50 **The DIMACS Challenge: A Cooperative Experimental Study of Network Flow and Matching Algorithms**
Catherine C. McGeoch, Amherst College

3:10 **Finding the Minimum Cut in a Network**
Jianxiu Hao, GTE Laboratories Incorporated and James B. Orlin, organizer

3:30 **Diagnosing Infeasibilities in Network Flow Problems**
Jianxiu Hao, GTE Laboratories Incorporated and *James B. Orlin*, organizer

MS13/Regency A/B

Protein Folding - A Challenging Optimization Problem

Most proteins have a characteristic shape to which they quickly return after being provoked to another shape. Understanding why proteins assume the shapes they do is currently of considerable interest and could be of great practical importance in medicine and biotechnology.

In this minisymposium, the speakers view the protein folding problem as a large and difficult optimization problem - that of minimizing the energy of the protein. They will provide an informative overview and discuss aspects of the problem that show why it is of interest both as a global and as a local optimization problem.

Organizers: David M. Gay and Margaret H. Wright
AT&T Bell Laboratories

2:30 **An Introduction to Protein Folding - The Second Half of the Genetic Code**
Lynn W. Jelinski, Cornell University

2:50 **Use of Constraints and Other Approaches to Protein Folding**
David M. Gay, co-organizer, Teresa Head-Gordon and Frank H. Stillinger, AT & T Bell Laboratories, and *Margaret H. Wright*, co-organizer

3:10 **Renormalization Group and the Protein Folding Problem**
Panos M. Pardalos, University of Florida; David Shalloway, Cornell University

3:30 **A New Computational Approach to the Protein Folding Problem**
Thomas F. Coleman, David Shalloway and Zhijun Wu, Cornell University

MS14/Toronto Room

Advances in Operator/Matrix Splitting Methods

Operator/matrix splitting provides a powerful framework for developing broad classes of decomposition methods for large-scale continuous optimization. By tailoring the splitting to the problem, it has been possible to construct simple and highly parallelizable algorithms for linear and quadratic programming, network programming, stochastic programming, as well as the solution of boundary value problems.

The speakers in this minisymposium will present some recent results on splitting schemes and will address issues such as convergence and implementation (on either a sequential or a parallel machine).

Organizers: Paul Tseng and James V. Burke
University of Washington

2:30 **Some Saddle-Function Splitting Methods for Convex Programming**
Jonathan Eckstein, Thinking Machines Corporation

2:50 **Monotone Operator Splitting and Linear Complementarity**
Jonathan Eckstein, Thinking Machines Corporation; *Michael C. Ferris*, University of Wisconsin, Madison

3:10 **Splitting Methods for Symmetric Affine Variational Inequality Problems, with Application to Extended Linear-Quadratic Programming**
Jong-Shi Pang, John Hopkins University

3:30 **Forward-Backward Splitting in Large-Scale Optimization**
George H. G. Chen and R. Tyrrell Rockafellar, University of Washington

CP14/Acapulco Room

Constrained Optimization II

Chair: Stephen G. Nash,
George Mason University

2:30 **Line-search Techniques for Quasi-Newton Methods in Equality Constrained Optimization**
Jean Charles Gilbert, INRIA, Roquencourt, France

2:50 **A Penalty Function Approach to the General Bilevel Problem**
Paul H. Calamai and *Lori M. Case*, University of Waterloo, Canada and Andrew R. Conn, IBM Thomas J. Watson Research Center

3:10 **A Trust Region Method for Nonlinear Optimization Problems**
Yuan-An Fan, IMSL, Inc.; Jianzhong Zhang, City Polytechnic of Hong Kong, Hong Kong; and Detong Zhu, Shanghai Normal University, People's Republic of China

3:30 **The Value Function in Hierarchical Optimization**
Jay S. Treiman, Western Michigan University and Roxin Zhang, Northern Michigan University

CP15/Water Tower Room

Unconstrained Minimization

Chair: Ekkehard Sachs, Universität Trier,
Germany

2:30 **Parallel Implementation of Truncated Newton Methods**
Robert H. Leary, San Diego Supercomputer Center

2:50 **Vector Performance Criteria in Unconstrained Optimization**
Luigi Grippo, Università di Roma "La Sapienza", Italy; Francesco Lampariello and Stefano Lucidi, Instituto di Analisi dei Sistemi ed Informatica del CNR, Italy

3:10 **Implementing a Parallel Asynchronous Newton Method on a Distributed Memory Architecture**
Domenico Conforti, Lucio Grandinetti and Roberto Musmanno, Universita della Calabria, Italy

3:30 **Modifying the BFGS Update by Column Scaling Techniques**
Dirk Siegel, University of Cambridge, United Kingdom

CP16/Gold Coast Room

Convex Programming

Chair: J. Sun, Northwestern University

2:30 **The Global Convergence of a Class of Primal Potential Reduction Algorithms for Convex Programming**
Renato D.C. Monteiro, University of Arizona

2:50 **On the Affine Trust Region Interior Point Algorithm for Quadratic Programming**
Frederic Bonnans and Mustapha Bouhtou, INRIA, France

3:10 **Algorithms for the Convex Inequalities Problem**
Motakuri Venkata Ramana and Shin-Ping Han, Johns Hopkins University

3:30 **Experimentation with the Interior Cutting Plane Method (ICPM)**
J.-L. Goffin, McGill University, Canada and *J.-P. Vial*, Universite de Geneve, Switzerland

3:50/Regency D

Coffee

4:20-5:40

Concurrent Sessions
(Minisymposia and Contributed)

MS15/Belmont Room

Optimization in Control and Differential Equations

Algorithms for nonlinear equations and optimization in infinite dimensional spaces may differ in both analysis and formulation from conventional algorithms for such problems in finite dimension. Functional analytic considerations, such as choice of spaces or compactness properties of nonlinear maps, are important in the design and theory of such algorithms. When these algorithms are discretized, the resulting methods for the finite dimensional approximate problems are often new, preserve underlying functional analytic properties, and preserve structural properties such as sparsity pattern and symmetry. The role of compactness in superlinear convergence, the design of good preconditioners, and new methods that exploit functional analytic properties of infinite dimensional problems are research issues.

The speakers in this minisymposium will discuss a variety of such algorithms and their properties in the context of applications such as optimal control problems, integral equations, boundary value problems, and parameter identification.

Organizer: Carl T. Kelley
North Carolina State University

4:20 **Optimization Methods for Elliptic Systems**
Carl T. Kelley, organizer

4:40 **Numerical Methods for Nonlinear Parabolic Control**
Ekkehard W. Sachs and F.S. Kupfer, Universität Trier, Germany

5:00 **Parallel Optimization in Groundwater and Petroleum Resources Management**
R. Michael Lewis, Rice University

5:20 **Augmented Lagrangian and SQP Techniques for Nonlinear Illposed Inverse Problems**
Karl Kunisch, Technische Universitat Graz, Austria

MS16/New Orleans Room

Computational Global Optimization

Many important practical optimization problems (such as engineering design and protein folding problems) have multiple local optima, but it is the global optimum that is usually desired. Stochastic and deterministic methods for finding the global optimum have been proposed.

The speakers in this minisymposium will present recent computational results for both constrained and unconstrained global optimization problems, using stochastic and deterministic methods. In the stochastic method a likely global optimum is found with a high probability. In the deterministic method a point is found whose function value is within a specified tolerance of the global optimum. The speakers will discuss the advantages and disadvantages of these methods.

Organizer: J.B. Rosen
University of Minnesota

4:20 **Computational Comparison of Two Methods for Constrained Global Optimization**
A.T. Phillips, U.S. Naval Academy, Annapolis, MD and J.B. Rosen, organizer

4:40 **Computational Approaches for Solving Quadratic Assignment Problems**
Panos M. Pardalos, University of Florida, and Yong Li, Pennsylvania State University

5:00 **An MILP Relaxed Dual Formulation for the GOP Algorithm**
C.A. Floudas, V. Visweswaran and Brigitte Jaumard, Princeton University

5:20 **Minimizing the Lennard-Jones Potential Function on a Massively Parallel Computer**
G.L. Xue and W.R.S. Maier, Army High Performance Computing Research Center, Minneapolis and J.B. Rosen, University of Minnesota

MS17/Acapulco Room

ADIFOR - Automatic Differentiation in Fortran and Applications to Optimization

Given a collection of Fortran subroutines describing a function f ADIFOR produces a Fortran code that computes the matrix-matrix product $J \cdot S$, where J is the Jacobian of f, and S is a user-initialized imput matrix. This allows the user to compute the Jacobian itself $S = I$ exploit the sparsity of J by computing a compressed Jacobian, or compute a matrix-vector product $S = x$. The cost is roughly proportional to the number of columns of S, so in particular a matrix-vector product $J = x$ is about as expensive to compute as one column of the Jacobian. As a byproduct of the derivative computation, the user is able to determine the structure of the Jacobian automatically.

From a user's point of view, ADIFOR has a very simple interface to the optimization code, since only a Fortran code for the description of the initial function has to be provided, yet one need not worry about loss of accuracy or convergence due to finite-difference errors. The speakers will give examples illustrating how ADIFOR can be used to generate subroutines to evaluate the derivatives that are typically needed by optimization codes.

Organizers: Christian Bischof and George Corliss
Argonne National Laboratory

4:20 **The Functionality of ADIFOR**
George Corliss, co-organizer

4:40 **The Performance of ADIFOR Codes**
Alan Carle, Rice University

5:00 **Automatic Differentiation in Nonlinear Programming and Parameter Identification**
Alan Carle, J. E. Dennis, Jr., Guangye Li and *Karen Williamson*, Rice University

5:20 **Experience with Various Automatic Differentiation Tools in Orthogonal Distance Regression**
Janet Rogers, National Institute of Standards and Technology

CP17/Toronto Room

Linear Programming: Analysis and Theory I

Chair: Yinyu Ye, University of Iowa

4:20 **A Scaling Technique for Finding the Weighted Analytic Center of a Polytope**
David S. Atkinson and Pravin M. Vaidya, University of Illinois, Urbana

4:40 **Adding and Deleting Constraints in a Path-Following Method for Linear Programming**
D. den Hertog, *C. Roos* and T. Terlaky, Delft University of Technology, The Netherlands

5:00 **On the Convergence of Interior-Point Methods to the Center of the Solution Set in Linear Programming**
Yin Zhang, University of Maryland, Baltimore County and Richard A. Tapia, Rice University

5:20 **Interior-Exterior Augmented Lagangian Approach for LP**
Roman Polyak and Rina R. Schneur, IBM Thomas J. Watson Research Center

CP18/Water Tower Room

Nonlinear Least Squares

Chair: Ariela Sofer, George Mason University

4:20 **Nonclassical Gauss-Newton Methods**
C. Fraley, Statistical Sciences, Inc. and University of Washington, Seattle

4:40 **Variations of Structured Broyden Families for Nonlinear Least Squares Problems**
Hiroshi Yabe, Science University of Tokyo, Japan and Rice University

5:00 **Relationship between Structured and Factorized Quasi-Newton Methods for Nonlinear Least-Squares Problems**
Toshihiko Takahashi, Kajima Corporation, Japan and Hiroshi Yabe, Science University of Tokyo, Japan

CP19/Gold Coast Room

Linear Complementarity

Chair: Layne T. Watson, Virginia Polytechnic Institute and State University

4:20 **An Interior Point Algorithm for Linear Complementarity Problems**
Jiu Ding, University of Southern Mississippi

4:40 **A Superlinearly Convergent $O(\sqrt{n}L)$-iteration Predictor-corrector Algorithm for Linear Complementarity Problem**
Siming Huang, Jun Ji and Florian Potra, University of Iowa

5:00 **Solution of Large Scale-Monotone Linear Complementarity Problems**
Joao M. Patricio and Joaquim J. Judice, Universidade de Coimbra, Portugal and Luis M. Fernandes, Escola Superior de Tecnologia de Tomar, Portugal

5:20 **Undamped Newton Method for Solving Linear Complementarity Problems**
Ubaldo M. Garcia-Palomares, Universidad Simon Bolivar, Venezuela

6:00/Regency A/B

Poster Session 2

(There will be a cash bar during the session. Chips and dips are complimentary.)

UNCONSTRAINED OPTIMIZATION

On the Convergence of Pattern Search Methods
Virginia Torczon, Rice University

The Barzilai and Borwein Gradient Method for the Large Scale Unconstrained Minimization Problem
Marcos Raydan, University of Kentucky

The Development of Parallel Nonlinear Optimization Algorithm for Chemical Process Design
Karen A. High, Oklahoma State University and Richard D. La Roche, Cray Research, Inc.

Unconstrained Minimization on Massively Parallel Computers
Robert S. Maier and Guo-Liang Xue, University of Minnesota, Minneapolis

On the Detection and Exploitation of Unknown Sparsity Structure in Nonlinear Optimization Problems
Richard G. Carter, AHPCRC, University of Minnesota and Argonne National Laboratory

Fixed-Point Quasi-Newton Methods
Jose Mario Martinez, IMECC-UNICAMP, Brazil

Data Analysis Techniques for Optimization Code Test Results
John C. Nash, University of Ottawa, Canada

Efficient and Stable Computation of Quasi-Newton Updates
Vasile Sima, Research Institute for Informatics, Romania

Efficient Parallel Minimization Algorithms in Computational Fluid Dynamics
E. de Klerk and J.A. Snyman, University of Pretoria, South Africa and L. Pretorius, University of South Africa, Pretoria, South Africa

Experiments with the Broyden Class of Quasi-Newton Methods
M. Al-Baali, University of Calabria, Italy

On the Performance of a Trust Region Newton Method for Large-Scale Problems
Brett M. Averick and Richard G. Carter, Army High Performance Computing Research Center, Minneapolis, and Jorge J. Moré, Argonne National Laboratory

MAY 12

Tuesday Afternoon

CONSTRAINED OPTIMIZATION

A Flexible Elimination Method for Nonlinear Constrained Optimization
Natalia Alexandrov, John E. Dennis, Jr., Rice University

Local Convergence Analysis of the Method of Centers
Abdelhamid Benchakroun, *Jean-Pierre Dussault* and Abdelatif Mansouri, Universite de Sherbrooke, Canada

Bilevel Formulations in Concurrent Modeling of the Design Process
J.R. Jagannatha Rao, University of Houston

Nonlinear Programming Model for Software Development Process
Nalina Suresh, University of Wisconsin, Eau Claire and A.J.G. Babu, University of South Florida

An Interior-point Algorithm for Quadratically Constrained Entropy Minimization Problems
Jun Ji and Florian Potra, University of Iowa

Optimum Design of Rotational Wheel and Casing Structures under Transient Thermal and Centrifugal Loads
Toshio Hattori, Hitachi Ltd., Japan

The Choice of the Lagrange Multiplier in the Framework of Successive Quadratic Programming Method
Debora Cores and Richard Tapia, Rice University

Conditions for Continuation of the Efficient Curve for Multi-objective Control-structure Optimization
Joanna Rakowska, Raphael T. Haftka, and *Layne T. Watson*, Virginia Polytechnic Institute and State University

CONVEX PROGRAMMING

The Scaled Proximal Decomposition on the Graph of a Monotone Operator
Philippe Mahey, Laboratoire ARTEMIS, IMAG, France; Pham Dinh Tao, LMAI-INSA Rouen, France and S. Oualibouch, Laboratoire ARTEMIS, France

Convex Optimization Problem Yields the Markov Process Steady Probability Distribution
Vladimir Marbukh, New York City Department of Sanitation

A Lagrangian Dual Approach for Assigning Tools to Machines in a Flexible Manufacturing Systems
T.H. D'Alfonso and *Jose A. Ventura*, Pennsylvania State University

DATA FITTING PROBLEMS

Optimal Design for Model $\mu=ax/(1+bx)$ with Multiplicative Error
Shankang Qu, *Shriniwas Katti*, University of Missouri, Columbia

Pattern Recognition and Classification Using Time Series
Jen-Ming Chen, Jose A. Ventura and Chih-Hang Wu, Pennsylvania State University

Adaptive Filtering in Nonlinear Parameter Estimation with Serially Correlated Data Structures
Frank O'Brien, Marcus L. Graham, and Kai F. Gong, U.S. Naval Underwater Systems Center

GLOBAL OPTIMIZATION

Numerical Experiments with One Dimensional Adaptive Cubic Algorithm
Andre Ferrari, Universite de Nice-Sophia Antipolis, France and Efim A. Galperin, Universite du Quebec a Montreal, Canada

A Random Global Search Technique for Lipschitz Functions
Regina Hunter Mladineo, Rider College

GRAPH PROBLEMS

An Algorithm for Graph Imbedding
Yaghout Nourani, Andres Klinger, Luqing Wang and Peter Salamon, San Diego State University

The Inverse Shortest Paths Problem
Didier Burton and Ph. Toint, Facultes Universitaires Notre Dame de la Paix, Belgium

Optimization of Steiner Nodes and Trees on a Hypercube Architecture
Nikolaos T. Liolios, Computer Methods Corporation and Dionysios Kountanis, Western Michigan University

Two Approximation Algorithms for the Routing Problem
Dionysios Kountanis, Western Michigan University and Nikolaos T. Liolios, Computer Methods Corporation

OPTIMIZATION ALGORITHMS AND SOFTWARE

Quadratic Programming with Approximate Data: Ill-Posedness and Efficient Algorithms
Jorge R. Vera, Cornell University

Discontinuous Piecewise Differentiable Optimization
Andrew R. Conn, IBM Thomas J. Watson Research Center and *Marcel Mongeau*, Universite de Montreal, Canada

Nuclear Cones and Pareto Optimization
George Isac, College Militaire Royal, Canada

Study of Some Multiport Planar Stripline Discontinuities, Optimization of Their Characteristics by Consideration of Their Form
Christian Cavalli and Henri Baudrand, Laboratoire d'Electronique, ENSEEIHT, France; and Jacques Couot, Universite Paul Sabatier, France

On Width Minimization by Shift Transform Interval Multiplication
Chenyi Hu, University of Houston, Downtown

Optimal Sampling Design for Dynamic Systems
James G. Uber, University of Cincinnati

An Algorithm for Solving Linear Inequality System
Jiasong Wang, Nanjing University, People's Republic of China

Modelling of the Vectors, Uniformly-distributed on all Directions in Some Hyper-plane Intersection
Genrih Celestin Tumarkin, Moscow Geological-Prospecting Institute, Russia

Constructive Neural Network Algorithm for Approximation of Multivariable Function with Compact Support and Its Application for Inversion of the Radon Transform
Nicolay Magnitskii, Institute for Systems Studies Academy of Sciences, Russia

T-Stationary Replacement for the Average Model of MDP
Wei Liren, Hunan Normal University, People's Republic of China

NONSMOOTH PROGRAMMING

A Trust Region Method for Nonsmooth Programming
Liqun Qi, University of New South Wales, Australia, and *Jie Sun*, Northwestern University

Iteration Functions in Nonsmooth Optimization and Equations
Liqun Qi, University of New South Wales, Australia

7:30/ Belmont Room

Business Meeting
SIAM Activity Group on Optimization

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7:30/Ballroom Foyer

Registration opens

8:30/Regency A/B
IP7/Chair: Thomas F. Coleman,
Cornell University

Algorithms for Solving Large Nonlinear Optimization Problems

In this presentation the speaker will discuss recent developments in algorithms for solving large-scale, differentiable, nonlinear programming problems. Such problems arise quite naturally in many scientific, economic and engineering applications. It is now possible to solve a variety of problems in thousands of variables in a reasonable time on a modest workstation. However, there is considerable room for improvement in the design and implementation of algorithms for solving these problems.

The speaker will address developments that have taken place since the first release of the software package, LANCELOT, in 1991. Among the topics to be discussed are modified barrier methods for handling inequality constraints, trust-region methods for solving problems with convex feasible regions and the exploitation of problem structure, in particular, group partial separability, at a more basic level than is done at present.

Nicholas I.M. Gould
Numerical Algorithms Group
Rutherford Appleton Laboratory, United Kingdom

9:15/Regency A/B
IP8/Chair: Thomas F. Coleman,
Cornell University

Recent Developments in Interior-point Methods for Linear Programming

The speaker will describe recent developments in interior-point methods for linear programming and extensions. It is now accepted that these methods can be very effective for solving large-scale linear problems (including one with nearly 13 million variables), but there remain large gaps between their empirical behavior and the supporting theory. The most efficient algorithms in use employ a primal-dual approach with very long steps and usually infeasible iterates. In contrast, the theory typically addresses shorter step methods maintaining feasibility throughout. Recent work addresses the derivation of polynomial algorithms with fast local convergence and methods that approach feasibility and optimality simultaneously or can take advantage of warm starts. Finally, there are extensions to various nonlinear optimization problems, although computational results are mostly limited to quadratic programming with linear constraints.

Michael J. Todd
School of Operation Research
and Industrial Engineering
Cornell University

10:00/Regency D

Coffee

10:30-11:50

Concurrent Sessions (Minisymposia and Contributed)

MS18/Regency A/B

Parallel Algorithms in Optimization

Parallelism in optimization algorithms is most often achieved by taking advantage of the structure of certain problems or classes of problems. The speakers in this session will discuss a variety of optimization problems and applications, and will show why parallelism is needed and how it is achieved in each case.

Organizer: Stephen J. Wright
Argonne National Laboratory

10:30 **Solving Linear Stochastic Network Problems using the Proximal Point Algorithm on a Massively Parallel Computer, and an Application from the Insurance Industry**
Soren S. Nielsen and Stavros A. Zenios,
University of Pennsylvania

10:50 **Parallel Constraint and Variable Distribution**
M. C. Ferris and *Olvi L. Mangasarian*,
University of Wisconsin, Madison

11:10 **Parallel Algorithms for Minimizing the Ginzburg-Landau Free Energy Functional for Superconducting Materials**
Paul E. Plassmann, Argonne National Laboratory and Stephen J. Wright, organizer

11:30 **Parallel Optimization in Groundwater and Petroleum Resources Management**
Robert M. Lewis, Rice University

MS19/Toronto Room

Large-Scale Nonlinear Optimization

Recent research in large-scale nonlinear optimization has led to dramatic progress in several areas of application, including optimal power distribution, optimal trajectory calculation and optimal structural design. Much of this success can be attributed to new theoretical and algorithmic developments that have extended classical sequential quadratic programming (SQP) methods and barrier-function methods to large problems.

In this minisymposium the speakers will highlight some of these new developments and discuss some new results in optimal trajectory calculation and optimal structural design.

Organizer: Philip E. Gill
University of California, San Diego

10:30 **SQP Algorithms for Large-Scale Constrained Optimization**
Samuel K. Eldersveld, Stanford University and Philip E. Gill, organizer

10:50 **Large-Scale Issues in Newton Methods for Linearly Constrained Optimization**
Anders Forsgren, Royal Institute of Technology, Stockholm, Sweden and Walter Murray, Stanford University

11:10 **Optimization of Complex Aircraft Structures**
Ulf T. Ringertz, The Aeornautical Research Institute of Sweden, Bromma, Sweden

11:30 **SQP Methods and Their Application to Optimal Trajectory Calculations**
Philip E. Gill, organizer, Walter Murray and Michael A. Saunders, Stanford University

MS20/Acapulco Room

Complexity Issues in Numerical Optimization

Following the development of interior point methods for optimization, complexity analysis has become a major tool in the analysis of optimization algorithms. As problems of increasing size are attempted, understanding the asymptotic complexity issues becomes more important than ever. The speakers in this minisymposium will present recent research into complexity issues for linear and nonlinear optimization

Organizer: Stephen A. Vavasis
Cornell University

10:30 **Issues in Strong Polynomiality in Nonlinear Optimization**
Dorit Hochbaum, University of California, Berkeley

10:50 **The Complexity of Quadratic Programming**
Mihir Bellare, IBM Thomas J. Watson Research Center, and *Phillip Rogaway*, IBM, Austin, TX

11:10 **On Minimization of Convex Separable Functions**
Panos Pardalos, University of Florida, and Nainan Kovoor, Pennsylvania State University

11:30 **Toward Probabilistic Analysis of Interior-point Algorithms for Linear Programming—Part 2 of 2**
Yinyu Ye, University of Iowa

CP20/Belmont Room

Linear Programming: Computational Issues II

Chair: Robert J. Vanderbei,
Princeton University

10:30 **Numerical Comparisons of Local Convergence Strategies for Interior-Point Methods in Linear Programming**
Amr El-Bakry and *Richard Tapia*, Rice University and Yin Zhang, University of Maryland, Baltimore County

10:50 **L-Infinity Algorithms for Linear Programming**
Jerome G. Braunstein and Philip E. Gill, University of California, San Diego

11:10 **A New Approach for Parallelising the Simplex Method**
Frank Plab, University of Edinburgh, Scotland

11:30 **Solving Stochastic Linear Programs on a Hypercube Multicomputer**
George B. Dantzig, Stanford University; *James K. Ho*, University of Illinois, Chicago; and Gerd Infanger, Stanford University

CP21/Water Tower Room

Data Fitting Problems III

Chair: Susana Gómez, IIMAS-Universidad
National Autonoma de Mexico, Mexico

10:30 **The U.S. Coast Guard Interactive Resource Allocation Problem**
J. Walter Smith, U.S. Coast Guard R&D Center

10:50 **Optimization Problems Arising in Multidimensional Scaling**
Michael W. Trosset, Tucson, Arizona; Pablo Tarazaga, University of Puerto Rico, Mayaguez; and Richard A. Tapia, Rice University

11:10 **The Classical Newton Method for Solving Strictly Convex Quadratic Programs and Data Smoothing Problems**
W. Li and J. Swetits, Old Dominion University

11:30 **Objective Function Conditioning with Smoothness Constraints**
Stephen F. Elston, Princeton University

CP22/Gold Coast Room

Bound Constrained Problems II

Chair: Trond Steihaug,
University of Bergen, Norway

10:30 **A New Modified Newton Algorithm for Nonlinear Minimization Subject to Bounds**
Thomas F. Coleman and *Yuying Li*, Cornell University

10:50 **An Algorithm for Large Scale Optimization Problems with Box Constraints**
Francisco Facchinei and Laura Palagi, Universita di Roma "La Sapienza", Italy and *Stefano Lucidi*, Istituto di Analisi dei Sistemi ed Informatica del CNR, Italy

11:10 **A Trust Region Algorithm for Nonlinear Programming**
Pan-Chieh Chou, J. E. Dennis, Jr., and Karen A. Williamson, Rice University

11:30 **Trust Region Methods for Large Constrained Optimization**
Marucha Lalee and Jorge Nocedal, Northwestern University

■ ■ ■

12:00-1:30

Lunch

1:30/Regency A/B
IP9/Chair: Do[illegible]oldfarb,
Columbia University

Large-Scale Network Optimization: An Assessment

Algorithms and software for several fundamental network optimization problems have a rich variety of direct applications. But more importantly, they often serve as building blocks for procedures designed to solve more complex problems. Primarily due to the enormous improvement in computing resources and architectures during the past decade, practitioners and researchers are able to study methods for solving larger and more complex models. Along with advances in new algorithms, data structures and theoretical analyses, these developments present new challenges. The speaker will review the state-of-the-art in theory and implementation and will present recent experimental results for some classes of large-scale network optimization problems.

Michael D. Grigoriadis
Department of Computer Science
Rutgers University

2:30-3:50

Concurrent Sessions (Minisymposia and Contributed)

MS21/Belmont Room

Global and Local Optimization Methods for Molecular Chemistry Problems

Scientists often are interested in finding the configurations of chemical systems that have the lowest energy, because these configurations correspond to the most likely states in nature. The resulting optimization problems typically have large numbers of parameters and very large numbers of local minimizers. Thus, they are challenging global optimization problems, whose solutions also require efficient large-scale local optimization software. The speakers in this session will describe such molecular chemistry problems and will discuss methods for solving both the global and local optimization problems that arise from them.

Organizer: Robert B. Schnabel
University of Colorado, Boulder

2:30 **Potential Transforms Applied to Geometry Optimization in Macromolecular Chemistry**
Robert A. Donnelly, Auburn University

2:50 **Large-Scale Optimization in Computational Chemistry Problems**
Tamar Schlick, Courant Institute of Mathematical Sciences, New York University

3:10 **A Global Optimization Approach for Microcluster Systems**
C.A. Floudas and C.D. Maranas, Princeton University

3:30 **Global Optimization Methods for Molecular Configuration Problems**
Robert B. Schnabel, organizer, Elizabeth Eskow and Richard H. Byrd, University of Colorado, Boulder

MS22/Regency A/B

Finite Termination and Basis Recovery Using Interior-point Methods for LP

There has been considerable recent activity in constructing procedures to be used with interior-point methods that give exact (i.e. highly accurate) solutions in a finite number of steps. Two key ideas for accomplishing this are the projection of the current iterate on the optimal facet, once this facet has been identified, and the change over to a simplex-type method in order to obtain a basic solution.

The speakers in this minisymposium will discuss aspects of this activity.

Organizer: Amr S. El-Bakry
Rice University

2:30 **An Implementation of a Strongly Polynomial Time Algorithm for Basis Recovery**
Irvin J. Lustig, Princeton University

2:50 **Finite Termination in Interior-point Methods**
Sanjay Mehrotra, Northwestern University

3:10 **Recovering an Optimal LP Basis from an Interior Point Solution**
Robert E. Bixby, Rice University and *Matthew J. Saltzman*, Clemson University

3:30 **On Obtaining Highly Accurate or Basic Solutions using Interior-point Methods in Linear Programming**
Amr-S. El-Bakry, organizer, Robert E. Bixby and Richard A. Tapia, Rice University, and Yin Zhang, University of Maryland, Baltimore County

CP23/Water Tower Room

Combinatorial Optimization

Chair: Henry Wolkowicz,
University of Waterloo, Canada

2:30 **Approximation Algorithms for Indefinite Quadratic Programming**
Stephen A. Vavasis, Cornell University

2:50 **On Matroidal Knapsack Problems and Lagrangian Relaxation**
Richa Agarwala, *David Fernandez-Baca* and Anand Medepalli, Iowa State University

3:10 **Parallel Dynamic Programming Algorithms for the 0-1 Knapsack Problem**
Renato De Leone and Mary A. Tork Roth, University of Wisconsin, Madison

3:30 **Totally Unimodular Leontief Directed Hypergraphs**
Peh H. Ng, University of Minnesota, Morris; and Collette R. Coullard, Northwestern University

CP24/Toronto Room

Network Optimization II

Chair: Dimitri Bertsekas,
Massachusetts Institute of Technology

2:30 **A Fast Primal-Dual Algorithm for Generalized Network Linear Programs**
Norman D. Curet, University of California, Los Angeles

2:50 **Network Assistant to Construct, Test and Analyze Network Algorithms**
Gordon H. Bradley, Naval Postgraduate School and Homero F. Oliveira, Centro Tecnico, Aerospacial S Jose dos Campos, Brazil

3:10 **Advanced Implementation of the Dantzig-Wolfe Decomposition Applied to Transmission Networks**
Fatima G. Ayllon, Telefonica Investigacion y Desarrollo, Spain; Jorge Galan, *Angel Marin* and Angel Menendez, E.T.S. Ingenieros Aeroronauticos, Spain

3:30 **Algorithms for Solving the Large Quadratic Network Problems**
Chih-Hang Wu and Jose A. Ventura, Pennsylvania State University

CP25/Acapulco Room

Minimax Problems

Chair: Kaj Madsen,
The Technical University of Denmark,
Lingby, Denmark

2:30 **Min-max Problems Arising in Optimal m-stage Runge-Kutta Differencing Scheme for Steady-state Solutions of Hyperbolic Systems**
Mei-Qin Chen, The Citadel and Chichia Chiu, Michigan State University

2:50 **A Method for Generalized Minimax Problems**
Gianni Di Pillo and Luigi Grippo, Universita di Roma "La Sapienza", Italy and Stefano Lucidi, Instituto di Analisi dei Sistemi ed Informatica del CNR, Italy

3:10 **Convergence Conditions for the Regularization Methods that Solve the Min-max Problem**
Cristina Gigola, ITAM, Mexico and *Susana Gomez*, Instituto de Investigaciones en Matematicas Applicadas y en Sistemas-Universidad National Autonoma de Mexico, Mexico

3:30 **The Phase-Problem in Crystallography**
A. Decarreau, Universite de Poitiers, France; D. Hilhorst, Universite de Paris-Sud, France; *C. Lemarechal*, INRIA, France; and Jorge Navaza, Universite de Paris-Sud, France

CP26/Gold Coast Room

Optimization Problems Over Matrices

Chair: Richard G. Carter, AHPCRC,
University of Minnesota and
Argonne National Laboratory

2:30 **An Optimization Problem on Subsets of the Symmetric Positive Semidefinite Matrices**
Pablo Tarazaga, University of Puerto Rico, Mayaguez; Michael Trosset, Tucson, Arizona; and Richard Tapia, Rice University

2:50 **Minimization of Nonlinear Functionals Over Finite Sets of Matrices**
John Jones, Jr., Air Force Institute of Technology and George Washington University

3:10 **Positive Definite Constrained Least Square Estimation of Matrices**
H. Hu, Northern Illinois University

3:30 **An Interior-point Method for Minimizing the Largest Eigenvalue of a Linear Combination of Symmetric Matrices**
Florian Jarre, Universitat Wurzburg, Germany

3:50/Regency D

Coffee

4:20-5:40

Concurrent Sessions (Minisymposia and Contributed)

MS23/Accpulco Room

Genetic Algorithms in Function Optimization

Genetic algorithms are search procedures that use a population of candidate solutions in their search and use operators such as selection, crossover, and mutation that have analogies in population genetics and natural selection. A simple algorithm, GAs' has been successful in finding good solutions to a wide variety of difficult optimization problems.

The speakers in this minisymposium will present several applications of genetic algorithms to difficult optimization problems.

Organizer: David Levine
Argonne National Laboratory

4:20 **Genetic Algorithms in Combinatorial Optimization**
Kalyanmoy Deb, University of Illinois, Urbana

4:40 **Parallelization of Probabilistic Sequential Search Algorithms**
Prasanna Jog, DePaul University

5:00 **A Genetic Algorithm For The Set Partitioning Problem**
David Levine, organizer

5:20 **A Hybrid Genetic Approach to Energy Minimization in Layered Superconductors**
David Malon, Argonne National Laboratory

MS24/Belmont Room

Optimization Problems Involving Eigenvalues - Part 2 of 2

(See page 8 MS9 for description)

Organizer: Michael L. Overton
Courant Institute of Mathematical Sciences, New York University

4:20 **On Minimizing the Largest Generalized Eigenvalue of an Affine Family of Hermitian Matrix Pairs**
Michael K. H. Fan and Batool Nekooie, Georgia Institute of Technology

4:40 **On the Variational Analysis of All the Eigenvalues of a Symmetric Matrix**
Dongyi Ye, and Jean-Baptiste Hiriart-Urruty, Universite Paul Sabatier, Toulouse, France

5:00 **Optimality Conditions and Duality Theory for Minimizing Sums of the Largest Eigenvalues of a Symmetric Matrices**
Michael L. Overton, organizer and *Robert S. Womersley*, University of New South Wales, Australia

5:20 **Variational Properties of the Spectral Abscissa and Spectral Radius Maps**
James V. Burke, University of Washington and Michael L. Overton, organizer

MS25/Water Tower Room

Optimal Control of Flexible Systems

The central purpose of this minisymposium is to present mathematical and engineering aspects of suppressing the vibrations of flexible structures which arise in several branches of engineering. The speakers will discuss control problems for distributed parameter systems governed by partial differential equations. Problems in structural mechanics and spacecraft applications are often of this type. The speakers will address the assessment of the current state of control theory and its applications, evaluate the needs of the control community, and identify possible directions for future development.

Organizers: M.R. Nouri-Moghadam
Penn State University and
I. S. Sadek
University of North Carolina, Wilmington

4:20 **A Mathematical Programming Approach for Optimal Control of Distributed Parameter Systems**
M. Nouri-Moghadam and I.S. Sadek, organizers

4:40 **Optimal Control of Distributed Parameter Systems: Exact and Approximate Methods**
I. S. Sadek, organizer

5:00 **Optimal Control of Thin Plates by Point Actuators and Sensors**
Maria Blanton, University of North Carolina, Wilmington

5:20 **Optimal Control of Non-Classically Damped Distributed Structures**
Ramin S. Esfandiari, California State University, Long Beach

5:40 **Simultaneous Design - Control Optimization of Composite Structures**
Sarp Adali, University of California, Santa Barbara

CP27/Regency A/B

Linear Programming: Analysis and Theory II

Chair: Roman Polyak,
IBM Thomas J. Watson Research Center

4:20 **On the Complexity of Approximately Solving LP's Using Minimal Computational Precision**
James Renegar, Cornell University

4:40 **Pre-Selection of the Phase I - Phase II Balance in a Path-Following Algorithm for the "Warm Start" Linear Programming Problem**
Robert M. Freund, Massachusetts Institute of Technology

5:00 **Global Convergence of a Primal-Dual Exterior Point Algorithm for Linear Programming**
Masakazu Kojima, Tokyo Institute of Technology, Japan; Nimrod Megiddo, IBM Almaden Research Center and School of Mathematical Sciences, Israel; and *Shinji Mizuno*, The Institute of Statistical Mathematics, Japan

5:20 **Polynomial Complexity versus Fast Local Convergence for Interior Point Methods**
Florian Potra, University of Iowa

Registration Information

CP28/Gold Coast Room

Control Problems II

Chair: Layne T. Watson,
Virginia Polytechnic Institute
and State University

4:20 **Implicit Functions and Lipschitz Stability in Control and Optimization**
A.L. Dontchev, Mathematical Reviews, Ann Arbor, MI and W.W. Hager, University of Florida, Gainesville

4:40 **Optimization in Impulsive Stochastic Control: Time Splitting Approach**
Alexander A. Yushkevich, University of North Carolina, Charlotte

5:00 **H^∞-Optimization with Decentralized Controllers**
Garry Didinsky and *Tamer Basar*, University of Illinois, Urbana

CP29/Toronto Room

Constrained Optimization III

Chair: Luigi Grippo,
Universita di Roma "La Sapienza", Italy

4:20 **A Comparison of Barrier Function Methods with Lagrangian Method for Nonlinear Programming**
Amarinder Singh and Kumaraswamy Ponnambalam, University of Waterloo, Canada

4:40 **Recent Improvements on FSQP**
Jian L. Zhou and *Andre L. Tits*, University of Maryland, College Park

5:00 **An Affine-Scaling, Nonsmooth Newton Hybrid for Constrained Optimization**
Danny Ralph, Cornell University

5:20 **A Primal-Dual Interior Point Method for Linear and Nonlinear Programming**
Hiroshi Yamashita and Takahito Tanabe, Mathematical Systems Institute, Inc., Japan

6:00 Conference adjourns

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Registration Fees

		SIAG/ OPT*	SIAM Member	Non-Member	Student
Tutorial**	Advance	$120	$120	$135	$55
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Conference	Advance	$120	$125	$150	$25
	On-Site	$145	$150	$180	$25

*Members of SIAM Activity Group on Optimization
**Lunch is included in the cost of registration for tutorial attendees.

The registration desk will be open as follows:

Saturday, May 9	6:00 PM - 8:00 PM
Sunday, May 10	8:00 PM - 4:00 PM 6:30 PM - 9:00 PM
Monday, May 11	7:00 AM - 4:30 PM
Tuesday, May 12	7:30 AM - 4:30 PM
Wednesday, May 13	7:30 AM - 2:30 PM

Special Note
There will be no prorated fees. No refunds will be issued once the conference has started.

If SIAM does not receive your Advance Registration Form and payment by May 4, you will be asked to give us a check or a credit card number at the conference. We will not process either until we have ascertained that your registration form has gone astray. In the event that we receive your registration form after the conference, we will destroy your check or credit card slip.

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Special Notice to All Conference Participants
SIAM requests attendees to refrain from smoking in the session rooms during lectures. Thank you.

F Y I
Contributed and minisymposium presentations are spaced twenty minutes apart, allowing each presenter fifteen minutes for presentation and five minutes for discussion.

For presentations with more than one author, the speaker's name is in italics.

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ABSTRACTS: MINISYMPOSIA AND CONTRIBUTED PRESENTATIONS

(in chronological order)

MONDAY AM

Interior Point Methods for Large Scale Quadratic Programming

The talk is concerned with logarithmic barrier methods for large scale quadratic programming problems. Several methods for preserving sparsity when the Hessian matrix is sparse will be discussed, with some comparative computational results. Several variants of the conjugate projected gradient method for problems with dense Hessians will also be discussed, again with comparative computational results.

David Shanno
Rutgers University
New Brunswick, NJ 07960

Tami Carpenter
Princeton University
Princeton, NJ

Primal-Dual Symmetric Formulations of the Predictor-Corrector Method for QP

Replacing the usual standard form with one allowing equality and inequality constraints as well as sign-constrained and free variables yields problem formulations that are primal-dual symmetric and closer to industry standard MPS form. We will report on our computational experience regarding an implementation of the predictor-corrector variant of the one-phase primal-dual path-following algorithm for convex quadratic programming problems presented in (almost) primal-dual symmetric form.

R. J. Vanderbei
Department of Civ. Eng. and Ops. Res.
Princeton University
Princeton, NJ 08544

Solving Symmetric Indefinite Systems in Interior Point Methods

It is standard to solve the least squares problem in interior point methods by forming normal equations. In this talk we discuss the use of augmented system approach to solve the these least squares problems. This approach handles dense columns naturally. We show that this approach also leads to an easy and numerically stable treatment of free variables. We give computational results on the problems in netlib using higher order primal-dual methods to demonstrate the effectiveness of augmented system approach.

Robert Fourer and Sanjay Mehrotra
Department of IE/MS
Technological Institute
Northwestern University
Evanston, IL 60208-3119

Switching from interior to vertex solutions in OSL

The Optimization Subroutine Library (OSL) contains a variety of both interior point and simplex methods for linear programming. Many applications solve rapidly as LPs by interior methods but require basic solutions, e.g. for continuing to MIP by branch and bound. We discuss methods used in OSL for this switch-over process.

J.J.H. Forrest
IBM Watson Research Centre
Yorktown Heights, NY 10598

J.A. Tomlin
IBM Almaden Research Centre
San Jose, CA 95120

The Degree Constrained Forest Problem

We consider the problem of finding a maximum weight forest that satisfies given upper and/or lower bound constraints on the degree of each node. This problem is NP-hard in general. We will consider several special cases of this problem and decide for each whether it is NP-hard or polynomially solvable. Both algorithms and polyhedral results will be presented.

Bruce Gamble
M.E.D.S. Department
J.L. Kellogg Graduate School of Management
Northwestern University
Evanston, IL 60208

Delta-Wye-Delta Reducibility of Three Terminal Planar Graphs

We study Wye-Delta (star to triangle) and Delta-Wye transformations in graphs. G. Epifanov in 1966, proved the Akers-Lehman conjecture, that any planar graph with two terminals can be reduced by means of Delta-Wye-Delta operations to a single edge. The last two nodes being the original two terminals. The three terminal case, also conjectured by Akers remained open. We settle the 3-Terminal conjecture by proving that any 2-connected planar graph with three terminals can be Delta-Wye-Delta reduced to K_3, with vertex set the original three terminals. As a consequence of this result, we characterize some classes of nonplanar reducible graphs, in particular we show that graphs not contractible to K_5 are reducible. The applications of the Delta-Wye-Delta method include: shortest path and maximum flow problems, K-terminal reliability, counting spanning trees, counting perfect matchings, computing the partition function for the Ising model, knot theory, and reducibility of almost regular matroids, among other. We discuss our results in relation to some of these problems. The Delta-Wye-Delta method in rare cases provides the most efficient algorithm to solve a particular problem. It does however give a general framework to solve many problems efficiently. The results presented in this work imply efficient algorithms, for some we explicitly provide them.

Isidoro Gitler
Dept. of Combinatorics & Optimization
University of Waterloo
Waterloo, Ontario, Canada N2L 3G1

Minimum weight bases for vector spaces.

The all pairs min cut problem on a nonnegative edge weighted graph is to find, for each pair of nodes, a min cut that separates the pair. We show that this problem and others are special cases of the more general problem of finding a minimum weight basis for a vector space (when an arbitrary basis is given). We present a polynomial time algorithm (based on linear programming) for this general problem (over the reals).

David Hartvigsen
Kellogg Graduate School of Management
Northwestern University
Evanston, IL 60208

Algorithmic and polyhedral results for the 2-connected Steiner subgraph problem

The 2-connected Steiner subgraph problem for a given edge-weighted graph is to find a minimum-weight 2-connected subgraph that spans a specified subset of vertices. A special case of this problem is the Traveling-Salesman problem. This talk discusses some algorithmic and polyhedral aspects of the problem on special classes of graphs which include series-parallel graphs, graphs with no four-wheel minor, and Halin graphs. This is joint work with C. R. Coullard, R.L. Rardin, and D.K. Wagner.

Abdur Rais
School of Industrial Engineering
Purdue University
W. Lafayette, IN 47907

A Concise Overview of Chemical Engineering Optimization Applications

This talk serves to introduce the SIAM minisymposium and briefly surveys the application of optimization algorithm tools in chemical engineering. Qualitative descriptions of problems will be given in process analysis and the development of engineering models, design and optimization of flowsheets and optimization algorithms applied to process dynamics. Also various aspects of chemical engineering models will be classified and summarized according to problem size and functionality; characteristics of appropriate optimization algorithms are then discussed. The talk will therefore set the stage for more detailed aspects of each optimization application, which will be addressed by speakers in this minisymposium

Lorenz T. Biegler
Carnegie Mellon University
Chemical Engineering Department
Pittsburgh, PA 15213

Theoretical Modelling of Amoco's Gas Phase Horizontal Stirred Bed Reactor for the Manufacturing of Polypropylene Resins.

Rigorous theoretical treatment of Amoco's gas phase horizontal stirred bed reactor allowed us to develop a mathematical model that closely follows the behavior of the commercial reactor over a wide range of operating conditions. The modeling equations derive from a fundamental kinetic mechanism of the propylene/ethylene polymerization over Amoco's proprietary Ziegler-Natta based supported catalyst.

The model accounts for the effects of catalyst deactivation, cocatalyst and catalyst modifier as well as the effect of the chain transfer agents, in this case hydrogen and alkyl aluminum. The flow pattern of the powder inside the horizontal reactor is modelled by a series of continuous stirred tank reactors of equal volume but unequal mean residence times. The residence times form a strictly monotonically decreasing sequence. The yield is then calculated by applying the principles of superposition over the train of the continuous stirred tank reactors.

This analysis provides us with flexibility of performing model discrimination studies in order to predict the optimal number of continuous stirred tank reactors that follow the behavior of the commercial unit over a wide range of operating conditions. Further extension of the model to permit optimization of the catalyst activity while reducing temperature gradients inside the reactor has led to a tri-level mixed-integer nonlinear optimization problem which is currently under investigation and will be the focus of this presentation.

Dr. Mike Caracotsios
Amoco Chemical Company
Polymers Research and Development
Post Office Box 3011
Naperville, Illinois 60566

Optimization Using Process Simulators

Chemical process simulators are used to optimize processes in all phases from original process conception through design, scale-up, and operations. Some characteristics of the NLP problem, such as number of variables and constraints, change considerably from one application to another. Other characteristics are common to almost all applications. These include the nonlinear nature of the equations and discontinuities, especially those caused by changes in the state of the system.
This paper reviews the current algorithms used in process simulation and optimization and typical applications solved by optimization using process simulators.

H.S. Chen and T.P. Kisala
Aspen Technology, Inc.
Cambridge, MA 02139

Large Scale Process Optimization with Differential Equations

Large Scale process optimization problems involving differential/algebraic equations (DAE) will be discussed. The approach used for solving these problems is based on using a sparse successive quadratic programming (SQP) algorithm combined with orthogonal collocation on finite elements. Using orthogonal collocation allows the conversion of the DAE constraints in the optimization problem to a representative set of algebraic equation constraints that can be handled in the traditional nonlinear programming format. This method has been applied to the real time optimization of commercial chemical processing units. Issues in the formulation and solution of these problems will be discussed.

A.M. Morshedi
DOT Products, Inc.
1613 Karankawas Center
Deer Park, TX 77536

Recursive Components in Large Optimization Models

Large models, linear as well as nonlinear, often have many recursive equations, both before and after a simultaneous core. The paper will discuss how to take advantage of this structure in nonlinear models, both in a preprocessing step and during the optimization itself, and the requirements this will have on the model representation. It will give statistics on the percentage of recursive equations in a set of large practical models from engineering and economics implemented in GAMS, and on the savings that have been achieved by using the recursive structure.

Arne Stolbjerg Drud
ARKI Consulting and Development A/S
Bagsvaerdvej 246 A
DK-2880 Bagsvaerd
Denmark

Numerical experience with LANCELOT (Release A) in large scale nonlinear programming

The field of large scale nonlinear programming has been growing considerably in the past five years, due to the combined interest of practioners and the ongoing progress in algorithm design. The LANCELOT project is a joint project of the authors whose purpose is to develop suitable theory, algorithms and software for the general (nonconvex) nonlinear programming problem in a large number of variables. The talk will concentrate on the last aspect of the project and report some numerical experiments with the first version of the LANCELOT package on a wide collection of problems, both academic and arising from practical applications. Some conclusions on the relative merits of various algorithmic options will be drawn and software perspectives outlined.

A. Conn (IBM Watson Research Center, USA)
N. Gould (Rutherford Appleton Laboratory, GB)
Ph. Toint (FUNDP, Belgium) (speaker)

Singularities in Large-Scale Structural Optimization

Singularity conditions associated with rank deficient, behavior constraint gradient matrices can arise during structural optimization. These degrade the performance of large-scale, optimal structural design codes. Examples of the types of singularities which arise and a description of a framework in which they can be recognized, and thus avoided, will be presented. Singulari- ties can be identified by examination of the stress-displacement relations, and the compati- bility conditions derived in the Integrated Force Method of Structural Analysis. The proposed method will be illustrated with numerical examples.

James D. Guptill
Computer Services Division MS 142-2
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

Surya N. Patnaik
Structural Mechanics Branch MS 49-8
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

Laszlo Berke
Structural Mechanics Branch MS 49-8
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135

The Design of a Large-Scale NLP Code for Trajectory Optimization Problems

In this talk we describe the design of a nonlinear programming (NLP) algorithm to facilitate the solution of large-scale parameter optimization problems arising from the collocation of trajectories. In a collocation approach, a discretization is applied to the differential equations and mission constraints to obtain a parameter optimization problem. As is typical in the collocation approach of solving boundary value problems, these parameter optimization problems involve many variables and constraints, but are sparse. Various techniques to reduce the computational cost can be employed, such as the exploitation of sparsity and adaptive mesh strategies. The focus of this talk will be on the redesign of a generalized reduced gradient algorithm to exploit the *modified almost block diagonal* structure of linear systems arising during the constraint solving phase of the NLP code. Numerical results for an experimental trajectory optimization code based on the Hermite-Simpson collocation method will be presented.

K. Brenan, W. Hallman. and W. Yeung
The Aerospace Corporation
P. O. Box 92957
Los Angeles. CA 90009

POSM – A Nonlinear Optimization Program Suitable for Engineering

We present a novel, efficient, nonlinear constrained optimization program called POSM which stands for the Pseudo Objective function Substitution Method. POSM is designed specifically for those nonlinear least square optimization problems of which the evaluation of the objective function and its derivatives are very costly in terms of both time and computing resources. These problems often arise in engineering disciplines where the objective function must be evaluated via large scale simulation programs such as the finite element analysis. The three main design objectives of POSM are: (1) to eliminate the need for the derivatives of the objective function; (2) to minimize the linear search steps when needed; and (3) to converge in as few iterations as possible. In addition to achieving all these objectives, POSM is also very robust to the perturbations on the initial condition, as well as the evaluated objective function. Tested on a set of "difficult" benchmark problems, POSM successfully solved all the problems, while other two state-of-the-art packages failed many of them.

ShaoWei Pan, Yu Hen Hu
Dept. of Electrical and Computer Engineering
University of Wisconsin - Madison, WI 53706
Email: Pan@ece.wisc.edu
Phone: (608) 262 9205

A Comparison of Some Methods for Estimating Rate Constants in Chemical Kinetics

Estimation of unknown rate constants in chemical kinetics is an application of nonlinear least squares problems, where the model function is defined by a system of ODE's, usually stiff. We present here a comparison of different ways of formulating and solving the optimization problem. The standard approach, which can take advantage of stiffness, is to let an ODE-solver compute the value of the function to be minimized in each iterative step of the optimization procedure. An alternative approach [illegible] use a difference approximation of [illegible] a constrained nonlinear least squares pro[illegible] method has the advantage that it mak[illegible] compute derivatives with respect [illegible] ameters

The testbatch consis[illegible] ly sized artificial and real w[illegible] ms. The testruns have been performed with [illegible] ATLAB-system, in which a function library, diffpar, has been developed for this kind of problem.

Per-Ake Wedin
Institute of Information Processing
University of Umea
S-901 87 Umea, SWEDEN

Lennart Edsberg
Department of Numerical Analysis
and Computing Science
Royal Institute of Technology
S-100 44 Stockholm, SWEDEN

On the EM Algorithm and a Generalization of the Proximal Point Method

The EM algorithm is a very well known method for computing maximum likelihood estimates, appearing in several important applications like emission computed tomography, factor analysis, finite mixtures computation,etc. On the other hand, the proximal point algorithm (PPA) is another important method for solving general optimization problems using a sequence of regularized subproblems.

In this work we show the close relations existing between the EM algorithm and some generalization of the PPA.

MONDAY AM

ALVARO RODOLFO DE PIERRO
Universidade Estadual de Campinas
Instituto de Matemática, Estatística e
Ciência da Computação - IMECC
Departamento de Matemática Aplicada
C.P. 6065 - 13081 Campinas, S.P.
Brasil

Experimental Data Integration in Large Scale System Analysis

In complex flow systems such as the Space Shuttle Main Engine (SSME), reconciliation of experimental data with predictions based on theoretical analysis is a difficult task. Although heuristic integration methods are common such techniques lack a firm statistical foundation. More robust reconciliation schemes are needed for accurate performance prediction. The speaker will describe a generic optimization strategy for the systematic integration of experimental data in large scale system analysis. The theoretical basis of this strategy will be discussed, and the results of SSME flow system analysis with test data integration will be presented.

L. Michael Santi
Christian Brothers University
Mechanical Engineering Department
650 East Parkway South
Memphis, TN 38104

John P. Butas
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Propulsion Laboratory - EP52
Marshall Space Flight Center, AL 35812

Bounded Least Squares for PET

The image reconstruction problem in positron emission tomography can be written as a large linear least squares problem subject to nonnegativity constraints. There are hundreds of elements that will eventually be zero, but it is not important to distinguish between small and zero. The important information is in the large elements. Projected gradient techniques and active constraint techniques spend too much time determining which elements are at bound. A better approach uses a projective transformation and solves the least squares problem with preconditioned conjugate gradients with a diagonal preconditioner containing an approximate distance to the constraints.

Linda Kaufman
Room 2c-461
Bell Labs
Murray Hill, N.J. 07974

Data Parallel Quadratic Programming with Box-Constrained Problems

We develop designs for the massively parallel solution of quadratic programming problems subject to box constraints. In particular we consider the class of algorithms that iterate between projection steps that identify candidate active sets, and Newton-like steps that explore the working space.

Implementations are carried out on a Connection Machine CM-2. They are shown to be very efficient in solving very large problems - up to 360,000 variables. The massively parallel implementation outperforms significantly implementations of the same algorithm on a shared memory vector architecture, (Alliant FX/8) and of interior point algorithms implemented on an IBM 3090-600S vector supercomputer.

Jill Mesirov
Mike McKenna
Thinking Machines Corporation
245 First Street
Cambridge, MA 02142

Stavros A. Zenios
University of Pennsylvania
Philadelphia, PA 19104

Massively Parallel Solution of Quadratic Programs via Successive Overrelaxation

In this talk we will discuss serial and parallel successive overrelaxation (SOR) solutions of specially structured large scale quadratic programs with simple bounds. By taking advantage of the sparsity structure of the problem, the SOR algorithm was successfully implemented on two massively parallel Single-Instruction-Multiple-Data machines: a Connection Machine CM2 and a MasPar MP1. Computational results for the well-known obstacle problems show the effectiveness of the algorithm. Problems with millions of variables have been solved in a few minutes on these massively parallel machines, and speedups of 90or more were achieved.

Renato De Leone
Center for Parallel Optimization,
Computer Sciences Department,
University of Wisconsin Madison,
1210 West Dayton Street, Madison, WI 53706 phone: (608) 262-5083
FAX: (608) 262-97
email: deleone@cs

Mary A. Tork Roth
Center for Parallel Optimization,
Computer Sciences Department,
University of Wisconsin Madison,
1210 West Dayton Street, Madison, WI 53706
email: torkroth@cs wisc.edu

On the effects of scaling on Projected Gradient Methods for Solving Bound Constrained Quadratic Programming Problems

We consider the bound constrained quadratic programming problem $\min_{u \in \mathbb{R}^n} \frac{1}{2}u^T Au - u^T b$ subject to $c \leq u \leq d$. Here A is an $n \times n$ symmetric matrix, b,c, and d are known n-vectors. We have investigated projected gradient strategies for this problems. In this paper, we give reasons why such strategies will tend to be well behaved for positive definite matrices A. Moreover, we show why diagonal scaling will greatly improve this behavior. We present bounds on the difference between the optimal stepsize for the gradient direction and the optimal stepsize for the projected gradient direction for positive definite A. We show that diagonal scaling will improve that bound and that the bound is particularly good for generalized diagonally dominant matrices. We present computational results from the journal bearing problem which demonstrate the effects of scaling of convergence.

Jesse L. Barlow
Computer Science Department
The Pennsylvania State University
University Park, PA 16802
E-mail: barlow@cs.psu.edu
Telephone: 814-863-1705
FAX: 814-865-3176

Gerardo Toraldo
Universita della Basilicata
85100 Potenza, Italy
E-mail: TORALDO@PZVX85.CINECA.IT
Telephone: 011-39-81-551-6996
FAX: 011-39-81-551-6355

A Truncated SQP Algorithm for Large Scale Nonlinear Programming Problems

In this paper we propose an SQP algorithm for the inequality constrained nonlinear programming problem. The emphasis here will be on two aspects of the general procedure, namely, the approximate solution of the quadratic subprogram and the need for an appropriate merit function. We first describe an appropriate merit function for the inequality constrained problem and an (iterative) interior-point method for solving (approximately) the quadratic subproblem. We then show that the approximate solution yields a descent direction for the merit function. An implementation of our algorithm is suggested and some numerical results are presented.

Paul T. Boggs
National Institute for Standards and Technology, Gaithersburg, MD
Jon W. Tolle
University of North Carolina, Chapel Hill, NC

A direct search method that employs quadratic model functions

Recently the author extended the Nelder and Mead simplex method to constrained optimization calculations by constructing linear models of the objective and constraint functions, these models being defined by linear interpolation at the vertices of the current simplex. Excellent accuracy can be achieved, but usually the number of iterations is high due to the unsuitability of linear models when curvature is important. Therefore we address the idea of defining quadratic models by interpolation at $\frac{1}{2}(n+1)(n+2)$ points, where n is the number of variables. A way of picking and updating the points is described that maintains nonsingularity of the interpolation equations. Further, some numerical results compare this technique with other methods.

M.J.D. Powell
University of Cambridge
Dept of Applied Maths and Theor Phys
Silver Street
Cambridge, CB3 9EW, England
Telephone: (England) 223-337889
Fax: 223-337918

An Interior Point Algorithm for Nonlinearly Constrained Problems

We describe an extension of the primal-dual interior point LP algorithm to large sparse NLP's of general form. It applies the equation solving procedure of Duff, Nocedal, and Reid to the Kuhn-Tucker conditions of a barrier problem, so each trial step is computed by solving an LP. Options investigated include predictor-corrector variants, and second order corrections for speeding up the equation solver. Second derivatives are required, and we discuss how these may be obtained and manipulated, when coupled to an algebraic modeling language like GAMS. Computational results are provided for an implementation using IBM's OSL simplex LP code.

Prof. Leon Lasdon and Prof. Gang Yu
both have the following address:
Department of Management Science and
Information Systems
College of Business Administration
The University of Texas at Austin
Austin, TX 78712-1175

Prof. John C. Plummer
Department of Computer Information Systems
and Administration Sciences
Southwest Texas State University
San Marcos, TX 78666

Constrained Optimization Algorithms Using Limited Memory Methods

In optimization problems where the number of variables is too large to allow a full Hessian approximation to be stored, limited memory methods generate a quasi-Newton approximation to the Hessian reflecting only the most recent updates, with a great savings in storage. These methods have proven very effective for unconstrained optimization. In this talk we consider some issues in adapting limited memory methods to solving large scale bound constrained and generally constrained optimization problems. We make use of a new compact closed form representation for limited memory quasi-Newton matrices that facilitates operations with constraints. We discuss an algorithm for bound constrained optimization that uses this representation with significant savings in linear algebra costs. We also consider the use of limited memory approximations in a successive quadratic programming method for general constrained optimization.

Richard H. Byrd
Computer Science Department
University of Colorado
Boulder, Colorado 80309

Jorge Nocedal
Dept. of Electrical Engineering and Computer Science
Northwestern University
Evanston, Illinois 60208

Control System Radii and Nonstandard Optimization Problems

The development of numerical methods for control of systems governed by partial differential equations often makes use of finite element, finite difference or Galerkin schemes to produce a finite dimensional "design model". Once this finite dimensional "approximating" control system is constructed, numerical or linear algebra algorithms are used to solve the corresponding finite dimensional control problem. The numerical conditioning of the finite dimensional control problem will depend on the choice of the approximation scheme as well as the type of control problem to be solved. Control system radii often provide a measure of the conditioning of specific control problems. In this talk, we discuss several nonstandard optimization problems that occur when one attempts to compute control system radii for Galerkin approximations of infinite dimensional control systems.

John A. Burns
Kimberly L. Oates
Interdisciplinary Center for Applied Mathematics
Department of Mathematics
Virginia Polytechnic Institute
and State University
Blacksburg, VA 24061

Gunther Peichl
Institut fur Mathematik
Universitat Graz
A-8010 Graz, AUSTRIA

An algorithm for optimizing MESFET design

We discuss an optimization algorithm for use in MESFET design. This resulting code is used in conjuction with a GaAs MESFET model (TEFLON) in a widely distributed CAD package for microwave semiconductor devices. The n-dimensional functions to be optimized have two levels of structure. A simple larger level, and a finer level of structure which imposes a rough surface on the basin. This rough surface gives the problem many local extrema. The algorithm is a projected quasi-Newton method which uses a decreasing sequence of finite difference steps to avoid local extrema and approximate the global minima as well as possible.

P. Gilmore & C.T. Kelly
Department of Mathematics
North Carolina State University
Box 80205
Raleigh, NC 27695

Optimization Techniques for Molecular Structure Determination

An important area of research in computational biochemistry is the design of molecules for specific applications including, for example, the treatment of cancer. The design of these chemicals depends on the accurate determination of the structure of biological macro-molecules. The underlying assumption in this problem is that molecules assume the structure of lowest free energy which reduces the problem to a global minimization problem. However the large number of local minima makes this an extremely difficult problem for all standard optimization methods. We will discuss several approaches to this problem, including a genetic algorithm, a Nelder-Mead simplex method, and a Newton method, along with numerical results.

Michael E. Colvin, Richard S. Judson, Juan C. Meza,
Sandia National Laboratories, Livermore, CA

Velocity Estimation: A Difficult Nonlinear Optimization Problem from Seismology

The estimation of velocities in the earth from seismic waveform data is a difficult and still uncompleted task in geophysical data processing. Straightforward formulations of velocity estimation as a best-fit problem are plagued by severe computational difficulties: local (Newton-like) optimization algorithms simply fail to yield useful results. This talk will review the reasons for the failure of best-fit via Newton, and outline a modification of the best-fit approach more amenable to local techniques.

William W. Symes
Department of Mathematical Sciences
Rice University
P.O.B. 1892
Houston, TX 77251

Newton-like Proximal Point Method: Convergence and Application

The Proximal Point Method (PPM) has long been noticed as one of the attractive methods for convex programming and min-max convex-concave programming. Yet, the classical PPM typically exhibits slow convergence so a key question concerns how the convergence of the method can be accelerated. It has been noticed that the PPM is equivalent to the steepest descent method for minimizing a certain differentiable function associated with the problem. Thus, one way is to apply a second order method to minimize this function. Unfortunately, owing to the complexity of the function, this approach does not appear to be feasible. Instead, we will introduce an extended proximal point algorithm. This method is no more difficult to implement than the classical PPM and yet, under mild conditions on the problem, is superlinearly convergent. When applied to convex programming and min-max convex-concave programming, this method shows encouraging numerical results compared with the classical PPM.

Maijian Qian
Department of Mathematics
University of Washington
Seattle, Washington 98195

Some Recent Results on Proximal-like Methods in Convex Optimization

Proximal-like minimization methods can be constructed by replacing the usual quadratic regularization kernel with kernels which are typically entropy-like in form. This approach leads to several interesting algorithms for solving convex programs. This talk will report on some recent progress on convergence analysis, new variants and potential applications of these proximal-like methods.

Marc Teboulle
Department of Mathematics & Statistics
University of Maryland
Baltimore County Campus
Baltimore, MD 21228

Convergence Rates of Proximal Point Algorithms for Convex Minimization

Traditionally, the convergence analysis for the proximal point algorithm (PPA) for the minimization of a convex function $f : \mathbf{R}^n \to \mathbf{R} \cup \{\infty\}$ has been studied in terms of the distances $\|x^{k+1} - x^k\|$, where x^k is the kth iterate. In this talk, we show that global estimates can be obtained in a simple manner for the residual $f(x^k) - \min f$, without any restrictive assumptions on the function f.

We first obtain such estimates for the classical PPA method. It is also shown that the trajectory of the PPA is asymptotically indistinguishable from a continuous trajectory. This fact throws light on the efficiency of some aggressive stepsize selection rules employed in the literature.

We then propose an acceleration of the classical PPA, using some ideas of Nesterov. This algorithm has close connections with the conjugate gradient algorithm of Hestenes and Stiefel.

Osman Guler
Faculty of Technical Mathematics and Informatics
Delft University of Technology
Mekelweg 4, Room 6.14
2628 CD Delft
THE NETHERLANDS

Partial Proximal Algorithms and Partial Methods of Multipliers: The Quadratic and Entropy Cases

We consider an extension of the proximal minimization algorithm where only some of the minimization variables appear in the quadratic proximal term. We interpret the resulting iterates in terms of the iterates of the standard algorithm and we show a uniform descent property, which holds independently of the proximal terms used. This property is used to give simple convergence proofs of parallel algorithms where multiple processors simultaneously execute proximal iterations using different partial proximal terms.

Dimitri P. Bertsekas, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, MA 02139.

Paul Tseng, Department of Mathematics, University of Washington, Seattle, WA 9819[illegible].

A Generic Auction Algorithm for the Minimum Cost Network Flow Problem

In this paper we broadly generalize the assignment auction algorithm to solve linear minimum cost network flow problems. We introduce a generic algorithm, which contains as special cases a number of interesting algorithms, including the E-relaxation method, the auction algorithm for transportation problems, a new network auction algorithm, and a new algorithm for the K node-disjoint shortest path problem. We provide a broadly applicable complexity analysis of the generic algorithm, and we demonstrate the performance of various special cases of the algorithm via computational experimentation.

Dimitri P. Bertsekas
Department of electrical Engineering
and Computer Science
Massachusetts Insitute of Technology
Cambridge, MA 02139

David A. Castanon
Department of Electrical and
Computer Engineering
Boston University
Boston, MA 02215

An Efficient Implementation of a Network Interior Point Method

DLNET, an efficient implementation of the dual affine scaling algorithm for minimum cost capacitated network flow problems is described. The efficiency of this implementation is the result of three factors: the small number of iterations taken by interior point methods; efficient solution of the linear system that determines the ascent direction using a preconditioned conjugate gradient algorithm; and a strategy used to stop the algorithm with an optimal primal vertex solution. The combination of these three ingredients results in a code that can solve minimum cost network flow problems having hundreds of thousands of vertices in a few hours on a MIPS R3000 processor, whereas the a network simplex implementation requires several days. Extensive computational experiments compare DLNET with NETFLO

Mauricio G.C. Resende
AT&T Bell Laboratories, Murray Hill, NJ
Geraldo Veiga
University of California, Berkeley, CA

A Class of Trust Region Algorithms for Optimization Using Inexact Projections on Convex Constraints: Application to the Nonlinear Network Problem

A class of trust region based algorithms is presented for the solution of nonlinear optimization problems with a convex feasible set [1]. At variance with previously published analysis of this type, the theory presented allows for the use of general norms. Furthermore, the proposed algorithms do not require the explicit computation of the projected gradient, and can therefore be adapted to cases where the projection onto the feasible domain may be expensive to calculate. The talk will concentrate on the application of a particular practical algorithm of the class to the solution of the nonlinear network problem and some numerical experiments will be reported.

[1] A.R. Conn, N.I.M. Gould, A. Sartenaer and Ph. L. Toint, "Global convergence of a class of trust region algorithms for optimization using inexact projections on convex constraints", (submitted to SIAM Journal on Optimization), 1991.

Annick Sartenaer
F.U.N.D.P.
Departement de Mathematique
Rempart de la Vierge 8
B-5000 Namur, Belgique

LSNNO, a FORTRAN Subroutine for Solving Large-scale Nonlinear Network Optimization Problems

We describe the implementation and testing of LSNNO, a new FORTRAN subroutine for solving large-scale nonlinear network optimization problems. The implemented algorithm applies the concepts of partial separability and partitioned quasi-Newton updating to high-dimensional nonlinear network optimization problems. Some numerical results on both academic and practical problems are reported.

Daniel Tuyttens
Faculte Polytechnique de Mons
Departement de Mathematique et de Recherche Operationnelle
Rue de Houdain, 9
B-7000 Mons, Belgique

Classification Tree Optimization by Simulated Annealing

This research investigates a new approach to the design of classification trees. Trees have application in such areas as diagnostic systems, the design of data processing algorithms, pattern recognition, and expert systems. Current methods of tree design that guarantee optimal solutions, such as dynamic programming, are not practical since required storage and/ or CPU time grow exponentially with problem size. Greedy algorithms, based on Information Theory, while being fast, do not guarantee optimality and do not easily accommodate constraints. Our research applies simulated annealing to find tree designs that are optimal or near-optimal with respect to arbitrary cost criteria.

Richard S. Bucy
University of Southern California
Los Angeles, CA, and
The Aerospace Corporation
P. O. Box 92957
Los Angeles, CA 90009
Raymond S. DiEsposti
The Aerospace Corporation

Ensemble Simulated Annealing for Parallel Architectures

An adaptive implementation of simulated annealing for parallel architectures is presented. The implementation uses ensembles of random walkers, i.e. many identical copies of the problem running nearly independently. One processor (the master) collects values of the first two moments of the energy and adaptively adjusts the temperature and the ensemble size. The other processors perform independent simulated annealing and share only a common temperature. The implementation is easily adapted to different problems and different parallel platforms.

Peter Salamon, Luqing Wang, Andrew Klinger, and Yaghout Nourani
Department of Mathematical Sciences
San Diego State University
San Diego, CA 92182

The Demon Algorithm

A generalization of simulated annealing is introduced. The algorithm is constructed in analogy to the action of MaxwellUs Demon and has been motivated by an information-theoretic analysis of simulated annealing. The algorithm is based on an ensemble of identical systems that are annealed in parallel The ensemble evolves according to a sequence of target distributions with the aim of ending up in a distribution that is concentrated on optimal solutions. The algorithm is based on collective moves and has been implemented for graph bipartitioning and seismic deconvolution Its performance is compared with conventional simulated annealing and a downhill search algorithm.

Theo Zimmermann and Peter Salamon
Department of Mathematical Sciences
San Diego State University
San Diego, CA 92182

MONDAY PM

Beamforming with Simulated Annealing

Beamforming is an excellent application of simulated annelaing because the number of parameters is large and it is possible to compute energy changes efficiently. The unknowns include the directions and discretized time series of the sources. Performance may be improved be including additional unknowns such as the contribution of noise or corrections to the locations of receivers. The cost function is parabolic in each of the time series parameters. Improved efficiency is achieved by accepting uphill perturbations only for the non-parabolic parameters. Beamforming by optimization significantly outperforms conventional beamforming methods in which all of the unknowns are collapsed to a single steering parameter. A smaller receiver-to-source ratio is required and it is easy to benefit from a priori information. Results will be presented for real and simulated acoustic data, including cancellation of noise from a horizontal array towed in the ocean and extraction of a single speaker from a crowd.

Michael D. Collins and W.A. Kuperman
Naval Research Laboratory
Washington, DC 20375

A Sparse Updating Approach to Problems in Column Block Angular Form

We propose a basis-updating technique for active set methods for the special case that the constraints are in column block angular form (CBAF) CBAF occurs in time-series and other partitioned problems. Our updating approach is based on an orthogonal factorization and has the special property that the CBAF structure is preserved after an arbitrary number of pivots. The algorithm allows block parallelization and individual block reinversions.

Julio M Stern, University of Sao Paulo
Stephen A. Vavasis, Cornell University

A New Iterative Method for Solving Symmetric Indefinite Linear Systems Arising in Optimization

Many optimization algorithms, such as interior-point methods for linear and nonlinear programs or sequential programming methods for constraind nonlinear programs, require the solution of Kuhn-Tucker optimality conditions. Typically, this leads to linear systems with symmetric, but highly indefinite coefficient matrices. Often, these systems are very large and sparse and it is attractive to use iterative techniques for their solution. Unfortunately, existing algorithms for symmetric systems, such as SYMMLQ and MINRES, usually converge slowly for highly indefinite matrices. Furthermore, these schemes can be used only with positive definite preconditioners, which leaves the systems highly indefinite. In this talk, we propose a new iterative method for solving symmetric indefinite linear systems, which can be combined with general symmetric preconditioners. The algorithm can be interpreted as a special case of the QMR approach for non-Hermitian linear systems, which was recently proposed by Freund and Nachtigal, and, like the latter, it generates iterates defined by a quasi-minimal residual property. The proposed method has the same work and storage requirements per iteration as SYMMLQ or MINRES, however, it usually converges in considerably fewer iterations. Numerical experiments for linear systems arising in optimization problems are reported.

Roland W. Freund
Research Institute for Advanced Computer Science
Mail Stop Ellis Street
NASA Ames Research Center
Moffett Field, CA 94035

Hongyuan Zha
Computer Science Department
Stanford University
Stanford, CA 94305

Preconditioned Iterative Techniques for Sparse Linear Algebra Problems Arising in Circuit Simulation

The DC operating point of a circuit may be computed by tracking the zero curve of an associated artificial-parameter homotopy, and it is possible to devise curve tracking algorithms for such homotopies that are globally convergent with probability one. These algorithms require computing the one dimensional kernel of the Jacobian matrix of the homotopy, and hence the solution of a linear system of equations. These linear systems are typically large, highly sparse, nonsymmetric and indefinite. A number of iterative methods, including Craig's method, GMRES(k), BiCG, QMR and LSQR, are applied to a suite of test problems derived from simulations of bipolar circuits. Preconditioning can have a significant impact on the performance of these methods, and several techniques are considered, including ILU and variations, and block diagonal preconditioners. Timings and convergence statistics are given for each iterative method and preconditioner.

William D. McQuain, Calvin J. Ribbens,
and Layne T. Watson
Department of Computer Science
Virginia Polytechnic Institute & State University
Blacksburg, VA 24061-0106

Robert C. Melville
AT & T Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974-2070

Graph coloring and the estimation of sparse Jacobian matrices using row and column partitioning

It is well known that a sparse Jacobian matrix can be estimated in much less function evaluations than the number of columns by using the CPR technique. The CPR method estimates a group of columns using one function evaluation. An often cited example by S. Eisenstat shows that if the rows of the matrix are partitioned in two blocks then fewer function evaluations is needed. In this talk we will discuss a direct method to estimate the Jacobian matrix and show the relationship between grouping together both rows and columns and the graph coloring problem. We will also discuss an implementation of the direct method.

Trond Steihaug and A.K.M.Shahadat Hossain
University of Bergen
Department of Informatics
Høyteknologisenteret
N-5020 BERGEN NORWAY

Toward Probabilistic Analysis of Interior-Point Algorithms for Linear Programming

We propose an approach based on interior-point algorithms for linear programming (LP). We show that the algorithm solves a class of LP problems in strongly polynomial time, $O(\sqrt{n}\log n)$-iteration, where each iteration solves a system of linear equations with n-variables. The statistical data of the solutions of the NETLIB problems seem to indicate that most of these problems are in this class. Then, we show that some random LP problems, with high probability (probability converges to one as n approaches infinity), are in this class. These random problems include Borgwardt's and Todd's probabilistic models with the Gauss distribution.

Yinyu Ye
Department of Management Sciences
College of Business Administration
The University of Iowa
Iowa City, IA 52242

An Artificial Self-Dual Linear Program.

How to initiate primal-dual interior point algorithms for linear programs is an important issue. One approach is to construct an artificial primal-dual pair of linear programs having known interior feasible solutions. Another is to modify primal-dual interior point algorithms so as to start from infeasible or exterior points. The latter leads to a so-called primal-dual exterior point algorithm. We introduce an artificial self-dual linear program for which we can adapt many primal-dual interior point algorithms, and discuss its relations to the exterior point algorithm.

Masakazu Kojima : Dept. of Information Sciences, Tokyo Institute of Technology, Oh-Okayama, Meguro, Tokyo 152, Japan

Nimrod Megiddo : IBM Research Division, Almaden Research Center, 650 Harry Road, San Jose, CA 95120-6099, USA

Shinji Mizuno : The Institute of Statistical Mathematics, 4-6-7 Minami-Azabu, Minato-ku, Tokyo 106, Japan

Akiko Yoshise : Institute of Socio-Economic Planning, University of Tsukuba, Tsukuba, Ibaraki 305, Japan

On the Convergence of the Iteration Sequence in Primal-Dual Interior Point Methods

Speaker: Richard Tapia, Rice University

(No abstract received at the time this Program went to press).

Ellipsoidal trust regions and prox functions for linearly constrained nonlinear programs

Trust region methods for inequality constrained optimization have been successfully developed mostly for simple constraints, using as trust regions the intersection of spheres and the feasible set. We approach linear constraints using interior points and ellipsoidal trust regions that change size and shape simultaneously to deal respectively with precision of the model functions and adaptation to the interior of the feasible region. In this talk we study the global convergence of the resulting algorithms both for convex and nonconvex problems, discussing the relationship of trust regions and prox functions.

Clovis C. Gonzaga
COPPE - Federal University of Rio de Janeiro
Cx. Postal 68511, 21945 Rio de Janeiro, RJ, Brazil
e-mail gonzaga@brlncc.bitnet.

"General Modeling Framework for Robust Optimization"

Robust optimization provides a systematic, practical approach for handling inaccuracies which occur in real-world data. Two forms of robustness are proposed: feasibility, and objective function. The framework encompasses several classical methods for noisy data. The resulting models are large-scale nonlinear programs, whose structure can be exploited by parallel/distributed algorithms.

John M. Mulvey
Department of Civil Engineering
and Operations Research
Princeton University
Princeton, New Jersey 08544
U.S.A.

"Decomposition and Robust Optimization"

We have been working for some time on decomposition approaches to solving a class of robust optimization problems that arise in stochastic programming. In this lecture we will outline the underlying mathematical techniques involved, and will describe some of the numerical work we have done to implement these techniques. We will also give some sample numerical results to illustrate the performance of these decomposition methods.

Stephen M. Robinson and Bock Jin Chun
Department of Industrial Engineering
University of Wisconsin - Madison
1513 University Avenue
Madison, WI 53706-1572

"Robust Optimization: Massively Parallel Solution Methodologies"

We will discuss strategies for designing a variety of algorithms for the solution of robust optimization problems on massively parallel architectures. One of the key attractive features of the algorithms is that (1) they are scalable and, hence, as the problems get larger they can exploit an increasing number of processing elements, and (2) they conform to the paradigm of data-level parallel programming. We will discuss our experience with one of the algorithms implemented on the Connection Machine CM-2.

Stavros A. Zenios
Decision Sciences Department
Suite 1300 Steinberg-Dietrich Hall
The Wharton School
University of Pennsylvania
Philadelphia, Pennsylvania 91904-6366
U.S.A.

"Robust Optimization: Interior Point Solution Methodologies"

Interior point methods for quadratic programming generally outperforms other methods on very large scale specially structured problems. An excellent example of such problems arises in the area of robust optimization. In this talk, we will describe our experience solving very large robust optimization problems using LOQO, which is an interior point code we have developed for quadratic programming problems.

Robert J. Vanderbei
Princeton University
Department of Civil Engineering
and Operations Research
Princeton, New Jersey 08544
U.S.A.

Semi-Definite Programming: Duality Theory, Eigenvalue Optimization, and Combinatorial Applications

We consider the problem of minimizing a linear function of a symmetric matrix X, subject to linear constraints on the matrix and the additional condition that X be positive semi-definite. Formally, we solve *the semi-definite programming problem* (SDP):

$$\min\{C \bullet X : X \succeq 0,\ A_i \bullet X = b_i \text{ for } i = 1, \cdots, m\}$$

where "$\bullet$" indicates the inner product of matrices (that is, $A \bullet B = \sum A_{ij}B_{ij} = \text{trace} A^T B$), and $X \succeq 0$ means X is positive semi-definite. We will develop a duality theory for this problem, and show that this theory is quite similar to duality in linear programming. We will also derive a "complementary slackness" theorem analogous to linear programming. Furthermore, we will show that various eigenvalue optimization problems are special instances of the SDP problem. The most general form is:

$$\min\{m_1\lambda_1(X) + \cdots + m_k\lambda_k(X) : A_i \bullet X = b_i, \text{ for } i = 1, \cdots, m\}$$

where $m_1 \geq \cdots \geq m_k \geq 0$ are given constants and A_i are given matrices. We will derive dual problems and complementary slackness results for these problems as well. Finally, we will demonstrate some applications of the SDP problem in combinatorial optimization, in particular, in maximum clique, graph partitioning, and the largest k-partite subgraph problems.

Farid Alizadeh
University of Minnesota
Minneapolis, Mn, 55455
e-mail: alizadeh@cs.umn.edu

Measures for SR1 Updates

Measures of deviation of a symmetric positive definite matrix from the identity are introduced. They give rise to symmetric rank-one, (SR1) sized updates. The measures are derived by considering the volume of the symmetric difference of the ellipsoids, which form the current and updated quadratic models, for quasi-Newton methods for unconstrained minimization. In addition, it is shown that the ℓ_2 condition number provides a relationship between the various sized updates and provides a way of choosing between sized updates. A common theme for the measures is the importance of the eigenvalues of the updates. Replacing the eigenvalues by a (scaled) norm condition is discussed. Numerical tests are included.

Henry Wolkowicz
Department of Combinatorics and Optimization
Faculty of Mathematics
University of Waterloo
Waterloo, Ontario, N2L 3G1, Canada

Shape Optimizing Eigenvalues of the Laplacian

We present a numerical analysis of a 1956 conjecture of Payne, Polya, and Weinberger. The conjecture asserts that the ratio of the first two eigenvalues of the Laplacian on a bounded domain Ω of the plane with Dirichlet boundary conditions reaches its minimum value precisely when Ω is a disk. A crucial feature of this problem is the loss of smoothness of the objective function at the solution. The following results form the core of our numerical treatment. First, we construct finite dimensional families of deformations of a disk equipped with a uniform triangulation. This permits the formulation of a discrete model of the problem via finite element techniques. Second, we build on the work of M. Overton to derive optimality conditions in terms of Clarke's generalized gradients for nonsmooth functions. These ideas are then combined into an algorithm and implemented in Fortran.

J.-P. Haeberly
Fordham University
Bronx, NY

Bounds for Eigenvalues and Singular Values of Matrix Completions

Two kinds of completion problems are discussed:

- Identification of the least upper bound and of the greatest lower bound for the p-th eigenvalue of hermitian completions of a given $n \times n$ partial matrix (the eigenvalues of a hermitian matrix are arranged in the non-increasing order).
- identification of the greatest lower bound for the p-th singular value of completions of a given $m \times n$ block triangular partial matrix (again, the singular values are arranged in the non-increasing order.

The first problem is an extension of the results on positive completions (see H. Dym and I. Gohberg, *Linear Algebra Appl.* 36 (1981), 1-24 and R. Grone, C. R. Johnson, E. M. de Sa and H. Wolkowitz, *Linear Algebra Appl.* 58 (1984), 109-124).

The second problem may be viewed as an extension to other singular values of Parrott's theorem (S. Parrott, *J. Funct. Anal.* 30 (1978), 311-328).

The Toeplitz case will also be discussed.

The talk is based upon joint work with I. Gohberg, L. Rodman, and T. Shalom.

Hugo J. Woerdeman
Department of Mathematics
The College of William and Mary
Williamsburg, Virginia 23187

Advantages of Differential Dynamic Programming Over Stage-wise Newton's Method for Optimal Control Problems

This paper examines the analytical and computational differences between Differential Dynamic Programming (DDP) and stage-wise Newton's method, which are both quadratically convergent methods for solving discrete-time optimal control problems. Results presented indicate DDP converges in many fewer iterations and with less CPU time than that required by Newton's method. In addition, the numerical results indicate that Newton's method is more likely to require a shift procedure to overcome problems with non-positive definite matrices. Reasons for these differences are explained. For difficult, non-convex, large scale example problems, DDP computes solutions over ten times faster than the stage-wise Newton's method.

Christine A. Shoemaker and Li-Zhi Liao
School of Civil and Environmental Engineering
Cornell University
Ithaca, N.Y. 14853 USA

Numercial Solution of an Optimal Control Problem arising in Phase Field Models

This talk is concerned with the numerical solution of an optimal control problem governed by a parabolic PDE with a free boundary. The free boundary is handled using the enthalpy method. This leads to a system of nonlinear parabolic PDEs defining the state. We focus on the optimization part of the control problem discussing how to incorporate its structure and how to deal with the scale induced by discretization.

M. Heinkenschloss
Universität Trier
FB IV - Mathematik
Postfach 3825
D-W-5500 Trier
Federal Republic of Germany

Solution of a Nonlinear Boundary Control Problem by Reduced SQP

We present a new approach for the numerical solution of a control problem governed by a nonlinear diffusion equation. Problems of this type occur for example when firing ceramic products in a kiln. We interpret the discretized problem as a constrained minimization problem, and we use a suitable representation for the null space of the Jacobian of the constraints to develop a reduced secant method which exploits the sparsity pattern of the Jacobian and offers practicable storage requirements. Compared to Newton's method for the unconstrained problem the proposed algorithm avoids the solution of nonlinear equations per iteration and the computation of second derivatives. A fast two-step superlinear convergence can be observed numerically.

F.-S. Kupfer and E. W. Sachs
Universität Trier
FB IV - Mathematik
Postfach 3825
D-W-5500 Trier
Federal Republic of Germany

A New Homotopy Method for Solving the H^2 Optimal Model Reduction Problem

The optimal model reduction problem, arising from various engineering applications, is one of the fundamental problems in control and system theory. Current methods for solving this problem include reducing the problem to the optimal projection matrix equations, which are then solved by a homotopy method. For a large system the computer time needed to obtain a satisfactory solution may be prohibitive. The new approach we propose is to apply a probability-one homotopy method directly to the cost function and use far fewer independent variables than the optimal projection equation approach, thereby considerably reducing the execution time and storage requirements. Several examples are given and the results of the new approach are compared with those obtained by the current methods.

Yuzhen Ge, Layne T. Watson
Department of Computer Science
Virginia Polytechnic Institute and
State University
Blacksburg, VA 24061-0106

Emmanuel G. Collins, Jr.
Harris Corporation
P.O. Box 94000
Melbourne, Florida 32902

An Application of Semiinfinite Programming Methods to Nonlinear Approximation Problems

We consider the problem of uniform approximation by rational functions over compact sets. Such problems can be easily reduced to semiinfinite programming problems; unfortunately, these SIP problems are nonlinear and usually nonconvex. A method for finding global solutions to this type of SIP problems is described; it generates a sequence of (usually large scale) linear programming problems. Strategies for the reduction of the size of these LP problems based on their special structure are also investigated and illustrated on numerical examples.

Miroslav D. Asic
Department of Mathematics
The Ohio State University
Newark Campus, University Drive
Newark, OH 43055-1797

Vera V. Kovacevic-Vujcic
Department of Mathematics
Faculty of Organizational Sciences
University of Belgrade
ul. Jove Ilica 154
11040 Belgrade – Yugoslavia

New Method of a Global Optimization

Most practical problems are described by complex nonlinear equations (diffierential,decrete, combunatorial,etc). A new method of optimization of a re-definition of the functional over a wider set and a deformation of the functional on the initial and additional sets is proposed. The method allows
(a) to reduce the initial complex problem of optimizatiom to^{a}series of simplified problems,
(b) to find the subsets containing the points of global minimum and to find the subsets containing better (or worthier) solutions than the given one,
(c) to obtain a lower estimate of the global minimum. The author applied this method to many technical problems: control,automation,aviation,aeronautics,ecomics,games,theory of counter strategy,etc.
Reference: A.Bolonkin,"A New Approach to Finding a Global Optimum", New American's Collected Scientific Reports. Vol.1,1991, p.45-50. The Bnai Zion.

Alexander A. Bolonkin
Courant Institute of Mathematical Sciences
New York, USA

Efficient Hybrid Techniques for Solving some Global Optimization Problems

In this talk we discuss a number of hybrid techniques that seem to be worthwhile for the solution of bilevel, bilinear and nonconvex quadratic programs. The procedures are based on Sequential LCP or parametric optimization and incorporate interior point methods or descent algorithms for nondifferentiable optimization. Computational experience is included to show the appropriateness of these methodologies.

Luis N. Vicente and Joaquim J. Judice
Departamento de Matematica
Universidade de Coimbra
3000 Coimbra
Portugal

Potential Transformation Methods for Global Optimization

Several techniques for global optimization treat the objective function f as a force-field potential. In the simplest case, trajectories of the differential equation $\ddot{x} = -\nabla f$ sample regions of low potential while retaining the energy to surmount passes possibly leading to even lower local minima. A *potential transformation* is an increasing function $V: \mathbf{R} \to \mathbf{R}$. It determines a new potential $g = V(f)$, with the same minimizers as f, and new trajectories satisfying $\ddot{x} = -\nabla g = -\frac{dV}{df}\nabla f$. We discuss a class of potential transformations that greatly increase the attractiveness of low local minima. As a special case, this provides a new approach to Griewank's equation [JOTA 34(1981) 11-39].

Jack W. Rogers, Jr.
Division of Mathematics
Auburn University, AL 36849

Robert A. Donnelly
Department of Chemistry
Auburn University, AL 36849

A Global Convergence Theory for a Trust Region Algorithm for Constrained Optimization

A global convergence theory for a trust region algorithm for solving the large, smooth nonlinear programming problem is presented.
The algorithm is a generalization of the Steihaug-Toint dogleg method for the unconstrained case, via a Vardi subproblem. Using the augmented Lagrangian as merit function, a scheme for updating the penalty parameter is discussed and global convergence theorems are established.

J. E. Dennis, Jr.
Maria Cristina Maciel
Department of Mathematical Sciences
Rice University, P.O. Box 1892
Houston, Tx 77251.

An Implicit Trust Region Algorithm for Constrained Optimization

In order to solve the problem

$$\min f(x); g(x) = 0; \ \underset{\sim}{x} \le x \le \tilde{x} ,$$

we consider algorithms that at each iteration solve

$$\min \nabla f(x^k)^t d + \frac{1}{2} d^t M^k d + \frac{\alpha^k}{2} \| d \|^2$$

$$\text{s.t.} \ \ g(x^k) + g'(x^k) d^k = 0; \ \underset{\sim}{x} \le x^k + d^k \le \tilde{x} .$$

Although the direction d^k is also the solution of some trust region problem we find advantages in manipulating α^k instead of the size of the region. We establish asymptotic properties of the direction for large α^k. This allows us to design a globally convergent algorithm. Under reasonable assumptions this algorithm is superlinearly or quadratically convergent.

Frédéric BONNANS and Geneviève LAUNAY
INRIA - Projet PROMATH, Domaine de Voluceau,
BP 105, 78153 Rocquencourt, France.

Numerical Experience with a Merit Function for Inequality Constraints

Recently, Boggs, Tolle and Kearsley suggested a merit function for inequality constrained nonlinear programming problems. The merit function has many desirable properties. In this talk, we discuss the numerical effectiveness of this merit function for solving large scale, inequality constrained, nonlinear programs using the sequential quadratic programming (SQP) algorithm

Anthony J. Kearsley
Department of Mathematical Sciences
Rice University
Houston, TX 77251-1892

Another Look At Direction Finding Methods

Solving inequality constrained nonlinear programming problems by the method of feasible directions requires the solution of a linear or quadratic programming subproblem to determine an improving direction. Important consideration is the length of the direction vector. Several direction finding methods have been proposed, all of which impose a length constraint while using a gradient projecting criteria. A new formulation is suggested in which the trade-off between length and projection is made explicit in a quadratic objective function. Computational experience on published test problems will be reported.

Mark Cawood
Michael Kostreva
Department of Mathematical Sciences
Clemson University
Clemson, SC 29634-1907

Parallel Extreme Point Algorithms for Linear Programming

We view the linear program as a search graph. A node in this graph corresponds to a (row) basis, and an arc connects nodes whose corresponding bases differ in only one vector. Each node has a cost corresponding to the objective function value of the basis (plus penalties for violated constraints). A monotone path has successive nodes of non-increasing value. Searching for an optimal solution can be done in two ways: (a) taking parallel monotone paths, or (b) speeding the traversal of one monotone path. We discuss some strategies for parallel search. For the other approach, we present a non-deterministic algorithm based on revised simplex. The algorithm specification is architecture-free.

Mohan Sodhi
John Mamer
Anderson Graduate School of Management at UCLA
405 Hilgard Ave,
Los Angeles CA 90024.

An Algorithm for a Class of Continuous Linear Programs

This paper discusses a class of continuous linear programs posed in a function space called separated continuous linear programs (SCLP). A dual linear program and a corresponding discrete approximation are introduced followed by a discussion of their properties. The discrete approximation gives rise to an improvement step which is constructed from any given feasible (non-optimal) solution to SCLP. A strong duality result follows from this. There are a variety of possible implementations of an algorithm for solving SCLP problems using this improvement step. Finally some computational results are given from one possible implementation.

Malcolm Craig Pullan
Judge Institute of Management Studies
Mill Lane
Cambridge CB2 1RX, England

New directions for progressin linear and nonlinear programming.

Recent rapid progress in linear programming due to the use of interior point methods raised some challenging problems, in particular, of parallel acceleration and numerical stability [compare our paper in Computers and Mathematics with Applic., Modified Barrier Function Method and Its Extensions, vol. 20, pp. 1-14, 1990]. We will present some new techniques for such problems and demonstrate their efficacy.

Prof. Victor Pan
Department of Mathematics and Computer Science
Lehman College/CUNY
250 Bedford Park Boulevard West
Bronx, New York 10468

Perturbation analysis of Hoffman's bound for linear systems

In 1952, A. Hoffman published a bound on the distance from any point to the solution set of a linear system. This bound subsequently has found applications in the sensitivity analyis of linear programs and the convergence analysis of descent methods for linearly constrained minimization. In this talk, we give simple necessary and sufficient conditions under which the constant in Hoffman's bound is bounded under local perturbations on the linear operator and local/global perturbations on the right hand side. Also, we relate these conditions to a uniform boundedness property of the vertex solutions. This work may have additional co-authors.

Zhi-Quan Luo
Department of Electrical and Computer Engineering,
McMaster University, Hamilton, Ontario, L8S 4L7, Canada
and
Paul Tseng
Department of Mathematics,
University of Washington, Seattle, WA 98195, U.S.A.

Stability of the Optimal Solution of a Linear Program to Simultaneous Perturbations of All Data

Consider a linear programming problem having a unique nondegenerate basic optimal solution. We are interested in checking whether the set of optimal basis indices remains stable under simultaneous /mutually independent/ perturbations of all data within given tolerances and, in the positive case, in computing the exact bounds on the optimal solutions of the perturbed problems. These questions arise naturally e.g. in case of inexact data and cannot be seemingly solved by known parametric LP methods. We construct four nonlinear matrix equations having unique matrix solutions. If the diagonal vectors of the four matrices satisfy some conditions, then the problem is basis stable in the above sense and the four diagonal vectors form the exact bounds on the optimal solutions of the perturbed primal and dual problems.

Jiri Rohn
Dept. of Applied Math.
Charles University
Malostranske nam. 25
11800 Prague
Czechoslovakia

Interval Methods for Degenerate Linear Programs

We describe a simplex-like algorithm for Linear Programming which maintains reliability even for highly degenerate problems. The algorithm is based on a method of Fletcher [1] which dualizes the problem when degeneracy occurs. The original method of Fletcher has a guarantee of termination, but although it works usually well in practice there is no guarantee that it terminates at the exact solution. As a remedy we use interval arithmetic [2] to control the roundoff error so that we obtain guaranteed bounds for the solution, which are refined by an iterative process.

References

[1] R. Fletcher — "Degeneracy in the Presence of Roundoff Errors" *Linear Algebra Appl.*, 1988.

[2] U.W. Kulisch and W.L.Miranker (editors) — "A New Approach to Scientific Computation" Academic Press, New York, 1983.

Frank Plab
Edinburgh Parallel Computing Centre
University of Edinburgh
Edinburgh, Scotland, UK

Optimization of Large Structural Systems By Using Karmarkar's Method

Optimum design of structures is an engineering field where optimization techniques have been used from several years ago. Even though many of the problems are nonlinear they are sometimes solved by a sequence on linearization procedures.

The method proposed by N. Karmarkar for linear programming claims to be more efficient than simplex method for large size problems containing several hundred or thousand variables and conditions.

In this paper Karmarkar's method is used to solve some examples of optimum structural design as size optimization of trusses and shape optimization of steel cable in prestressed concrete beams. Each example is modeled with increasing range of variables and conditions in order to check effectively of the method to the problem scale

S. Hernandez, J. Mata, and J. Doria
Department of Mechanical Engineering
University of Zaragoza
Maria de Luna, 3
50015 Zaragoz, SPAIN

A Modified Termination Rule for Karmarkar's Algorithm

In this note we have proposed a modified termination rule for Karmarkar's algorithm for linear programming. It enables the algorithm to save a large number of iterations (about 80 percent) and ensures its early termination compared to that of Karmarkar.

J.N. Singh
College of Business Management
Chapra, Pin. 841301
Bihar, INDIA

D. Singh
Department of Humanities and
Social Sciences
I.I.T. Bombay
Bombay 400 076, INDIA

Applications of Linear Programming to Medical Diagnosis

We give application of interior point methods to medical diagnosis in this paper. Suppose that we have two pattern sets A and B which include features of cancer and non-cancer respectively. We find a pair of parallel planes which separate some points of A from B by solving 2n linear programming in each step. We can completely separate A from B by a finite number of steps, t.e, we can construct discriminant function f, such that f(a) 0, f(b) 0. Initial tests for samples of stomach cancer show that this method is efficient.

Xu Shu Rong et al.
Department of Computer Science
Zhongshan University
Guangzhou, China

Barrier Methods for Large-scale Nonlinear Programming

Barrier methods transform a constrained optimization problem to a sequence of unconstrained problems. We discuss the use of Newton-type methods to solve these unconstrained problems. Issues of stability and efficiency will be discussed, particularly in the large-scale case. Numerical experiments will be reported.

Stephen Nash and Ariela Sofer
ORAS Department
George Mason University
Fairfax, VA 22030

IMMAGE RECONSTRUCTION FROM NOISY PROJECTIONS: A REGULARIZED DUAL-BASED ITERATIVE METHOD.

An iterative method for a problem of image reconstruction from noisy projections which is a large scale optimization problem is presented. The method uses a regularization of the objetive functional and is based on its dual formulation which is

a semi-separable convex minimization problem with linear constraints, where the function to be minimized is the sum of a Burgs entropy and a quadratic function. From the special structure of this new formution in combination with a Bregman's type method, a computacionally attractive algorithm emerges and its convergence properties are proved.

ALFREDO NOEL IUSEM
Instituto de Matemãtica Pura e Aplicada
Estrada Dona Castorina, 110
IMPA - RIO DE JANEIRO, RJ - CEP 22460
BRASIL

Numerical Experience with the Modified Barrier Functions Method for Linear-Constrained Optimization Problems

We report our computational experience with the Modified Barrier Functions (MBF) method for solving optimization problems with linear constraints.

The numerical realization of the primal MBF method leads to Newton's method for finding a minimum of a strongly convex and smooth function, and updating the dual variables by using a simple formula. A primal-dual approach based on MBF also leads to solving a Lagrangian system of equations by the Newton method. In both cases the key procedure is the solution of a normal system of equations (a least squares problem).

The numerical results for linear, quadratic and convex programming problems with linear constraints are discussed.

D. Jensen, R. Polyak, and R. Schneur
IBM Thomas J. Watson Research Center
Yorktown Heights, NY 10598

The Nonconvex Separable Resource Allocation Problem with Continuous Variables

New results are presented for solving the well-known nonlinear programming problem: Minimize $F = \Sigma_1 f_i(x_i)$ subject to $\Sigma_1^n x_i = X$ and $x_i \geq 0$; which has been studied over the past thirty years in numerous application areas. Whereas current solution methods are restricted to convex $f_i(x_i)$ [1], the new results allow the functions $f_i(x_i)$ to be nonconvex and multimodal, with any number of maxima and minima over [0,X]. Necessary and sufficient conditions characterizing the local minima of $F(x_1,x_2,...x_n)$ are derived which enable the determination of all minimum points of $F(x_1,x_2,...x_n)$ and hence its global minimum. The results are used to solve examples which no other analytical criteria can solve.

[1] Ibaraki,T. and Katoh, N.: *Resource Allocation Problems*, The MIT Press, 1988

Emile Haddad, Ph.D.
Department of Computer Science, Virginia Polytechnic Institute and State University,
2990 Telestar Court, Falls Church, VA 22042

Optimization of Interactions in an Interconnected System

The problem of improving the performance of an interconnected dynamical system consisting of a gas turbine engine coupled to an airframe operating throughout the whole flight envelope in the presence of predominantly destructive dynamical interactions is addressed in this paper. It is shown that by optimizing the interactions between these subsystems significant performance improvements over previous control schemes can be obtained.

Ronald A. Perez
Mechanical Engineering Department
University of Wisconsin-Milwaukee
Milwaukee, WI 53201

Hierarchical Controls in Stochastic Manufacturing Systems with Convex Costs

We study production planning problems with unreliable machines. The method of hierarchical controls has proved effective in reducing the overall complexities of these problems. The idea is to construct an asymptotically-optimal control for the original problem from a near optimal control for a simpler limiting problem. So far the asymptotic errors have been obtained only for systems with linear production cost functions. We will present a new method to enable us to handle systems with general convex cost functions.

S. Sethi, Q. Zhang, and X. Y. Zhou

Faculty of Management
University of Toronto
246 Bloor St. W.
Toronto, Ontario
M5S 1V4 Canada

Methods of Solution of Boundary Value Problem of Optimal Theory

The author considers the usual optimal control problem of minimizing the functional among all the solutions of the differential system. The problem is solved by the following new methods: Method of Piecewise Optimization, Method of Sliding along a Directrix, Method of Descent along Phase Trajectories, Method of Iterations, Method of Descent in State Space.

Alexander A. Bolonkin
Courant Institute of Mathematical Sciences
New York, USA

On Certain Optimization Problems in Banach Spaces with Nonsmooth Equality Constraints

The problem of finding the tangent space in optimization problems with equality constraints is crucial in determining necessary conditions of optimality. The classical Lusternik theorem about the tangent space requires the operator F that describes equality constraints to be of class C^1 in the neighborhood of x_0. Here, a certain generalization of the Lusternik theorem which requires that the operator F be only differentiable at x_0 and Lipschitzian in its neighborhood is presented. Application to some general optimization problems in Banach spaces with mixed equality and inequality constraints is shown. The theory is illustrated with an example.

Urszula Ledzewicz-Kowalewska, Department of Mathematics and Statistics, Southern Illinois University at Edwardsville, Edwardsville, IL 62026;
Stanislaw Walczak, Institute of Mathematics, University of Lodz, 90-238 Lodz, Poland.

Comparative Study of Stochastic Approximation Algorithms in the Multivariate Kiefer-Wolfowitz Setting

Stochastic approximation (SA) algorithms are used to find a root of the multivariate gradient equation that arises in function minimization problems for which only noisy measurements of that function are available. This type of problem can be found in neural network training, stochastic optimization, adaptive control, etc. This paper studies three SA algorithms in the multivariate Kiefer-Wolfowitz setting: standard finite-difference SA (FDSA) of Kiefer-Wolfowitz (1952) /Blum (1954), random-directions SA (RDSA) of Kushner- Clark (1978), and simultaneous-perturbation SA (SPSA) of Spall (1988, 1992). These algorithms have been shown to be almost surely convergent to the root and to produce estimates having asymptotically normal distributions. The efficiency of the algorithms are judged from the mean square errors of the estimates. Although it is impossible to make a completely general statement about the efficiency of the algorithms, both theoretical and numerical studies indicate that SPSA tends to be more efficient than FDSA or RDSA in most cases of practical interest, especially in high-dimensional problems.

Daniel C. Chin
The Johns Hopkins University, Applied Physics Laboratory
Johns Hopkins Road
Laurel, Maryland 20723-6099

Comparison of approximate and exact solution methods for network location problems.

Medium to large network location problems have been solved approximately with considerable success. Standard techniques focus on the sequential choice of locations, often based on greedy heuristics. At the same time, exact solutions methods to solve network location problems have recently embodied Lagrangian relaxation methods. Their success depends crucially on Lagrangian heuristics to generate feasible incumbents. To analyze the relationships between the two approaches, we provide a Lagrangian framework which enables us to rank well-known reduction tests, and we propose a spectrum of new tests which we assess computationally. We view standard heuristics as approximations of exact Lagrangian relaxation algorithms and design an algorithm that provides an attractive time-accuracy tradeoff. These results can be applied to novel location problems on capacitated networks.

Geraldo R. Mateus
Universidade Federal de Minas Gerais,
Departamento de Ciencia da Computacao

Jean-Michel Thizy
Faculty of Administration,
University of Ottawa

Sensitivity of the Time Bounds for Network Flow Path Searches when Critical Nodes Are Altered.

It will be explained how to optimize the traffic flow (throughput) across the movement network of paths and cross-corridors generated by digital terrain map A* grid search algorithms. In this approach, in order to determine the sensitivity of the overall network movement graph to changing the flow values at certain critical nodes, the solution searches for the goal nodes over the whole path space. Some theorems will be used to compute time bounds for the number of paths searched (in terms of the maximal number of incoming and outgoing edges at a vertex) using this procedure to compute a maximal and min-cost flow.

Dr. Andrew W. Harrell
U.S. Army Waterways Experiment Station
Mobility Systems Division
Geotechnical Laboratory
Vicksburg, MS. 39181

An Implementation of a Parallel Interior Point Method for Multicommodity Flow Problems

An implementation of the primal-dual predictor-corrector interior point method is specialized to solve linear multicommodity flow problems. The block structure of the constraint matrix is exploited via parallel computation. The bundling constraints require the Cholesky factorization of a dense matrix. A method that exploits parallelism for the dense Cholesky factorization is described as well. The resulting implementation is 70 to 90 percent efficient, depending on the problem instance. For a problem with K commodities, a speedup for the interior point method of 0.8K is realized.

Guangye Li
CRPC and Dept. of Mathematical Sciences, Rice University

Irvin J. Lustig
Dept. of Civil Engineering and Operations Research, Princeton University

A General Overshipment Solution to Transportation Problem of Three Dimensions

In this paper the general solution of the Hitchcock transportation problem resulting from the application of the method of reduced matrices is emphasized. The initial solution have some negative X_{ij} values. A useful interpretation of such negative values may lead to overshipment solutions. Methods of finding optimal overshipment solutions are discussed.

Dr. Nabih N. Mikhail
Department of Mathematics
Liberty University
Box 20,000
Lynchburg, VA 24506-8001

A primal-dual interior point method with cutting planes for the linear ordering problem

We describe a cutting plane algorithm for the linear ordering problem, using linear programming relaxations. The linear ordering problem is an NP-hard combinatorial optimization problem with many applications, including triangulation of input-output matrices. The linear programs which arise are solved using a primal-dual interior point method. The method we use attempts to detect cutting planes early, in order to avoid vertices of the polyhedra of the relaxations. Computational results are presented. A simplex-based cutting plane algorithm for this problem has previously been described by Grötschel, Jünger and Reinelt (Operations Research 32(1984) pp1195-1220).

John E. Mitchell
Dept of Mathematical Sciences
Rensselaer Polytechnic Institute
Troy NY 12180

Brian Borchers
Dept of Mathematical Sciences
Rensselaer Polytechnic Institute
Troy NY 12180

Three Approximation Algorithms that Minimize the Rectilinear Steiner Tree on a Hypercube Network

This paper presents a generalizaion of the rectilinear Steiner tree from the plane to the m-hypercube and also three approximation algorithms that solve the generalized problem. The three approximations algorithms use heuristics based on the leftmost-oriented, rightmost-oriented and gravity-oriented strategies respectively. The gravity-oriented algorithm has time complexity O(nm^2+n^{2}m) whereas the other two O(n^{2}m). An implementation shows that the gravity-oriented algorithm results, on average, in fewer connections and fewer intermediate processors than the other two algorithms and all three produce smaller numbers than the rectilinear minimum spanning tree algorithm.

Tao Zhou and Dionysios Kountanis
Department of Computer Science
Western Michigan University
Kalamazoo, MI 49008

Alternating Sequences Relative to Maximum Independent Sets of Independence Systems

The concept of alternating sequence is introduced into independence systems. This kind of alternating sequence is shown to include almost all kinds of alternating sequences known in combinatorial optimization literature. It is shown that a Berge-type theorem holds: an independent set in an independence system is maximum if and only if there exists no odd maximal alternating sequence relative to it. Some examples, especially Hamiltonian Circuit Problem, are also discussed.

Tao Wang
Department of Mathematical Sciences
The Johns Hopkins University
Baltimore, MD 21218

Maximizing the Visibility Area from a Point Moving on a Curved Segment

Given a set of nonintersecting openings on the plane the visibility problem from a point P is to determine the position of P on the plane that maximizes the visibility area from P. In this paper we present an algorithm that maximizes the visibility area when the point P moves on a curved line of motion f(x,y). The algorithm is based on a Greedy strategy and performs in linear time. Our analytical and experimental results show that the algorithm approximates the "discrete" visibility maximization point within acceptable low and upper bounds. Our study demonstrates that the approximation algorithm is independent of the ordering of the visibility angles for each one of the openings in the plane and has extensive practical applications in robot vision and VSLI design.

Lambros Piskopos and Dionysios Kountanis
Computer Science Department
Western Michigan University
Kalamazoo, MI 49008

Practical Heuristics For Scheduling Precedence Graphs Onto Multiprocessor Architectures

The scheduling problem is the problem of optimally mapping the modules of an application program represented as a directed acyclic graph, onto a hardware architecture so that the final completion time of the application is minimized. It is well known, except for some special cases, that this problem is NP-Complete. Many heuristics have been developed, however, the important issues of data dependencies among modules and the inter-processor communication overhead have been neglected or strongly restricted. In this paper we propose more practical heuristics that include the above-mentioned parameters. We extend the HWANG's ETF (earliest task first) heuristic to handle complete heterogenous architectures, and observe that a random scheduling of the source modules could result in a less efficient schedule, a point that was overlooked. Also, for this architecture an assumption is made that algorithmic edges are always mapped to architecture edges, although a more efficient communication path could exist. Furthermore, we lift the above assumption and consider incomplete, as well as complete hardware architectures. So, in addition to selecting processors for module execution, we also select optimal communication channels for message transfers.

Kiran Bhutani
The Mathematics Department
The Catholic University Of America, Washington D.C
Abdella Battou
The Electrical Engineering Department
The Catholic University Of America, Washington D.C

Minimizing Communication in Domain Decomposition via Minimum-Perimeter Tiling

For certain classes of problems defined over two-dimensional regions with grid structure, minimum-perimeter domain decomposition provides tools for partitioning the problem tasks among processors so as to minimize interprocessor communication. Minimizing interprocessor communication is shown to be equivalent to tiling the domain so as to minimize total tile perimeter, where each tile corresponds to the tasks assigned to some processor. A tight lower bound on the perimeter of a tile as a function of its area is developed. We then show how to generate all possible minimum-perimeter tiles. Certain classes of domains are shown to be optimally tilable.

Jonathan Yackel
Robert R. Meyer
Center for Parallel Optimization
Computer Sciences Department
University of Wisconsin-Madison
1210 West Dayton Street
Madison, WI 53706

Transfer Method for Optimization on Non-Transitive Binary Relations

Optimization on non-transitive binary relations is important in economics, decision analysis and game theory. For an example, in consumer theory, a consumer's preference is in general not transitive. When one searchs for maximal elements on a set X, one looks for some "nice" properties in X, which guarantee the existence of maximal elements. However, "nice" properties on lower levels have nothing to do with the existence. Only "nice" properties on upper levels contribute to the existence. This motivates the transfer method in [1] and their further applications will be discussed.

Jianxin Zhou, Department of Mathematics
Texas A&M University, College Station, TX 77843

Integer Search Method

Optimizing the plan manufacturing products is referred to the Integer Programming (IP). It is an important problem how effectively to solve IP. The current methods for IP are almost finding in the real domain indirectly. It appears that the potential advantage of integer number does not be explored thoroughly and the computational complexity is added implicitly. The Integer Search Method (ISM) is closely combining the cutting method with the search method in the integer domain. ISM greatly explores the effect of the own character of IP on the solving process and breaks free from conventions of the current methods for IP.

Wu Xingbao
Department of Applied Mathematics
Wuhan College of Metallurgic Management Cadre
Renjia Road, Wuhan, Hubei, Zip Code, 430081
People's Republic of China

Newton Modified Barrier Function Complexity for Quadratic Programming Problems

The numerical realization of the Modified Barrier Function method for the Quadratic Programming (QP) problem leads to the Newton MBF method

It was shown that for any nondegenerate QP problem there exists a so called "hot start". From this point on, after each Lagrange multipliers update, subsequent iterates remain in the Newton area for the new function associated with the new multipliers This means that from the "hot start" on, only $\ln\ln\varepsilon^{-1}$ Newton steps are necessary after each update in order to reach the next update ($\varepsilon > 0$ is the desired accuracy for the solution) Taking into account the basic MBF property, one obtains that the number of Newton steps from the "hot start" to the solution is $O(\ln\ln\varepsilon^{-1})\,O(\ln\varepsilon^{-1})$

To reach the "hot start" one has to spend $O(\sqrt{m}\,\lg k)$ Newton method steps, where $k > 0$ is defined by the condition of the QP which in turn can be characterized explicitly by the parameters of the QP in the primal-dual solution

All results can be extended to nondegenerate convex programming problems

A Melman, Caltech
R Polyak, IBM T J Watson Research Center

Interior Point Algorithms and Dynamic Systems

In this paper a unified view point for handling variety of interior point algorithms in solving LP is presented, that is dynamic systems. In the general situation the form of such system and the basic conditions imposed on have been discussed. The geometrical features of the trajectories have been investigated.

Zai-yun Diao
Mathematics Department
Shandong University
People's Republic of China, 250100

Modelling of an Economic Incentive Approac: .a Environmental Protection

The paper examines the schemes of economic incentive, called "closed-loop" (CEIS) for environmental protection, in wich pollution taxes are used for partial compensation pollution abatement costs [1]. This approach is used in water pollution control in Europe, in Oregon Bottle Bill and in a number of other cases. Simple mathematical model presents an incentive mechanism that encourage polluters to reduce their discharges to proper level in a cost-effective manner. It is shown that in CEIS optimal pollution taxes is to be proportional to the dual prices vector. Numerical experiments with real-life data are also analyzed.

[1] Rikun A.D. A "closed-loop" Economic Incentive Scheme for Ierarchical Management System //Dokladi USSR Academy of Science, v.311, N5

Dr. A.D.Rikun
Senior Scientific Researcher
Water Problems Institute of the USSR Academy of Sciences
Sadovo-Chernogriazskaya, 13/3, Moscow, 103064, USSR.

The optimization with formally-undefined criterion

It's known that optimization methods can be used only with formal criterion. Here estimation of solution and choice of model parameters are performed by the computer on every step of the search. The large class of the problems doesn't allow the complete formalization and therefore this operations are performed by user. Yet the last mode is accessible only for skilled user , which 'fills' the connection between the parameters and characteristics of model very well. In another way user will 'roam'.

It's suggested the heuristic proceduries which allow to use the optimization methods without formally-defined criteria. Here on every step of the search the user gives the quantity estimation of the solution , but the computer provides moving in parameter's space. It's consedered the applications of these proceduries to geophysics and mining.

Mikhael Aron Alexandrov
Moscow Geological-Prospecting Institute
Mathematical Modelling
Micluho-Maclai str., 23, Moscow 117873 USSR

Optimization Modelling for Neural Networks and Mathematical Biology

This paper presents some of the applications of optimization to the mathematical modelling of problems associated with neural networks and mathematical biology. The problems pertaining to neural networks include such applications as the dynamics of pattern retrieval, which entail network equilibrium properties, and learning rules which can be modelled by nonlinear optimization functions. The associated problems in mathematical biology include such applications to population dynamics, dynamic diseases, competition models, epidemic models and their spatial spread. The application of variational inequalities to these problems is also discussed.

Future directions of the research are discussed.

Dr. Richard S. Segall
Eastern Kentucky University
Department of Mathematics, Statistics and Computer Science
Richmond, KY 40475-3133

Optimal Regularity of Equilibria and Material Instabilities

The study of regularity of weak equilibrium solutions to, for instance, nonlinear systems of pde's originating from applications in continuum physics is still in its early stage. Within this context, there are very few known (Ball, Morrey, Murat, Virga...) results which, from a practice viewpoint, seem fundamentally dependent on the (a priori) availability of equilibrium solutions. Using the field theory of variational calculus, I will be presenting my recent result on optimal regularity of such solutions along with its connection to material instabilities (e.g. fracture). Remarks on a (new) seemingly promising approach to this study will be proposed.

Salim M. Haidar
Northern Michigan Univerisy
Department of Mathematics and Computer Science
Marquette, MI 49855

Functions with Unstable Images: Cracks.

The main subject of this paper deals with the conditions under which a continuous function g has an unstable image, crack C. This subject is motivated by the study of the converse problem of controllability and of attainable sets.

For the case when C is an $(n-1)$-dimensional manifold, we characterize cracks that admit "escape fields". Then we discussed the nonnegativity of a related function and the zero topological index condition fo g on C. For the case when the dimension of C is lower(which appears to be qualitatively different), we studied the sufficient conditions for a set C to be a crack respectively a local crack of g.

Guangxiong Fang, Engineering, Math and Science Division, Daniel Webster College, Nashua, NH 03063

Jack Warga, Department of Mathematics, Northeastern University, Boston, MA 02115

Optimization Model Management

The practical, day-to-day use of an LP, MIP, or NLP model requires not merely solving the model, but rather managing it. Optimization model management (MM) encompasses not only the basic tasks of matrix generation, solution, and report writing but also a host of essential supporting tasks: symbolic model formulation, database management, scenario (case) management, solution analysis and query, ad hoc reporting, and results presentation. The advent of desktop computing is stimulating development of new MM techniques and software products. This presentation offers (1) an overview of MM functions and requirements and (2) a quick survey of leading-edge MM software.

David S. Hirshfeld
MathPro Incorporated
1019 19th Street, N.W.
Suite 1300
Washington, DC 20036

Graph-Grammars for Network Flow Modeling

Graph-grammars provide a theoretically grounded, powerful, and graphical mechanism for manipulating graphs. We used graph-grammars to develop modeling tools for a wide variety of mathematical models that are conveniently expressed as graphs, e.g., project management, decision analysis, vehicle routing. We present the application of graph-grammars to minimum cost network flow modeling and discuss a prototype implementation.

Christopher V. Jones
Simon Fraser University
Faculty of Business Administration
Burnaby, B.C. V5A 1S6 Canada

AIMS: An Environment for Advanced Integrated Modeling Support

The AIMS system is designed to support mathematical programming modeling activities in an operational environment. In such an environment there is a need for a powerful modeling language as well as a fast and interactive modeling system capable to interact with other software systems. The current modeling systems that support large-scale linear, nonlinear, mixed-integer and combinatorial programming models have been designed for modeling in a strategic planning environment. In such an environment the requirements for speed and a sophisticated modeling language have been less pronounced. During the presentation the distinct features of the AIMS system will be discussed, and future developments will be outlined.

Johannes J. Bisschop

Department of Applied Mathematics

Technical University Twente

P.O. Box 217

7500 AE Enschede

The Netherlands

An Introduction to ASCEND: Its Language and Interactive Environment

Recently there has been a growing realization among researchers and practitioners that current technologies do not adequately support mathematical modeling "in the large". In this paper, we discuss a technology called ASCEND, which addresses this issue. We describe two aspects of the technology: a modeling language and an interactive modeling environment. The ASCEND language is structured, declarative, and strongly typed, and incorporates object-oriented extensions. The interactive environment is based on the notion of a concurrent set of tools which reflect the various phases of ASCEND modeling. These tools do not enforce a strict sequence of operations, but rather have been designed to support the flexible access implied by declaratively specified models. Algebraic equational models are the current class of the models that can be specified and worked with in ASCEND

Ramayya Krishnan,
Peter Piela,
Arthur Westerberg
Carnegie Mellon University,
Pittsburgh, PA 15213

Design/Analysis Process Integration for Shape Optimization of Mechanical Parts

Shape Optimization is becoming an increasingly important aspect of the design automation process. Shape optimization requires the ability to define and iteratively control the shape of a part, as the part evolves from some initial state to a converged solution. Both finite element based and geometry based approaches have been used for formulating and controlling this class of problems. The development of automatic mesh generators, that are capable of producing a valid finite element mesh in a complex domain, have made fairly large changes in the part's shape possible. In addition, the use of approximation concepts during the iterative design process have made shape optimization of large scale 3-D structures possible in a practical design environment.

Srinivas Kodiyalam
Solid Mechanics Program
General Electric Company
Building K-1, Room 2A25
P.O. box 8
Schenectady, NY 12301

Conjugate Directions Methods for Large-Scale Optimization

Large-scale NLP problems require enormous calculations. Most existing methods are not suitable for such problems. Following the approach for large-scale unconstrained problems, a concept of constrained conjugate directions is presented. Starting with a quadratic problem having equality constraints, the constrained conjugate directions method is developed, proving its finite convergence and other properties. The method is then extended for general nonlinear problems. Descent function, restart procedure, and step size determination are discussed. The method is evaluated using some 150 NLP problems of varying difficulty and dimensions. The new method solves most of the problems, thus the basic concept of the method is validated. For a large-scale structural optimization problem, the method is more efficient than the SQP method, by a factor of 3 in one case.

Jasbir S. Arora, Professor
Guangyao Li, Graduate Research Assistant
OPTIMAL DESIGN LABORATORY
College of Engineering
The University of Iowa
Iowa City, Iowa 52242

Optimization Methods in Curve and Surface Design

Modern CAD systems often provide the capability for engineers to modify designs by changing design parameters without providing clues as to how these parameters should be modified. Optimization methods allow quantifiable design objectives to guide the modification of these parameters. Examples of design objectives include maximizing part strength, minimizing part weight, and minimizing manufacturing cost. Quantitative objectives allow the computer to perform the tedious iterative adjustments of design parameters which have traditionally been carried out iteratively at CAD terminals. This talk will explore some of the optimization techniques which can be used to produce better designs while significantly reducing the cost of producing them.

Thomas A. Grandine
The Boeing Company
P.O. Box 24346, MS 7L-21
Seattle, WA 98124

Data-Parallel Optimal Shape Design of Airfoils

The emergence of scalable, massively parallel computers has made it possible to solve some practical shape optimization problems, such as optimum wing design, and to envision the optimal design of a complete aircraft within the coming decade. Here, we describe data-parallel algorithms and data structures for a class of nonlinearly-constrained optimal shape design problems. We also describe an implementation on the Connection Machine CM-200 of a shape optimization methodology for airfoil design, using the full-potential approximation of the Navier-Stokes equations for flow simulation.

Omar N. Ghattas
Carlos E. Orozco
Carnegie Mellon University, Pittsburgh, PA

Computational Issues in the Interior Point Methods

Interior point methods used to solve linear programming problems are investigated. Specific computational issues are discussed using five netlib problems. A primal-dual projective algorithm (solved by both the Big M and the Two Phase Methods), an affine-scaling algorithm, and a path-following algorithm are investigated and compared.

Geraldine M. Hemmer
Department of Mathematics
Northeastern Illinois University
5500 N. St. Louis Ave.
Chicago, IL 60625-4699

More on Dual Ellipsoids and Degeneracy in Interior Algorithms for Linear Programming

We consider the problem of constructing ellipsoids, to allow the elimination of non-binding constraints, in a dual potential reduction algorithm for linear programming. When the problem being solved is nondegenerate, such a procedure is certain to eventually identify exactly which constraints are active at the solution. However, performance of the basic procedure on even mildly degenerate problems has been disappointing. In this talk we present a new strategy for strengthening the ellipsoid construction, and report results of the new method on problems with varying degrees of degeneracy.

Kurt M. Anstreicher and Jun Ji
Dept. of Management Science
University of Iowa
Iowa City, Iowa 52242

A Long-Step Inverse Barrier Hybrid Algorithm For Linear Programming.

The algorithm's direction is a weighted combination of the dual affine scaling (DAS) direction and a quasi-Newton inverse-barrier centering direction that unlike the Newton and the pure DAS directions behaves properly near the boundary. A long step to the boundary is thus possible. The weights forming the combination are obtained by a 2-variable dual simplex planar search making the algorithm a hybrid simplex-interior point algorithm. The algorithm retains DAS's long-step ascent property while eliminating its hugging-the-boundary weakness. Computational results are presented.

Alexander Hipolito
Department of Industrial and Systems Engineering
303 Weil Hall
University of Florida
Gainesville, FL 32611

Decomposition in LP based on Modified Barrier Function

We consider two approaches which are based on the Modified Barrier Function (MBF) for the decomposition of a block-diagonal linear programming problem

The first approach is applied to LP with inequality linking constraints. Using the MBF we remove the linking constraints. Then we find the minimum of the MBF under the remaining constraints for a fixed penalty parameter and fixed Lagrange multipliers This minimizer is used to update the Lagrange multipliers for the linking constraints We show that this method has a linear rate of convergence whenever the primal problem has a unique solution

To find the minimum of the MBF we use methods which decompose the problem and enable us to solve the subproblems for every block in parallel

The second approach we apply to linear programs with equality constraints and non-negative variables Again the MBF is used to remove the non-negativities and using the MBF minimum under linear constraints, we update the residuals for the dual problem. This method also converges with a linear rate of convergence if the primal problem has a unique solution.

The numerical realization of this method leads to the Newton method. To find the Newton direction one has to solve the normal system of equations which in this case can be decomposed because of the block-diagonal structure of the LP.

D. Jensen and R. Polyak
IBM T.J. Watson Research Center

Finding Optimal Orthotropic Composites

Many composite materials which appear in nature may be considered orthotropic. The elastic behaviour of these composites under shear stresses is characterized by three independent shear moduli. We consider the totality of orthotropic composites made from two isotropic linearly elastic components in fixed proportion. For a prescribed triple of shear stresses we provide a method for finding the strongest orthotropic composite. Since the constraint set turns out to be the convex hull of a surface, and since many algorithms for computing such convex hulls yield linear approximations instead, the problem is solved as one over a large number of linear constraints.

Rob Lipton
Department of Mathematical Sciences
Worcester Polytechnic Institute
Worcester, MA 01609
lipton@wpi.wpi.edu

Jim Northrup
Department of Mathematics and Computer Science
Colby College
Waterville, ME 04901
jinorthr@colby.edu
(207) 877-7249

Using Barrier Methods for Solving Large-scale Crystallographic Problems

A central problem of X-ray crystallography is to determine a set of phases corresponding to experimentally measured X-ray intensities. This problem can be formulated as a large-scale nonlinear program. Even small problems in this class can have more than 5,000 variables. Evaluation of the objective function and gradient involves three dimensional Fourier transforms, and the Hessian matrix is both dense and generally indefinite. The nonlinear programs are solved using a barrier approach, with a truncated-Newton method to solve the subproblems.

Paul B. Anderson
PRC Inc.
1500 Planning Research Drive
McLean, VA 22102

Stephen Nash and Ariela Sofer
ORAS Department
George Mason University
Fairfax, VA 22030

Optimal Design of Trusses by Smooth and Nonsmooth Methods

The talk will describe methods for optimal design of trusses (bridges, towers, etc.). These problems give rise to models which are large scale and often nonconvex. In important special cases, we derive equivalent formulations which are dramatically simpler (quadratic, or even linear programs). Often the equivalent problems are convex but nonsmooth. We report on the performance of several nonsmooth methods in solving these truss design problems.

Aharon Ben-Tal
Faculty of Industrial Engineering and Management
Technion - Israel Institute of Technology
Haifa 32000, Israel

On-line Optimal Control of a Large-Scale Water System

The paper describes an application of mathematical programming and network flow theory to the otpimal control of the Barcelona water system. The importance of the application lies in its reduction of the operation costs, mainly related to the treatment and pumping operations from the rivers to different elevations in the city, and the maintenance of a good quality of service to the users of the network.

The problem presents high dimensionality, constraints on states and controls and a nonlinear performance index, so that conventional dynamic programming techniques are not appropriate. The adopted method caters for these problems successfully and has been implemented in programmes for on-line operation in the Barcelona telecontrol system.

R. Griñó, G. Cembrano
Institut de Cibernètica (UPC - CSIC)
Diagonal 647, planta 2
08028 Barcelona
SPAIN

A continuation method for linear L1 estimation

The talk concerns the problem of minimizing a finite sum of absolute values of linear functionals. This non-differentiable problem is equivalent to the linear programming problem. The proposed method is based on exact smoothing of the objective and applying Newton type methods to a sequence smooth problems. After a finite number of smooth problems the L1 solution is detected. Extensive testing indicates that the method is superior to simplex type methods for large scale problems.With 1000 variables the new method is faster by a factor of 10 - 20 on the problems tested.

Kaj Madsen
Hans Bruun Nielsen
Institute for Numerical Analysis
The Technical University of Denmark
DK-2800 Lyngby, Denmark

AN ALGORITHM FOR NON-NEGATIVE LEAST ERROR MINIMAL NORM SOLUTIONS

In this paper we consider non-negative solutions of a system of m linear equations in n unknowns which minimize the residual error when the m dim. space is equipped with a strictly convex norm. Out of these solutions we seek the one which is of least norm when the n dim. space is equipped with a strictly convex and smooth norm. The algorithm we give is globally convergent and it does not require that a non-negative minimal error solution be found first. As a special case, we test the algorithm for the lp-norms ($1<p<\infty$). The algorithm was implemented in Fortran.

Panagiotis Nikolopoulos
and
Christos Nikolopoulos

Dept. of Computer Science
BRADLEY UNIVERSITY
Peoria, Illinois 61625

On the sensitivity of paired comparisons

When using an interactive system for a curve fitting problem, the user specifies a set of one-dimensional data and a model whose parameters are to be chosen to best fit the data. In the problem of tailoring a curve with interactive graphics the user is asked to make a choice of best fit among different computed fits. This process is repeated to achieve a set of paired comparisons. It is assumed that the user has qualitative information that should be incorporated into the fit. In this talk we show how to use this information i.e. the paired comparisons, to estimate the sensitivity of the data. This information is displayed grahically and used by the user to find out how he weights the data.

Trond Steihaug and Lars-Magnus Nordeide
University of Bergen
Department of Informatics
Høyteknologisenteret
N-5020 BERGEN NORWAY

Shape Matching via Piecewise Linear Approximation

The shape matching problem is concerned with fitting an input shape, represented by a set of discrete boundary data, to a defect-free shape. The proposed optimal approach is to minimize the Euclidean error norm of the boundary data with respect to the model shape. The analysis of polygonal objects is particularly important to automated inspection due to the large number of production parts with this type of profile. It is especially crucial to many machine vision applications, because an arbitrary shape can always be approximated by a polygon. This presentation will include two shape representation schemes, the matching procedure, and some computational results.

Jose A. Ventura and Jen Ming Chen
Department of Industrial and Management Systems Engineering,
The Pennsylvania State University
207 Hammond Bldg, University Park,
PA 16802

Numerical experiments with an interior point method for large sparse convex quadratic programming.

For theoretical and practical reasons, quadratic programming problems (QP) have attracted the interest of the mathematical programming community. In particular, interior point-like algorithms have been extended to deal with QP problems due to their relative success for solving large-scale LP problems in polynomial time. In this work we will present an implementation of the interior point algorithm proposed by Goldfarb and Liu [1]. The algorithm is based on the logarithmic barrier function method. It requires the solution of an equality constrained strictly convex quadratic problem at each Newton iteration. The implementation relies on the iterative solution of the Kuhn–Tucker equations associated with this problem with a preconditioned conjugate gradient–like method. We present a numerical comparison on a set of non-trivial strictly convex problems.

J.L. Morales-Pérez and R.W.H. Sargent.
Centre for Process Systems Engineering. Imperial College.
U.K.

A New Modified Newton Method for Large-Scale Quadratic Programming

We describe a new efficient method to solve general large-scale quadratic programming problems. In theory the method is globally and superlinearly convergent and in practice the method is efficient and robust. The method is applicable to both positive-definite and indefinite QP's. We discuss the ideas behind the algorithm and the theoretical results and will present numerical results.

Thomas F. Coleman, Computer Science Department, Cornell University, Upson Hall, Ithaca, New York, 14853

Jianguo Liu, Department of Applied Mathematics, Cornell University, Sage Hall, Ithaca, New York, 14853

A Robust Algorithm for Special Quadratic Programming

To develop a robust trust region algorithm for nonlinear programming, one needs an efficient, reliable algorithm for equality constrained quadratic programming (QP). In the context of nonlinear programming, the quadratic programming algorithm not only must be able to compute the solution to the QP if it has a unique solution, but it must be able to handle lack of second-order sufficiency in the QP. Thus, the algorithm must find a good descent direction of zero or negative curvature when the quadratic objective function is unbounded below on the feasible set. If the QP has an infinite number of solutions, then the algorithm will calculate the shortest of these. We use the Bunch-Parlett decomposition and shifted Power iterations to reach all the goals mentioned above. This approach is much (more than 20 times) cheaper than the eigen-decomposition approach. Also, it is easy to exploit parallelism by using this approach. Our numerical results show that both the sequential version and the parallel version of this algorithm are quite efficient.

Guangye Li
John E. Dennis, and Karen A. Williamson
CRPC and Dept. of Mathematical Sciences, Rice University

Implementation of a Schur-Complement Method for Large-Scale Quadratic Programming

Many engineering applications lead to large and sparse numerical optimization problems. These applications include data fitting, trajectory optimization and optimal design for fluid dynamics.

One of the most successful methods for solving numerical optimization problems is sequential quadratic programming. This talk focuses on quadratic programming which constitutes the inner-loop of this optimization method.

In particular, this talk describes implementation of a quadratic programming method based on a sparse symmetric matrix factorization and use of its Schur complement. A factorization of the Schur complement is updated to account for changes in the active set of constraints.

Theoretical aspects of the method, such as the posedness of successive equality constrained problems, will be considered. In addition, the problem of obtaining a feasible point will be examined. Test results on "real-world" engineering problems will be presented along with proposed extensions to the current work.

Paul Frank and John Betts
Boeing Computer Services
Seattle, WA

Proximal Minimizations with D-functions and the Massively Parallel Solution of Stochastic Networks

We will present algorithms for the solution of LINEAR stochastic network problems on massively parallel computers. The algorithms combine primal-dual, row-action algorithms with the proximal minimization with D-functions. Numerical results and comparisons with epsilon-relaxation algorithms will be reported.

Stavros A. Zenios
Soren S. Nielsen
Decision Sciences Department
The Wharton School
University of Pennsylvania
Philadelphia, PA 19104

The DIMACS Challenge: A Cooperative Experimental Study of Network Flow and Matching Algorithms.

Between November 1990 and October 1991, the center for Discrete Mathematics and Theoretical Computer Science (DIMACS) sponsored a cooperative "algorithm implementation contest" among members of the research community. Participants implemented algorithms for Maximum Flows, Min-cost Flows, Assignment, and (nonbiparitie) Matching problems, and performed experimental studies of algorithmic performance. A DIMACs group provided standard problem definitions and input formats, and suggested tests of the algorithms. The results of the project were presented at a workshop in October 1991. Several programs, instance generators, and related files are available from DIMACS through anonymous ftp.

Catherine C. McGeoch
Department of Mathematics
Amherst College
Amherst, MA 01002

Finding the Minimum Cut in a Network.

We consider the problem of finding the minimum capacity cut in a network G with n nodes. This problem has applications to network reliability and survivability and is useful in subroutines for other network optimization problems. One can use a maximum flow problem to find a minimum cut separating a designated source node s from a designated sink node t, and by varying the sink node one can find a minimum cut in G as a sequence of at most n maximum flow problems. We then show how to reduce the running time of these n maximum flow algorithms to the running time for solving a single maximum flow problem.

Jianxiu Hao
GTE Laboratories Incorporated
40 Sylvan Road
Waltham, MA 02254

James B. Orlin
MIT Sloan School of Management
Cambridge, MA 02139

Diagnosing Infeasibilities in Network Flow Problems.

In the case that there is no feasible flow for a minimum cost network flow model, the modeler may want to diagnose the source of the infeasibility and correct it if possible. A "proof of infeasibility" (or violating set) is a set S of nodes whose net supply exceeds the net capacity of arcs leaving S. In general, there may be a large number of different violating sets. We give procedures for finding violating sets with certain desirable properties including the following: (1) the set with the most infeasibility, (2) the set with the most infeasibility per node, and (3) violating sets S that are minimal, i.e., no proper subset of S is violating.

Jianxiu Hao
GTE Laboratories Incorporated
40 Sylvan Road
Waltham, MA 02254

James B. Orlin
MIT Sloan School of Management
E53-357
Cambridge, MA 02139

An Introduction to Protein Folding—The Second Half of the Genetic Code

The protein folding problems—how a linear string of amino acids codes for a precisely folded three-dimensional molecular structure—is one of the key contemporary problems in biophysics and biotechnology. Its solution would have enormous impact on medicine and technology, opening the door for "designer" materials and tailored drugs.

This talk will provide an overview for the following talks on optimization. The basic structural units of proteins will be defined, the hierarchy of assembly will be described, and the current status of the protein folding problem will be placed in a global framework.

Lynn W. Jelinski
Biotechnology Program, Cornell University, Ithaca, NY

Use of Constraints and Other Approaches to Protein Folding

Protein folding problems can be arbitrarily large; they are highly nonlinear and have many local minima. They exhibit dynamic near-sparsity: many terms in the energy function only matter when the affected atoms are close together. We discuss the structure of the problem and describe some approaches to solving it. In particular, temporarily imposing suitable constraints appears sometimes to be helpful.

David M. Gay
Margaret H. Wright
AT&T Bell Laboratories, Murray Hill, NJ

Renormalization Group and the Protein Folding Problem

We will present an overview of general global optimization techniques which may be applicable to the protein folding problem. In particular, we will describe the application of renormalization group methods, which have been successful in other difficult problems in statistical physics, in this context. This approach can be used to provide a novel, deterministic computational annealing procedure that should be applicable to a variety of global minimization problems with partially-separable objective functions.

Panos M. Pardalos
University of Florida, Gainesville, FL
David Shalloway
Cornell University, Ithaca, NY

A New Computational Approach to the Protein Folding Problem

Protein folding problems can be expressed as optimization problems. Unfortunately, the optimization formulation usually requires a global minimizer of a nonlinear function of many variables - a very difficult problem. In this talk, we discuss a new approach to this problem emphasizing computational issues, including the use of parallelism. Preliminary computational results will be presented.

Thomas F. Coleman, Computer Science Department,
Cornell University, Upson Hall, Ithaca,
New York, 14853

D. Shalloway, Department of Biochemistry,
Cornell University, Biotechnology Building,
Ithaca, New York, 14853

Zhijun Wu, Advanced Computing Research Institute,
Cornell University, Engineering and Theory
Center Building, Ithaca, New York, 14853

Some Saddle-Function Splitting Methods for Convex Programming

By applying operator splittings to the saddle-point formulation of convex programs, one can derive some new optimization methods, including an alternating direction version of Rockafeller's proximal method of multipliers (PMOM). In general, the algorithms contain primal proximal terms, multipliers, and quadratic penalties, but exhibit separability absent in the PMOM. Preliminary computational results are reported.

Jonathan Eckstein
Mathematical Sciences Research
Thinking Machines Corporation
245 First Street
Cambridge, MA 02142

Monotone Operator Splitting and Linear Complementarity

We apply various splittings to an operator associated with the monotone linear complementarity problem without a symmetry assumption on the underlying matrix M. Conditions for convergence are given and preliminary computational experience on the Connection machine will be outlined.

Jonathan Eckstein
Mathematical Sciences Research
Thinking Machines Corporation
245 First Street
Cambridge, MA 02142

Michael C. Ferris
Computer Sciences Department
University of Wisconsin
1210 West Dayton St.
Madison, WI 53706

Splitting Methods for Symmetric Affine Variational Inequality Problems, With Application to Extended Linear-Quadratic Programming

We show how, under a semi-quadratic assumption, an extended linear-quadratic programming problem can be converted into a symmetric affine variational inequality problem. This reformulation provides the basic framework for the potential application of a host of matrix splitting methods, exact or inexact, for solving the extended linear-quadratic program.

Jong-Shi Pang
Department of Mathematical Sciences
Johns Hopkins University
Baltimore, MD 21218-2689

Forward-Backward Splitting in Large-Scale Optimization

Among splitting methods for large-scale optimization, the forward-backward algorithm holds special potential because it requires backward steps on only one of the component mappings. It can be used to solve saddle point problems, in which the Lagrangian is the sum of two expressions, one of which is highly separable while the other is far from separable. Such problems cover a wide range of models in dynamic and stochastic optimization. For these, forward-backward splitting leads to decomposition into separate subproblems to be solved in each time period. New convergence results support the viability of such an approach.

George H.-G. Chen
Department of Applied Mathematics
University of Washington
Seattle, WA 98195

R. Tyrrell Rockafellar
Dept. of Math./Dept. of Applied Mathematics
University of Washington
Seattle, WA 98195

Line-search Techniques for Quasi-Newton Methods in Equality Constrained Optimization

Quasi-Newton methods with line-searches are not easy to implement in equality constrained optimization. The nice combination of the BFGS formula and the Wolfe line-search cannot be readily extended because of the difficulty in realizing the positivity of $\gamma_k^T\delta_k$, where γ_k is the change of some gradient and δ_k is some corresponding step.

It is known that this extension can be done when only the projected Hessian of the Lagrangian is updated. A way of realizing this consists in modifying the search path at the step-size trials where the Wolfe condition is not satisfied. The path becomes piecewise linear and, *asymptotically*, only one evaluation of the reduced gradient is necessary per iteration.

We will present further theoretical results on this subject, including a discussion on the connection between the line-search method and the update criterion, which determines when an update is appropriate. We will also present numerical experiments comparing different implementations with the SQP method.

Jean Charles GILBERT, INRIA – Rocquencourt
BP 105, 78153 Le Chesnay Cedex, France.

A Penalty Function Approach to the General Bilevel Problem

The bilevel programming problem is a two level mathematical program:

$$
\begin{array}{ll}
\min\limits_{x,y} & F(x,y) \\
\text{s.t.} & G_i(x,y) \geq 0, \quad \forall i \in R = \{1,\cdots,r\}, \\
& y \text{ solves} \\
& \qquad \begin{array}{ll} \min\limits_{y} & f(x,y) \\ \text{s.t.} & g_i(x,y) \geq 0, \quad \forall i \in P = \{1,\cdots,p\}. \end{array}
\end{array}
$$

We propose solving the problem by replacing the inner problem by the Kuhn-Tucker first order necessary optimality conditions and then solving the resulting single level problem by an exact penalty function technique. We will present both theoretical and preliminary numerical results, as well as discussing some of the difficulties and advantages of such an approach.

Paul H. Calamai
Department of Systems Design Engineering
University of Waterloo
phcalamai@dial.waterloo.edu Lori M. Case
Department of Computer Science
University of Waterloo
lmcase@neumann.waterloo.edu
Andrew R. Conn
T. J. Watson Research Center
P. O. Box 218, Yorktown Heights, N. Y. 10598
arconn@watson.ibm.com

A Trust Region Method for Nonlinear Optimization Problems

In this paper, we consider the optimization problem with nonlinear equality constraints

$$
\begin{array}{ll}
\min & f(x) \\
\text{s.t.} & c(x) = 0
\end{array}
$$

where $f(x) : \Re^n \rightarrow \Re^1$ and $c(x) : \Re^n \rightarrow \Re^m, m \leq n$. The usual Newton or quasi-Newton method has to deal with a full Hessian which is an $n \times n$ matrix. Therefore, it is not suitable for solving large problems. Here we suggest a reduced Hessian algorithm with a double dogleg method to solve the trust region subproblem approximately. The detail of the algorithm will be discussed and test results from different sets of problems will also be presented.

Yuan-An Fan
IMSL, Inc., 2500 Permian Tower, 2500 CityWest Blvd.,
Houston, TX 77042
Jianzhong Zhang
Department of Mathematics, City Polytechnic of Hong Kong,
Tat Chee Avenue, Kowloon, Hong Kong
Detong Zhu
Department of Mathematics, Shanghai Normal University,
200234, Shanghai, China

The Value Function in Hierarchical Optimization

We consider the properties of the value function of perturbed hierarchical, two-level, optimization problem. The properties of the value function are one measure of the stability of an optimization problem. We show that Lipschitz type properties of the argmin multifunction for the lower level problem translate to Lipschitz properties of the value function for the whole problem. This, combined with nonsmooth analysis, may be used to derive optimality conditions for hierarchical optimization problems. The conditions required for this work and their implications for the study of the argmin of the whole hierarchical optimization problem will be discussed.

Jay S. Treiman
Western Michigan University, Kalamazoo, MI
Roxin Zhang
Northern Michigan University, Marquette, MI

Parallel Implementation of Truncated Newton Methods

We describe the parallel implementation of a class of truncated Newton methods for the solution of large-scale unconstrained optimization problems. These methods are of particular interest in computations where analytic derivatives are available, such as potential energy minimization for large molecules, or neural network training. The methods are characterized by a) approximate solution of the Newton equation by Krylov subspace methods, with a truncation criterion based on norm of the residual, and b) approximation of the required Hessian-gradient products by gradient differences. Computational results are presented for solution of a neural network problem on an Intel iPSC/860 MIMD parallel supercomputer.

Robert H. Leary
San Diego Supercomputer Center
P. O. Box 85608
San Diego, CA 92186

Vector Performance Criteria in Unconstrained Optimization

We are concerned with globalization techniques for unconstrained minimization algorithms.

Current methods for ensuring global convergence are based on the enforcement of a monotonic decrease of the objective function values. It is known that this requirement may cause severe inefficiencies in the minimization of highly nonlinear functions. To overcome this difficulty, some nonmonotone algorithms have been proposed.

In this work we present a more general theory of global convergence based on the introduction of a vector performance criterion and we relate this approach to the use of vector Lyapunov functions in the stability analysis of dynamical systems.

Luigi Grippo
Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", via Eudossiana 18, 00184 Roma, Italy

Francesco Lampariello, Stefano Lucidi
Istituto di Analisi dei Sistemi ed Informatica del CNR, Viale Manzoni 30, 00185 Roma, Italy

Implementing a Parallel Asynchronous Newton Method on a Distributed Memory Architecture

A parallel asynchronous version of the Newton method for solving nonlinear optimization problems has been developed. In particular, a hierarchical parallel scheme, whereby multiple processors are used within each tasks, has been proposed. The aim is to investigate the parallel asynchronous behavior of the Newton method for the solution of large scale unconstrained optimization problems on a distributed memory parallel computing environment, to experimentally give evidence of the possible benefits and drawbacks of the asynchronous idea. A set of test problems, with different characteristics, has been used to carry out the numerical experiments, with the aim of evaluating and assessing the behavior of the parallel algorithm when faced with several kind of problems. The results demonstrate the efficiency of the asynchronous parallel implementation.

Domenico Conforti, Lucio Grandinetti, Roberto Musmanno

Dept. di Elettronica, Informatica e Sistemistica (D.E.I.S.),
Università della Calabria
87036 Rende-Cosenza, Italy

Modifying the BFGS Update by Column Scaling Techniques

We consider variable metric algorithms that use an approximation B to the second derivative matrix in order to calculate the search direction. Specifically, we work with the decomposition $ZZ^T = B^{-1}$. Many researchers have studied modifications of the BFGS update that apply scaling techniques to the columns of the matrix Z. The author has suggested a scaling algorithm that preserves global and superlinear convergence and outperforms the unmodified BFGS update on a range of ill-conditioned test problems. New research in the field including an extension of the new method to large-scale problems is presented.

Dirk Siegel
Department of Applied Mathematics and Theoretical Physics
University of Cambridge
Silver Street
Cambridge CB3 9EW
England

The Global Convergence of a Class of Primal Potential Reduction Algorithms for Convex Programming

We describe the global convergence of a class of interior point primal potential reduction algorithms for the linearly constrained convex programming problem. Interior point algorithms for convex programming have been presented which require that the functions involved satisfy an unusual Lipschitz condition. Our algorithm is the first potential algorithm which does not impose any such condition. The directions used by our class of algorithms are sufficiently general so as to include as special case several directions that have been used in the literature in the context of LP problems.

Renato D. C. Monteiro
Systems and Industrial Engineering Department
University of Arizona
Tucson, AZ 85721

On the Affine Trust Region Interior Point Algorithm for Quadratic Programming

The subject of this talk is the theorical and numerical study of the algorithm for quadratic programming with trust region and affine scaling. We show that, under mild hypotheses, the algorithm converges towards a point satifying the first-order optimality conditions, and give an estimate of the asymptotic rate of convergence. Our hypotheses are 1)the linear independence of gradients of active constraints and 2)that the quadratic problems where all positivity conditions are deleted or converted to equalities have at most one solution. We discuss the numerical implementation and give numerical results that indicate a good behavior for a number of test problems.

M. Bouhtou and F. Bonnans
INRIA, BP105, 78153 Rocquencourt,France

Algorithms for the Convex Inequalities Problem

Let f_i, $i=1,2,\ldots,m$, be twice continuously differentiable convex functions. Let $G = \{g \mid \{x \mid f(x) \leq g\} \neq \phi\}$. Then there exists a unique $\hat{g}$ in the closure of G, such that $\|\hat{g}\|_2 = \inf\{\|g\|_2 \mid g \in G\}$. We develop a globally convergent algorithm that generates sequences $\{x^k\}$ and $\{g^k\}$ such that $f(x^k) \leq g^k$ and g^k converges to $\hat{g}$ under the minimal assumption that the set $\{x \mid f(x) \leq \hat{g}\}$ is non-empty.

As a special case, when $\hat{g}=0$, any accumulation point of the sequence $\{x^k\}$ belongs to the set $\{x|f(x) \leq 0\}$.

Motakuri Venkata Ramana and Shih-Ping Han
Department of Mathematical Sciences
The Johns Hopkins University
Baltimore, MD 21218-2689, USA

Experimentation with the Interior Cutting Plane Method (ICPM)

The interior point cutting plane method essentially applies to convex programming. It deals with a linear relaxation of the original problem. The relaxation is made of supporting and separating hyperplanes which are sequentially generated by a so-called oracle. The ICPM strives to follow the central path of the current linear relaxation, but the path is modified by the introduction of new cutting planes. This strategy makes it possible to solve a convex programming problem by generating only a few cutting planes.

The method has been subjected to rather extensive testing on a variety of problems, ranging from geometric programming, to standard nondifferentiable programs and to the decomposition of linear programming problems. It has been found robust and reliable. We shall discuss various implementation issues and we shall present the results of our experimentations.

J.-L. Goffin
Faculty of Management
McGill University
1001 Sherbrooke St. West
Montreal, P.Que., H3A 1G5, Canada

J-P. Vial
Département d'économie commerciale et industrielle
Université de Genève
2 rue de Candolle
CH-1211 Genève 4, Switzerland

Optimization Methods for Elliptic Systems

Systems of semilinear elliptic partial integro-differential equations arise in the study of competitive systems, optimal damping, and semiconductor modeling. These systems may be transformed to compact fixed point problems by premultiplying by the inverse of the highest order term, typically a Helmholtz operator. The resulting problems can often be attacked with conventional Newton-like methods, such as Broyden's method or the chord method, if a good preconditioner can be found. The search for such preconditioners is made complicated in many applications by large convection terms and/or nonsmooth nonlinearities. In this presentation I will discuss some of the issues that arise in construction of preconditioners and proofs of superlinear convergence.

C. T. Kelley
North Carolina State University, Raleigh, NC

Numerical Methods for Nonlinear Parabolic Control Problems

Many optimal control problems with partial differential equations described by evolution processes occuring e.g. in heat conduction can be reformulated as optimization problems. Often the constraints and the objective functional in the optimization formulation exhibit a special structure which can be used for the design of fast numerical algorithms. Also the choice of function spaces is an issue which influences the results on the convergence for the numerical methods. We discuss some of these features for Sequential Quadratic Programming and related methods. We present numerical results for some nonlinear boundary control problems.

F.-S. Kupfer and E. W. Sachs
Universität Trier
FB IV - Mathematik
Postfach 3825
W-5500 Trier
Germany

Parallel Optimization in Groundwater, and Petroleum Resources Management

A number of optimization problems arise in the management of groundwater and petroleum resources. The dominant computational expense in these NLP is the solution of the p.d.e. that describe flow in porous media. We will describe an approach to such problems that integrates domain decomposition methods with NLP algorithms, thereby exploiting computational parallelism.

Our idea is based on the observation that in the context of NLP, domain decomposition methods contain implicit constraints which should be made explicit in the NLP. We will discuss our approach for the case of a parameter identification problem from subsurface flow.

Robert Michael Lewis
Department of Mathematical Sciences
Rice University
Houston, Texas 77251-1892

Augmented Lagrangian and SQP Techniques for Nonlinear Illposed Inverse Problems

Augmented Lagrangian techniques are robust solvers for nonlinear illposed inverse problems combining the equation error and the output least squares techniques. Their convergence is analyzed and their numerical behaviour is compared for different norms in the observation space as well as between regularization in parameter and in output space. Reduced SQP-methods are then compared to the augmented Lagrangian technique both with respect to convergence rate and numerical behaviour. Finally second order update augmented Lagrangian techniques are described and compared to SQP methods. Numerical results are given on identifying interfaces from boundary measurements.

Karl Kunisch
Technische Universitat Graz
Institut fur Mathematik
Kopernikusgasse 24
Graz
AUSTRIA

Computational Comparison of Two Methods for Constrained Global Optimization

Computational results comparing two different linearly constrained concave global minimization algorithms, evaluated on the same set of test problems, will be presented. The first method is a stochastic approach which applies a pair of bayesian stopping rules involving the number of total local minima found and the fraction of the domain explored. The second method is a deterministic approach utilizing linear underestimators and sufficient condition tests.

J.B. Rosen
Computer Science Department
University of Minnesota
4-192 EE/CSci Building
200 Union Street S.E.
Minneapolis, MN 55455

A.T. Phillips
Computer Science Department
United States Naval Academy
572 Holloway Road
Annapolis, MD 21402-5002

TUESDAY PM

COMPUTATIONAL APPROACHES FOR SOLVING QUADRATIC ASSIGNMENT PROBLEMS

We will present heuristics and exact algorithms for solving the quadratic assignment problem (QAP). Computational results will be presented based on classical test problems available in the literature and problems generated by a new test problem generator. We will also discuss parallel algorithms for solving the QAP and present preliminary computational results.

Yong Li, Penn State University, Computer Science Dept., University Park, PA 16802

Panos M. Pardalos, University of Florida, Dept. of Industrial & Systems Engineering, Gainesville, FL 32611

An MILP Relaxed Dual Formulation For The GOP Algorithm

In Floudas and Visweswaren (1990), a new global optimization algorithm (GOP) was proposed for solving constrained nonconvex problems. The approach involves the decomposition of the original problem into primal and relaxed dual subproblems that are solved iteratively to converge to the global solution. In this paper, a new formulation of the relaxed dual problem, where binary variables are introduced to represent combinations of bounds of the x variables, is proposed. The reformulation enables the solution of all the relaxed dual problems at each iteration through a single mixed-integer linear programming (MILP) problem. The reformulated MILP approach is illustrated through a simple example and comparisons with the original algorithm are presented.

V. Visweswaran and C.A. Floudas and Brigitte Jaumard
Department of Chemical Engineering
Princeton University
Princeton, N.J. 08544-5263

Minimizing the Lennard-Jones Potential function on a Massively Parallel Computer

The Lennard-Jones potential energy function arises in the study of low-energy states of proteins and in the study of cluster statics. This paper presents a mathematical treatment of the potential function, deriving lower bounds as a function of the cluster size, in both two and three dimensional configurations. These results are applied to the minimization of a linear chain, or polymer, in two-dimensional space to illustrate the relationship between energy and cluster size. An algorithm is presented for finding the minimum-energy lattice structure in two dimensions. Computational results obtained on the CM-5, a massively parallel processor, support a mathematical proof showing an essentially linear relationship between minimum potential energy and the number of atoms in a cluster. Computational results for as many as 50000 atoms are presented. This largest case was solved on the CM-5 in approximately 40 minutes at an approximate rate of 1.1 gigaflops.

G.L. Xue, R.S. Maier

Army High Performance Computing Research Center
1100 South Washington Avenue
Minnesota Tech Center
Minneapolis, MN 55415

J.B. Rosen
Computer Science Department
University of Minnesota
200 Union Street S.E.
Minneapolis, MN 55455

The Functionality of ADIFOR

Library packages for optimization either expect the user to provide code for the Jacobians or the Hessians required by the optimization algorithm, approximate the required derivatives by finite differences, or else have gone to great length to develop derivative-free algorithms. However, given the code defining the objective function and the constraints, the techniques of automatic differentiation support the computer generation of code defining the derivatives using the chain rule. ADIFOR (Automatic Differentiation In FORtran) is a Fortran source-to-source translator. Given Fortran code for a function, ADIFOR employs the data analysis capabilities of the ParaScope Fortran programming environment to generate portable Fortran 77 code. The calling sequence for the ADIFOR-generated code is a straight-forward extension of the calling sequence for the original code. The generated code uses a hybrid combination of the forward and reverse modes of automatic differentiation to compute the derivatives. ADIFOR preserves the parallelization and vectorization already present in the code and extends the scope of possible further parallelization and vectorization.

George Corliss
Mathematics and Computer Science Division
Argonne National Laboratory

The Performance of ADIFOR codes

The ADIFOR project's goal is to provide exact (up to machine precision) derivatives of functions defined by Fortran programs as cheaply as possible. This talk outlines the implementation of ADIFOR and presents experimental results indicating that the time required for ADIFOR-generated codes to compute exact derivatives is quite competitive with divided differences on codes in which symbolic differentiation would almost certainly fail. We conclude that ADIFOR-generated derivatives are a more than suitable substitute for hand-coded or divided-difference derivatives, especially considering that the availability of exact derivatives may significantly increase the efficiency of codes in which good derivatives are critical to convergence.

Alan Carle
Center for Research on Parallel Computation
Rice University
P. O. Box 1892
Houston, TX 77251-1892

Automatic Differentiation in Nonlinear Programming and Parameter Identification

In this talk we will discuss how automatic differentiation makes feasible the solution of some ODE inverse problems. Our algorithms for estimating the parameters that appear in ordinary differential equation models are based on a nonlinear programming framework, and by incorporating the structure of the parameter identification problem into the optimization algorithm, the calculation of analytical derivatives required for the optimization becomes both tractable and cheap.

Alan Carle, John E. Dennis, Jr., Guangye Li and Karen A. Williamson
Center for Research on Parallel Computation
Rice University
P. O. Box 1892
Houston, TX 77251-1892

Experience with Various Automatic Differentiation Tools in Orthogonal Distance Regression

In this talk, we examine the effect of using Jacobian matrices obtained by automatic differentiation on the performance of the orthogonal distance regression package ODRPACK. Analyzing regression problems arising at NIST, we compare results obtained using Jacobian matrices generated by automatic differentiation tools such as ADIFOR with results obtained using a divided difference Jacobian. Several characteristics are considered, including the quality of the solution, the size of the resulting generated code, and the CPU time required to obtain the solution.

Janet E. Rogers
Applied and Computational Mathematics Division
National Institute of Standards and Technology
Boulder, Colorado 80303-3328

A Scaling Technique for Finding the Weighted Analytic Center of a Polytope

Let a bounded full dimensional polytope be defined by the system $Ax \geq b$ where A is an $m \times n$ matrix. Let a_i denote the ith row of the matrix A, and define the *weighted analytic center* of the polytope to be the point that minimizes the strictly convex barrier function $-\sum_{i=1}^{m} w_i \ln(a_i^T x - b_i)$. The proper selection of weights w_i can make any desired point in the interior of the polytope become the weighted analytic center. As a result, the weighted analytic center has applications in both linear and general convex programming. If some of the w_i's are much larger than others, then Newton's method for minimizing the resulting barrier function is very unstable and can be very slow. Previous methods for finding the weighted analytic center relied upon a rather direct application of Newton's method potentially resulting in very slow global convergence. We present an enhancement of Newton's method that is based on the scaling technique of Edmonds and Karp. The scaling algorithm runs in $O(\sqrt{m} \log W)$ iterations, where m is the number of constraints defining the polytope and W is the largest weight given on any constraint. The complexity of each iteration is dominated by the time needed to solve a system of linear equations.

David S. Atkinson
University of Illinois at Urbana-Champaign, Urbana, IL
Pravin M. Vaidya
University of Illinois at Urbana-Champaign, Urbana, IL

Adding and Deleting Constraints in a Path–Following Method for Linear Programming

We analyse the effect of shifting, adding and deleting respectively of a constraint on the position of the analytic center, the distance to the central path, and the value of the potential function. Based on the obtained results we are able to analyse a strategy for building up and down the linear program while using a path–following method. We will prove that in the worst case the complexity is the same as the complexity of the standard path–following method. In practice this build-up and -down scheme is likely to save much computational effort. The method starts with a (small) subset of the constraints, and follows the corresponding central path until the iterate is close to (or violates) one or more of the constraints. Then these constraint are added to the current system. On the other hand, when the current iterate is close to the central path, constraints which, in some sense, lie far from the iterate, are deleted. This process is repeated until we reach an optimal solution.

D. den Hertog
Delft University of Technology, Delft, The Netherlands
C. Roos
Delft University of Technology, Delft, The Netherlands
T. Terlaky
Delft University of Technology, Delft, The Netherlands

On the Convergence of Interior-Point Methods to the Center of the Solution Set in Linear Programming

The notion of the central path plays an important role in the convergence analysis of interior-point methods. Many interior-point algorithms have been developed based on the principle of following the central path, either closely or otherwise. However, whether such algorithms actually converge to the center of the solution set has remained an open question. In this paper, we demonstrate that under mild conditions, when the iteration sequence generated by a primal-dual interior-point method converges, it converges to the center of the solution set.

Yin Zhang
Department of Mathematics and Statistics
University of Maryland, Baltimore County
Baltimore, Maryland 21228

Richard A. Tapia
Department of Mathematical Sciences
Rice University
Houston, Texas 77251-1892

Interior-Exterior Augmented Lagrangian Approach for LP

We consider LP problems of the form

$$(1)\quad x^* = \operatorname{argmin}\{(p,x) \mid Ax = q,\ x \geq 0\} \text{ where } p, x \in \mathbf{R}^n, q \in \mathbf{R}^m, A : \mathbf{R}^n \to \mathbf{R}^m, m < n$$

We are treating the inequality constraints with the Modified Barrier function, which one can consider as the Interior Augmented Lagrangian, and the equality constraints with Classical Augmented Lagrangian terms. Let $k > 0$ be the penalty as well as the barrier parameter, $v \in \mathbf{R}^m$ be the vector of dual variables, $u \in \mathbf{R}^n$ be the vector of dual residuals, and $\Omega_k = \{x \mid Ax = q, x \geq -k^{-1}\}$ Our method is based on the properties of the function

$$(2)\quad F(x,v,u,k) = \begin{cases} (p,x) - (v, Ax - q) + \frac{k}{2}\|Ax - q\|^2 - \frac{1}{k}\sum_{i=1}^{n} u_i \ln(k x_i + 1) & x \in \operatorname{int}\Omega_k \\ \infty & x \notin \operatorname{int}\Omega_k \end{cases}$$

We start with an initial solution $x^0 \in \operatorname{int}\Omega_k$ $v^0 \in \mathbf{R}^m, u^0 = (1, 1, \ldots, 1) \in \mathbf{R}^n$. Suppose that x^s, v^s, u^s have already been found at step s, then we find the next approximation by the formulas

$$(3a)\quad x^{s+1} = \operatorname{argmin}\{F(x, u^s, v^s, k) \mid x \in \mathbf{R}^n\}$$

$$(3b)\quad u_i^{s+1} = u_i^s(k x_i^{s+1} + 1)^{-1},\ i = 1, \ldots, n$$

$$(3c)\quad v^{s+1} = v^s - k(Ax^{s+1} - q)$$

We prove the convergence of the sequence $\{x^s, u^s, v^s\}$ to the primal and dual solution and define the conditions under which method (3) has a linear rate of convergence

The numerical realization of method (3) leads to the Newton method for finding the approximation for x^{s+1} and updating u and v by (3b) and (3c)

Roman Polyak and Rina Schneur
IBM Thomas J. Watson Research Center
Department of Mathematics
P.O. Box 218
Yorktwon Heights, NY 10598

Nonclassical Gauss-Newton Methods

The classical Gauss-Newton method for nonlinear least squares may converge to a point that is not a stationary point if the sequence of Jacobians approaches a loss of rank. This talk introduces a new class of linesearch algorithms in which the search direction at each iteration is an unmodified Gauss-Newton direction, possibly different from the classical Gauss-Newton direction. Global convergence to a stationary point is a consequence of the fact that, in the worst case, the Gauss-Newton direction that is used is actually the steepest-descent direction.

C. Fraley
Statistical Sciences, Inc.
1700 Westlake Ave N, Suite 500
Seattle, WA 98109 USA
fraley@statsci.com

Department of Statistics, GN-22
University of Washington
Seattle, WA 98195 USA
fraley@stat.washington.edu

Finding the Global Minimum of Nonlinear Least Squares Using Real and Interval Arithmetic

We address the problem of finding the global minimum of a nonlinear least squares problem with box constraints (NLSB). These problems are currently solved by using software, either for local minimization of NLSB-problems or for global minimization of general box constrained problems. We combine real and interval arithmetic in using a stabilized

Gauss-Newton algorithm for local minimization and a revised interval analysis method for excluding subregions not containing local minima. The proposed algorithm is suitable for implementation on parallel computers of MIMD-type. Now a sequential implementation is discussed and compared to the interval analysis method.

Jerry Eriksson
University of Umeå , Umeå Sweden
Per Lindström
University of Umeå , Umeå Sweden

VARIATIONS OF STRUCTURED BROYDEN FAMILIES FOR NONLINEAR LEAST SQUARES PROBLEMS

We consider methods for finding a local solution to a nonlinear least squares problems. Among numerical methods, structured quasi-Newton methods seem very efficient. Recently, factorized versions of the structured quasi-Newton methods have been studied by Sheng Songbai and Zou Zhihong, and Yabe and Takahashi. In this presentation , we generalize the update of Sheng Songbai et al. and propose a new family corresponding to the Broyden family. Further the relationship between the factorized quasi-Newton family and the structured secant update from the convex class proposed by Martinez is suggested and some numerical experiments are shown.

Hiroshi Yabe

Faculty of Engineering
Science University of Tokyo
Tokyo, JAPAN

Relationship between Structured and Factorized quasi-Newton Methods for Nonlinear Least-Squares Problems

Recently, structured quasi-Newton methods for nonlinear least-squares problems have been studied by several researchers. These methods employ $J^TJ + A$ as an approximation of the Hessian matrix, and give updating formulae for A, for J can be steadily available, analytically or numerically. Their convergence theorems have been established based on the bounded deterioration theory.
On the other hand, we proposed factorized quasi-Newton methods in the viewpoint of preserving positive definiteness of the Hessian approximation. Specifically, the factored form, $(J + L)^T(J + L)$, was employed, and also their convergence theorems were given. However, in proving convergence theorems, our approach can be considered almost the same as that of structured quasi-Newton methods by regarding $J^TL + L^TJ + L^TL$ as A.
In this paper, following to this observation, we further discuss the relationship between structured and factorized quasi-Newton methods.

Toshihiko Takahashi
Infomation Processing Center
Kajima Corporation
2-7, Motoakasaka 1-Chome, Minato-ku,
Tokyo, 107, Japan

Hiroshi Yabe
Faculty of Engineering
Science University of Tokyo
1-3, Kagurazaka, Shinjuku-ku,
Tokyo, 162, Japan

An Interior Point Algorithm for Linear Complementarity Problems

Most current interior point methods for the linear complementarity problem can be classified as the potential reduction method and the path-following method. We propose a new approach which solves the corresponding quadratic programming problem directly, using the scaled projections of gradients of the objective function. Then we explore the polynomial-time convergence property of the new algorithms.

Jiu Ding
Department of Mathematics
Southern Station Box 5045
University of Southern Mississippi
Hattiesburg, MS 39406-5045

A Superlinearly Convergent $O(\sqrt{n}L)$-iteration Predictor-corrector algorithm for Linear Complementarity Problems

Ye, Tapia and Zhang proved that a version of Mizuno-Todd-Ye predictor-corrector algorithm for LP which solves the LP in at most $O(\sqrt{n}L)$ iterations has the property that locally the duality gap converges to zero Q-superlinearly. In this paper we extend the algorithm to a class of linear complementarity problems. The extended algorithm possesses the same global complexity and local superlinear convergence property.

Siming Huang
University of Iowa, Iowa city, IA
Jun Ji
Florian Potra
University of Iowa, Iowa City, IA

SOLUTION OF LARGE SCALE-MONOTONE LINEAR COMPLEMENTARITY PROBLEMS

The Linear Complementarity Problem (LCP) consists of finding vectors z and w in Rn such that

$$w = q + Mz, z \geq 0, w \geq 0, ztw = 0$$

where q in Rn and M in Rnxn are given. The LCP is said to be monotone if its matrix M is positive semi-definite. In this talk we discuss the most important direct and iterative algorithms for the solution of large-scale monotone LCPs, namely principal pivoting algorithms, damped-Newton and proximal-point procedures, interior-point methods and projected-gradient algorithms. A comparative study of the efficiencies of these algorithms which highlights the benefits and drawbacks of each one of the different methodologies.

Joao M. Patricio, Joaquim J. Judice
Departamento de Matematica, Universidade de Coimbra,
3000 Coimbra, Portugal

Luis M. Fernandes
Escola Superior de Tecnologia de Tomar,
2300 Tomar, Portugal

Undamped Newton Method for Solving Linear Complementarity Problems

Linear Complementarity Problems (LCP) arises in economic equilibrium and quadratic optimization problems; therefore many practical problems can be formulated as LCP. Actually, Newton Method is used for solving LCP, but a damped formulation, which requires the use of a stepsize procedure, has to be used in order to attain global convergence. It has been observed that this damped Newton method could become impractical when excessive Armijo-like stepsize procedures have to be performed at many iterations. We prove theoretically that global convergence is guaranteed even if no stepsize procedure is performed; that is, Newton's method solves the LCP globally and with a superlinear rate of convergence under conventional assumptions. Numerical experiments support the theory.

Ubaldo M. Garcia-Palomares
Universidad Simon Bolivar
Departamento de Procesos y Sistemas
Apartado 8900
Caracas, 1086. Venezuela

The Barzilai and Borwein Gradient Method for the Large Scale Unconstrained Minimization Problem

We consider the use of the Barzilai and Borwein gradient method for the solution of large scale unconstrained minimization problems. This method requires no line search and so, near the solution, it requires considerably less computational effort than any of the Conjugate Gradient methods.

We discuss the convergence properties of the method and present numerical results.

Marcos Raydan
Department of Mathematics
University of Kentucky
Lexington, KY 40506.

The Development of Parallel Nonlinear Optimization Algorithm for Chemical Process Design

This study investigated parallel nonlinear optimization for chemical process design. A sequential successive quadratic programming algorithm was developed with the BFGS inverse Hessian update. Algorithms using a parallel finite difference Hessian, Straeter's parallel variable metric update, and Freeman's projected parallel variable metric update were investigated. Schnabel's parallel partial speculative gradient evaluation technique was used to calculate the numerical gradient. Simultaneous function evaluations were performed for a parallel line search algorithm. Simultaneous minimizations were performed with the sequential BFGS algorithm for parallel global optimization. The success of these algorithms show potential for efficient minimization of design problems.

Karen A. High
School of Chemical Engineering
Oklahoma State University
Stillwater, Oklahoma 74078

Richard D. La Roche
Gray Research, Inc.
Gray Research Park
655 E. Lone Oak
Eagan, MN 55121

Unconstrained Minimization on Massively Parallel Computers

We describe recent experience with two computational models for massively parallel optimization on high-performance supercomputers, including the next-generation Connection Machine. The "single-problem" model employs fine-grain parallelism to solve large-scale problems. The "multi-problem" model employs large-grained parallelism to address global optimization problems. For the single-problem model, We present comparative results for the Truncated Newton (Nash) and the LM-BFGS (Nocedal and Liu) on a number of large-scale test problems. We discuss performance in terms of kernal speed, iterations, and code adaptability. For the multi-problem model, we present results for stochastic global optimization of several nonconvex test problems using standard algorithms for local search. We discuss performance in terms of speed, number of local searches, and convergence behavior of the local search routines.

Robert S. Maier and Guo-Liang Xue
Army High Performance Computing Research Center
University of Minnesota
Minneapolis, MN 55415 USA

On the Detection and Exploitation of Unknown Sparsity Structure in Nonlinear Optimization Problems

Given a known sparsity structure, dramatic computational improvements can typically be realized through the use of specialized linear algebra routines and/or the use of graph coloring algorithms to efficiently generate Hessian approximations. In practical applications, however, the true structure of a problem may not be obvious to the unsophisticated user, or may even be specified incorrectly. Another difficulty involves problems for which the sparsity structure changes during the iteration.

We investigate the consequences of errors in the assumed sparsity structure, and present an inexpensive algorithm for detecting significant errors. Global convergence is demonstrated in a trust region framework.

Richard G. Carter
AHPCRC, University of Minnesota

Fixed-Point Quasi-Newton Methods

We study iterative methods defined by

$$x_{k+1} = \phi(x_k, E_k),$$

where $x_k \in \mathbb{R}^n$ and E_k lies on a space of parameters. We establish sufficient conditions for local convergence and for convergence at an ideal linear or superlinear rate. We develop a theory of least-change secant update methods for this class of processes. Several examples are given showing a wide range of applications of the new theory.

José Mario Martínez
Dept. of Applied Mathematics
IMECC - UNICAMP
CP 6065 - 13081 Campinas SP
E-MAIL:MARTINEZ@BRUC.ANSP.BR

Data Analysis Techniques for Optimization Code Test Results

The comparison of test results for optimization codes involves fairly large sets of multivariate data. This poster presentation considers some of the presentation and analysis approches which have been used by different workers. These are compared to a variety of techniques recently developed or popularized in statistical research. The availability and ease of use of such methods are considered. The author will attempt to suggest some choices of techniques which require little effort or expenditure from the user but which elucidate important features of test result data.

John C. Nash,
Faculty of Administration,
University of Ottowa,
Ottowa, Ontario, K1N 6N5.

Efficient and Stable Computation of Quasi-Newton Updates

Quasi-Newton techniques are frequently used for the numerical solution of quadratic programming or linearly and nonlinearly constrained optimization problems. The key computational step of these techniques is the updating of a symmetric positive definite matrix after a symmetric rank two modification, involving an addition and a subtraction of dyads. Most current implementations rely on updating the Cholesky factor of this matrix using standard plane rotations. Some inefficiencies and numerical difficulties may arise mainly due to the subtraction operation.

The paper discusses efficient and stable quasi-Newton updates using modified Householder transformations and hyperbolic transformations.

Vasile Sima
Computer Process Control Laboratory
Research Institute for Informatics
71316 Bucharest, Romania

Efficient Parallel Minimization Algorithms in Computational Fluid Dynamics

Parallel computing in computational fluid dynamics has grown increasingly important in the last decade. In particular, parallel solution algorithms for discretization equations constitutes a major research field. This presentation concerns the implementation of Snyman's dynamic minimization algorithms as nonlinear solvers for systems of discretization equations in fluid flow and heat transfer. These particular algorithms evaluate only the gradient of the objective function and not the function itself, and are therefore efficient parallel algorithms. Different formulations of the minimization problem for this application, as well as numerical experiments to obtain the parallel efficiency of the minimization algorithms concerned, are presented.

E. de Klerk and J.A. Snyman
Department of Mechanical Engineering
University of Pretoria, Pretoria
Republic of South Africa

L. Pretorius
Department of Computer Science
University of South Africa
Pretoria
South Africa

A Flexible Elimination Method for Nonlinear Constrained Optimization

The authors propose a new elimination method for solving problems in the SQP framework. The theory has its roots in the Brown-Brent methods for nonlinear systems of equations. The practical motivation lies in the nature of many "real-life" problems, especially engineering problems where the constraints are given in the form of differential equations. Such problems, when discretized, are usually large and sparse and have a structure that can be exploited. The proposed method offers a flexible way to solve problems, given a particular structure. The constraints can be processed in groups, aggregated according to various criteria, such as minimum fill-in during solution, degree of non-linearity, or natural grouping. This flexibility makes it possible to solve problems of varying size, sparsity and structure with a single optimization code.

Natalia Alexandrov
John E. Dennis, Jr.
Department of Mathematical Sciences
Rice University, P.O. Box 1892
Houston, Tx 77251.

Local convergence analysis of the method of centers

In this talk, we investigate the asymptotic behavior of the method of centers when applied to the nonlinear program $\min_{g(x)\leq 0} f(x)$. This method consists in solving a sequence of subproblems

$$\min p \log(f(x) - t_k) - \sum \log(g_i(x)).$$

We investigate conditions on p which ensure that the solutions $x(t_k)$ form a differentiable trajectory. If $x(t)$ denotes a local solution of the unconstrained subproblem, we define a function $h(x(t), t)$ such that $h(x(t^*), t^*) = 0$ for a point $x^* = x(t^*)$ satisfying the sufficient second order conditions. We investigate again conditions on p, this time to ensure that $h'(x(t^*), t^*) \neq 0$. This allows us to apply Newton's Method to the function h, thereby yielding a quadratic convergence rate with respect to function values. Finally, we evaluate the tradeoffs of *approximately* solving the unconstrained subproblems. More precisely, we propose an approximation criterion such that the quadratic convergence rate for the function values is retained, and we evaluate the work needed to obtain such an approximate solution. Improvements are made available by the use of an extrapolation strategy, as used recently in numerically efficient penalty algorithms.

Abdelhamid Benchakroun
Jean-Pierre Dussault
Abdelatif Mansouri

Département de mathématiques et d'informatique
Faculté des sciences
Université de Sherbrooke
Sherbrooke, PQ, CANADA
J1K 2R1

Bilevel Formulations in Concurrent Modeling of the Design Process

Concurrent modeling, as an emerging theme in engineering design research, also offers interesting new challenges in applied optimization. The basic problem is to include downstream product-life considerations in early design decision-making. In current methods, concurrency has usually been modeled by different multiobjective formulations. As a way to further improve the designer's insight in modeling concurrency, we propose the use of a bilevel formulation and its various interpretations in input optimization and stackelberg games.

Using applications from mechanical design, this presentation will address nondifferentiability in bilevel models and will report on new computational approaches to solve these models.

J. R. Jagannatha Rao
Assistant Professor
Department of Mechanical Engineering
The University of Houston
Houston, TX 77204-4792.

Nonlinear Programming Model For Software Development Process

Software developer deals with two conflicting objectives of minimizing the resources utilized and maximizing the quality accomplished in the development process. This paper develops nonlinear programming model that enables a software manager to determine optimal levels of resource allocation in each stages of software development process that maximize the software quality within the given budget. Software quality is described through a number of quality factors such as reliability, maintainability, portability, and etc. Each quality factor is a function of the quality metrics which affect that quality factor. Nonlinear relationship is assumed between resources spent and level of quality metric attained. An example will illustrate the model.

Nalina Suresh
Department of Mathematics
University of Wisconsin-Eau Claire
Eau Claire, WI 54701

A.J.G. Babu
Department of industrial and Management Systems
University of South Florida
Tampa, Florida 33620

An interior-point algorithm for quadratically constrained entropy minimization problems

Entropy minimization problems with linear or quadratic constraints are widely used in engineering and social sciences. Traditionally, the solution of such problems were solved by Lagrange multipliers techniques. Interior point methods for linearly constrained entropy minimization problems have recently been studied and they have proved successful in solving some large scale problems in image reconstruction. we present an interior point algorithm for quadratically constrained entropy problems. The algorithm uses a variation of Newton's method to follow a central path trajectory in the interior of the feasible set. The algorithm follows some central path called trajectory. This approach was also used by other authors for different problems. The primal-dual gap is made less than a given ϵ in at most $O(| ln\epsilon | \sqrt{m+n})$ steps where n is the dimension of the problem and m is the number of quadratic inequality constraints.

Jun Ji.
University of Iowa, Iowa city, IA
Florian Potra.
University of Iowa, Iowa city, IA

Optimum Design of Rotational Wheel and Casing Structures under Transient Thermal and Centrifugal Loads

Transient thermal and centrifugal loads on turbomachinery rotors have increased with recent increases in gas temperatures and tip speeds. Rotor weights must be decreased to improve rotor dynamics and to reduce bearing loads. Moreover, blade tip clearance must be decreased to improve aerodynamic efficiency. An optimum design technique offering the lightest possible wheel shape under specified stress and clearance limits is therefore required.

This paper introduces an optimum design system developed for turbo-machinery rotors. Sequential linear programming is used in the optimizing process, and non-steady-state thermal analyses of wheels and casings are performed by numerically analyzing multi-ring models. Stress and deformation analyses of these wheels and casings are performed by using Donath's method with the same multi-ring model. This optimum design program is applied to the design of multistage axial flow compressor wheels.

Toshio Hattori

3rd Dept.,Mech.Eng.Res.Lab.,

Hitachi Ltd.,

502,Kandatsu,Tsuchiura,Ibaraki,Japan

The choice of the Lagrange multiplier in the framework of successive quadratic programming method

We study the choice of the Lagrange multiplier for equality constrained optimization problem when the successive quadratic programming strategy is used to solve the problem. Some of the fundamental properties of the distinct Lagrange multiplier formulas will be discussed. The numerical stability of all these Lagrange multiplier formulas and some numerical results will also be presented.

Debora Cores
Richard Tapia
Department of Mathematical Sciences
Rice University, P.O. Box 1892
Houston, Tx 77251.

Conditions for Continuation of the Efficient Curve for Multi-objective Control-structure Optimization

In recent years there has been considerable interest in bi-objective structural optimization, which gives the designs (known as efficient solutions) where one objective can be improved only at the expense of the other one. The optimal solutions to the problem of minimizing the bi-objective cost function $\mathcal{J} = (J_s, J_c)$ can be found by optimizing the convex combination $(1-\alpha)J_s + \alpha J_c$ of a structural cost J_s and a control cost J_c. A recently developed active set algorithm using homotopy methods to trace the efficient curve has been implemented for the bi-objective control-structure optimization of a ten-bar truss with two collocated sensors and actuators. The efficient curve for this example consists of three disconnected parts. Two parts are discontinuous with stationary solutions bridging the discontinuities. The relevant question is what the conditions are for continuation of the path. This paper attempts to apply Robinson's general theory about the stability of perturbed systems for determining such conditions, and to examine their computational feasibility.

Joanna Rakowska
Department of Mathematics

Raphael T. Haftka
Department of Aerospace and Ocean Engineering

Layne T. Watson
Department of Computer Science
Virginia Polytechnic Institute & State University
Blacksburg, VA 24061-0106

The scaled proximal decomposition on the graph of a monotone operator

We present a different derivation of Spingarn's decomposition method for convex programming (Math.Prog.32,2,1985). It is based on the proximal decomposition on the graph of a maximal monotone operator. The convergence of the method is proved without using the concept of the Partial Inverse. This allows us to add a scaling factor which accelerates the convergence in the strongly monotone case. These results are supported by numerical experiments performed on a minisum facility location problem with mixed polyhedral norms.

Philippe Mahey
Laboratoire ARTEMIS
IMAG, BP 53X, F-38041 Grenoble, France
Pham Dinh Tao
LMAI- INSA Rouen
BP 86, 76131 Mont St Aignan
France

Convex Optimization Problem Yields the Markov Process Steady Probability Distribution

We show that the solution of a steady Kolmogorov system for the markov process probability distribution minimizes the convex function having a form of free energy of the certain thermodynamic system. Based on this observation we deploy numerical methods of convex optimization and statistical mechanics for approximating the steady probability distribution of large-scale markov processes. We apply this approach to performance analysis and optimization of large-scale circuit switched communication networks.

Vladimir Marbukh
NYC Department of Sanitation
Operations Management Division
125 Worth Street, Room 811
New York, NY 10013

A LAGRANGIAN DUAL APPROACH FOR ASSIGNING TOOLS TO MACHINES IN A FLEXIBLE MANUFACTURING SYSTEM

The flexible manufacturing system (FMS) considered has machines capable of handling several tools stored in a magazine. Magazine capacity is restricted, and tools can occupy more than one unit space. Cluster analysis techniques determine dependency between each pair of tools. Tools common in a production sequence and located in different machines result in FMS travel. A linear integer program is formulated to minimize travel among a predetermined number of machines. Lagrangian relaxation is applied to a set of constraints, resulting in a separable problem. The dual problem is solved by a subgradient algorithm.

T. H. D'Alfonso and J. A. Ventura
Department of Industrial and
Management Systems Engineering
The Pennsylvania State University
University Park, PA 16802

Optimal Design for Model $\mu=ax/(1+bx)$ with Multiplicative Error

We solve an optimum experimental design problem which involves a nonlinear statistical model $\mu=ax/(1+bx)$ with multiplicative random error. The model has been used in various industrial fields, where it is named as Langmuir model or Michaelis-Menten model. In both finite sample case and asymptotic case, we find the location of the design points (levels) of the control variable and the weight at each point such that the generalized variance of the estimates of the parameters a and b is minimized. The assumptions for achieving this optimization are reduced to minimum. The methodology can be applied to other nonlinear regression optimal design problems.

(1) Shankang Qu
(2) Shriniwas Katti
Department of Statistics
University of Missouri-Columbia
Columbia, MO 65211

Pattern Recognition and Classification Using Time Series

Pattern recognition is concerned with comparing a shape A, which is found in a scene, to a set of shapes B, which are pre-stored as reference shapes. Based on a similarity measure, the shape A will be recognized and classified as one of the reference shapes in B. An investigation of a two-dimensional object recognition technique based on the use of autoregressive-integrated-moving average (ARIMA) approach is proposed. The boundary profile of the object is first extracted as a set of sequential discrete data. This set of data is then described in a time series manner. An ARIMA scheme is applied to derive the best-fitting model based on statistical evaluation. This recognition process uses the sum of weighted Euclidean distances of the model parameters between the input shapes and the reference shapes. This approach is invariant to the object size, position, orientation, and the starting point.

Jen-Ming Chen, Jose A. Ventura and Chih-Hang Wu
Department of Industrial and Management Systems Engineering
The Pennsylvania State University
207 Hammond Bldg, University Park, PA 16801

Numerical Experiments with One Dimensional Adaptive Cubic Algorithm

A code and numerical experiments with one dimensional adaptive cubic algorithm are presented. It is demonstrated that the algorithm is applicable for full global optimization of a large class of functions including discontinuous and unbounded functions. Experiments with such functions show that successive runs yield monotonically improving results which descend onto the set of all global optimizers, if the sequence of experimental runs is properly organized.

André Ferrari
LASSY, Université de Nice-Sophia Antipolis,
équipe de l'URA 1376 du C.N.R.S.,
41 Bd. Napoléon III, 06041 Nice, CEDEX, FRANCE

Efim A. Galperin
Département de mathématiques et d'informatique
Université du Québec à Montréal
C.P. 8888, Succ. A, Montréal, Qué., CANADA H3C 3P8

A Random Global Search Technique for Lipschitz Functions

We present results of a random search technique for global optimization of Lipschitz continuous functions. This is in answer to the ongoing challenge of efficient algorithm development in this area. In particular our algorithm is an attempt to approximate Pure Adaptive Search. It "brackets" the level set with upper and lower envelopes, using Lischitz cones. This paper explores the expected closeness of the bracket to the level set for various functions.

Regina Hunter Mladineo
Management Sciences Dept.,
Rider College, Lawrenceville, NJ 08648.

An Algorithm for Graph Imbedding

An algorithm is presented for imbedding a copy of a graph A into graph B. The algorithm uses penalty functions which penalize for self-intersection and simulated annealing to minimize the penalty. The algorithm is conveniently implemented on parallel platforms. Assuming imbeddings of A into B exist, the algorithm can be used further to search for imbeddings with minimum edge lengths. Applications for adapting a given parallel algorithm for different parallel platforms are described.

Yaghout Nourani, Andrew Klinger, Luqing Wang, and Peter Salamon
Department of Mathematical Sciences
San Diego State University
San Diego, CA 92182

The Inverse Shortest Paths Problem

The inverse shortest paths problem in a graph is considered, that is the problem of recovering the arc costs given some information about the shortest paths in the graph. The problem is first motivated by some practical examples arising from important applications. An algorithm for one of the instances of the problem is then proposed and analysed. Preliminary numerical results are reported. The problem where arc costs are subject to correlation constraints is also considered. A generalization of the first algorithm is then presented with some numerical experience.

Didier Burton and Philippe Toint
Faculties Universitaires de la Paix
Belgium

Optimization of Steiner Nodes and Trees on a Hypercube Architecture

Given a set of N nodes, randomly distributed on a hypercube network, find an optimal Steiner tree that minimizes the number of links needed to connect the N nodes.

In this paper it is proven that for N=3 the corresponding Steiner node is unique and an efficient method is developed that computes this node. This result was utilized to develop an algorithm with time complexity $O(N^2 \log N)$ that closely approximates the optimal Steiner tree. The results of this paper have been experimentally verified.

Nikolaos T. Liolios
Computer Methods Corporation
2487 Stone
Ann Arbor, MI 48105

Dionysios Kountanis
Western Michigan University
Department of Computer Science
Kalamazoo, MI 49008

Two Approximation Algorithms for the Routing Problem

Several algorithms have been presented in the past that construct approximate solutions to the optimal Rectilinear Steiner Tree problem.

This paper reviews some of the known efficient routing algorithms. These algorithms are experimentally analyzed using their time complexity, total size of the resulting Steiner tree, number of changes in direction, separability and stability as quality measures.

Two new algorithms are also presented and analyzed. It is shown that both algorithms perform better than the previously know algorithms, relative to the above mentioned criteria

Dionysios Kountanis
Western Michigan University
Department of Computer Science
Kalamazoo, MI 49008

Nikolaos T. Liolios
Computer Methods Corporation
2487 Stone
Ann Arbor, MI 48105

Discontinuous Piecewise Differentiable Optimization

A theoretical framework and a practical algorithm are presented to solve discontinuous piecewise differentiable optimization problems. A penalty approach allows one to consider such problems subject to a wide range of constraints involving piecewise differentiable functions. The descent algorithm elaborated uses active set and restricted gradient approaches. It is a generalization of the ideas used to deal with nonsmoothness in the l_1 exact penalty function. Numerical results will also be presented.

Andrew R. Conn
T. J. Watson Research Center, P. O. Box 218, Yorktown Heights. N. Y. 10598
arconn@watson.ibm.com
Marcel Mongeau
Centre de recherches mathématiques, Université de Montréal, C. P. 6128, Succ. A, Montréal, Canada H3C 3J7
mongeau@ere.umontreal.ca

Nuclear Cones and Pareto Optimization

We present a general necessary and sufficient existence test for Pareto optimum in a general ordered locally convex space.

By this result we can see the importance of nuclear cones in Pareto optimization.

Several interesting conclusions are also obtained.

George Isac
Departement de Mathematiques
College Militaire Royal
St-Je Quebec
Canada, J0J 1R0

STUDY OF SOME MULTIPORT PLANAR STRIPLINE DISCONTINUITIES OPTIMIZATION OF THEIR CHARACTERISTICS BY CONSIDERATION OF THEIR FORM

This Papur Presents one Approach for the Study of Multiport Planar Stripline Structures Using Isotropic or Anisotropic Substrate.

Our Work is Based on the Combination of the Conventionnal Boundary Element Method in the Junction, with Equivalent Waveguide Model or Edge Line Concept for the Transmission Lines. Using Green's Formula for the Inner Junction, the Expression of the Electromagnetic Field at Any Point can be Obtained. Our Approach Allows Us to Optimized the Characteristics of the Compensated Bend or Tee by Consideration of the Form.

Christian CAVALLI , Henri BAUDRAND
Laboratoire d'Electronique, ENSEEIHT,
2, Rue Charles CAMICHEL,
31071 TOULOUSE CEDEX
Jacques COUOT
Laboratoire d'Analyse Numérique
Université Paul SABATIER
118, Route de NARBONNE
31406 TOULOUSE France

On Width Minimization by Shift Transform Interval Multiplication

Applying interval arithmetic, we may find reliable solution bounds in finite digit computations. In interval function evaluation, we need design algorithms to minimize the width of result intervals. People have studied the standard centered form to bound the range of functions and claimed it is optimal. In this presentation, we treat the centered form as a special case of shift transformation We present that the centerized form may not be optimal in general. This is because the centerization may cause larger width penalty from other terms. We present algorithms to apply general shift transformations to obtain optimal results for certain functions Numerical examples will be discussed also.

Chenyi Hu
Department of Applied Mathematical Sciences,
University of Houston-Downtown,
Houston, TX 77002.

Optimal Sampling Design for Dynamic Systems

We describe the use of Quasi-Newton nonlinear optimization methods to design optimal sampling schemes for dynamic systems. The system is assumed to be described by a set of ordinary differential equations that include a number of physical parameters to be identified. The objective of the optimal sampling design problem is then to select values of sampling design variables that minimize the determinant of the theoretical parameter covariance matrix. This criteria is equivalent to minimizing the volume of a statistical confidence region for the parameters. Since the determinant of the parameter covariance matrix involves first order derivatives of the system state variables with respect to the parameters, the gradients of the sampling design objective function requires second order derivatives of the dynamic system. One key feature of the numerical approach is the use of dynamic system sensitivity analysis techniques to calculate the needed first and second order derivatives efficiently and accurately. The general approach is applied to a complex biological process that describes the processes and reaction rates involved in the conversion of substrate to biomass, with the consumption of an electron acceptor. In this example, the optimal sampling design approach is used to design batch experiments for use in estimating various biochemical parameters.

James G. Uber
University of Cincinnati
Cincinnati, Ohio

An Algorithm for Solving Linear Inequality System

Solving a system of linear inequalities is one of the fundamental problems in optimization. A descent method to solve the question is presented in this paper. Usually, its decent direction can be obtained via the solution of a linear least square problem, otherwise, we need to solve a constrained least square subproblem. The step factor for the search direction is easy to calculate. Numerical experiments illustrate the feasibility of the new algorithm, but an efficient code for solving the special constrained least square problem is necessary.

Jiasong Wang, Professor
Department of Mathematics
Nanjing University
Nanjing, Jiangsu Province
P.R.CHINA 210008

Modelling of the vectors, uniformly-distributed on all directions in some hyperplane intersection

It's considered the method of random vector generation. The vectors must have uniformly distribution and must belong to some hyperplanes. This procedure of modelling is necessary for random search methods when various parameters must be satisfactory for some linear limits. Analogical problem is arrived in iptimisation on multicomponent mixture.

First it's used the well-known algorithm of modelling of the points, uniformly-distributed on (n-k)-dimensional sphere (k-num- ber of limits). Then the set of orthogonal transformations is performed in order to transmit these points to our n-dimensional space. These transformations are the generalization of the famous Helmert transformation. The method have been used for optimisation problems in gydrogeology and geochemistry.

Genrih Celestin Tumarkin
Moscow Geological-Prospecting Institute
Mathematical Modelling
Micluho-Maclai str., 23, Moscow 117873 USSR

Constructive Neural Network Algorithm for Approximation of Multivariable Function with Compact Support and its Application for Inversion of the Radon Transform

Presenter: Nicolay Magnitskii
Institute for Systems Studies
Academy of Sciences
9, Prospect 60-let
Oktyabrya, Moscow
117312 Russia

No brief abstract received, only extended (3-page) version.

T-Stationary Replacement for the Average Model of MDP

We consider an unbounded nonstationary Markov Decition Programming (MDP) with the average reward criterion. This problem has been little studied. In our earlier paper (see: 91b-90211 "Math Reviews") we provide a conception T-Stationary replacement property which is extended to average model in this paper. By use of this property the existence of optimal policies is proved under some hypotheses. Our work opens up a new way for the discussion about this field.

Wei Liren
Applied Mathematics Research Laboratory
Hunan Normal University
Changsha, Hunan 410006
People's Republic of China

Solving Linear Stochastic Network Problems using the Proximal Point Algorithm on a Massively Parallel Computer, and an Application from the Insurance Industry.

We use the proximal minimization algorithm with D-functions (PMD) superimposed on a row-action algorithm for solving *linear*, two-stage stochastic network problems. The proximal point subproblems decompose by scenario and non-anticipativity is enforced iteratively. Extensive results from an implementation on a massively parallel Connection Machine CM–2 are presented, and an application from the management of a portfolio of insurance products (SPDAs) is discussed.

Soren S. Nielsen
University of Pennsylvania, The Wharton School, Decision Sciences Dept., Philadelphia PA 19104;
Stavros A. Zenios, University of Pennsylvania, The Wharton School, Decision Sciences Dept., Philadelphia PA 19104;

Parallel Constraint and Variable Distribution

Approaches for distributing constraints and variables among parallel processors are described. Eash processor handles either a subset of the constraints or the variables with appropriate modifications to the problem. Typically an augmented penalty term is introduced in each subproblem to reflect the variables or constraints not treated by the subproblem. Convergence results and computational experience will be reported.

M.C. Ferris & O.L. Mangasarian
Computer Sciences Department
University of Wisconsin
1210 West Dayton Street
Madison, WI 53706

Parallel Algorithms for Minimizing the Ginzburg-Landau Free Energy Functional for Superconducting Materials

The Ginzburg-Landau theory of superconductivity effectively models many of the observed properties of superconducting materials, most notably the vortex lattice solutions which arise in the mixed state" when the strength of the applied magnetic field lies between two critical values. The solutions can be obtained by minimizing a discretized version of the Ginzburg-Landau free energy functional. The resulting optimization problem can be very large and nonlinear. Other difficulties arise because of the presence of saddle points and degeneracy at the solution. In this talk, we discuss parallel implementation of an inexact Newton strategy for minimizing the free energy functional. The core operation of solution of the damped Newton equations (a large sparse linear system in which the coefficient matrix is a damped version of the Hessian) is performed with a parallel preconditioned conjugate gradient technique.

Paul E. Plassmann and Stephen J. Wright
MCS Division,
Argonne National Laboratory
Argonne, IL, 60439, USA

Parallel Optimization in Groundwater and Petroleum Resources Management

A number of optimization problems arise in the management of groundwater and petroleum resources. The dominant computational expense in these NLP is the solution of the p.d.e. that describe flow in porous media. We will describe an approach to such problems that integrates domain decomposition methods with NLP algorithms, thereby exploiting computational parallelism.

Our idea is based on the observation that in the context of NLP, domain decomposition methods contain implicit constraints which should be made explicit in the NLP. We will discuss our approach for the case of a parameter identification problem from subsurface flow.

Robert Michael Lewis
Department of Mathematical Sciences
Rice University
P.O. Box 1892
Houston, TX 77251-1892

SQP Algorithms for Large-scale Constrained Optimization

We discuss several theoretical and practical issues concerning the extension of sequential quadratic programming (SQP) methods to large problems with equality and inequality constraints. An important feature of the methods to be discussed is the approximation of a *reduced* Hessian of the Lagrangian function. We shall define certain *pseudo*-superbasic variables and show how they can be used to improve efficiency when strict complementarity does not hold at the solution of a quadratic programming subproblem. Comparisons with NPSOL and MINOS are presented for about 100 small and large examples.

Samuel K. Eldersveld
Stanford University, Stanford, CA

Philip E. Gill
University of California at San Diego, La Jolla, CA

Large-scale Issues in Newton Methods for Linearly Constrained Optimization

In this talk, modified Newton methods of the linesearch type are described. The methods are based on computing directions of sufficient descent and sufficient negative curvature, and are suitable for large sparse problems with linear constraints. The focus of the talk is on how to compute the directions efficiently, and how to combine them in the linesearch. Finally, we discuss the role of the procedures described within algorithms for nonlinearly constrained problems.

Anders Forsgren
Royal Institute of Technology
Department of Mathematics
S-100 44 Stockholm, Sweden

Walter Murray
Stanford University
Stanford, CA 94305

Optimization of Complex Aircraft Structures

In design of aircraft structures it is crucial to minimize structural weight without violating structural strength requirements. Combining numerical optimization techniques with finite element analysis, it is possible to solve the design problem as a large nonlinear optimization problem. Design variables are used to define the size and shape of the structural members, and state variables describe the deformation of the structure caused by external loads. The number of state variables is large since these variables arise from a discretization of a partial differential equation. It is common practice in structural optimization to use the state equations to explicitly eliminate the state variables. The talk will discuss this approach and describe when it could be beneficial to keep the state equations in the optimization problem. In particular it will be described how keeping the state equations as nonlinear constraints is advantageous when the state equations are nonlinear. Numerical examples from minimum weight design of nonlinear shell structures will be presented.

Ulf T. Ringertz
The Aeronautical Research Institute of Sweden
Box 11021, S-161 11 Bromma Sweden

SQP Methods and their Application to Optimal Trajectory Calculations

A particularly successful application of nonlinear optimization has been in the area of *optimal trajectory simulation*. Optimal trajectory simulation involves the calculation of the best flight path of a spacecraft or aircraft. Recently, an approach based on Hermite collocation and the sequential quadratic programming method NPSOL has been implemented in the optimal trajectory code OTIS. The code has had a significant impact on the area of space vehicle design, and is being used in the calculation of trajectories for the National Aerospace Plane, the Mars Lander and the single-stage-to-orbit test vehicle. We review the application of SQP methods to optimal trajectory design and describe how the choice of method for the QP subproblem can have a substantial effect upon the time needed to compute an optimal trajectory. We conclude by describing recent developments in large-scale optimization that are likely to have an impact upon optimal trajectory calculations.

Philip E. Gill
University of California at San Diego, La Jolla, CA

Walter Murray
Stanford University, Stanford, CA

Michael A. Saunders
Stanford University, Stanford, CA

Issues in Strong Polynomiality of Nonlinear Optimization

It is demonstrated that problems of convex separable optimization over linear constraints are solvable in polynomial time provided that the largest subdeterminant of the constraint matrix is bounded. In particular, problem over a totally modular matrix of constraints are solvable, in integers, in polynomial time. Such problems with a linear objective function, are solvable in STRONGLY polynomial time. We demonstrate that such algorithms are impossible for a nonlinear nonquadratic objective function, for a widely acceptable complexity model. The case of quadratic objective function may allow for strongly polynomial algorithms. Cases where such algorithms are known, and important open question will be described.

Dorit S Hochbaum
Department of IE&OR
University of CA, Berkeley, CA 94720

The Complexity of Quadratic Programming

The QUADRATIC PROGRAMMING problem is to maximize a polynomial of degree two, $f(x) = x^T Ax$, inside the convex set $Bx \leq c$. Not only is this problem NP-hard, but no polynomial-time algorithm is known for approximating the optimum, even very poorly. Here we give evidence why this is so. assuming that NP cannot be decided in $n^{\log^{O(1)} n}$-time, we show that there is no constant-factor polynomial-time approximation algorithm for QUADRATIC PROGRAMMING. (That is, any polynomial-time algorithm will produce estimates which are sometimes off by more than $\omega(1)$ times the true optimum.) The techniques used to establish this theorem stem from the study of interactive proof systems. In particular, we rely heavily on the recent contributions of [Babai, Fortnow, Lund], [Feige, Goldwasser, Lovasz, Safra, Szegedy], and [Feige, Lovasz]. We derive similar results for some other problems in continuous optimization.

Mihir Bellare
IBM T.J.Watson Research Center, Yorktown Heights, NY

Phillip Rogaway
IBM, Austin, TX

ON MINIMIZATION OF CONVEX SEPARABLE FUNCTIONS

We consider the problem of minimizing a convex separable function in R^n subject to box constraints and m equality constraints. We provide a characterization of solutions in terms of an arrangement of hyperplanes in R^m. We use the characterization to provide an exact algorithm for the problem which takes $O(n^m)$ operations (including function inversions). In particular, for the special case of the least-distance problem, we obtain a strongly polynomial algorithm for fixed m, with running time $O(n^m)$.

Nainan Kovoor, Penn State University, Computer Science Dept., University Park, PA 16802

Panos M. Pardalos, University of Florida Dept. of Industrial & Systems Engineering, Gainesville, FL 32611

Toward Probabilistic Analysis of Interior-Point Algorithms for Linear Programming, Part 2

This is the second part of our talk on interior-point algorithms. Based on our finite termination result in Part 1, we rigorously show that some random LP problems, with high probability (probability converges to one as n approaches infinity), can be solved in $O(\sqrt{n} \log n)$ interior-point iterations. These random LP problems include Borgwardt's and recent Todd's probablistic models with the standard Gauss distribution. Our result also holds for the average complexity analysis.

Yinyu Ye
Department of Management Sciences
College of Business Administration
The University of Iowa
Iowa City, IA 52242

Numerical Comparisons of Local Convergence Strategies for Interior-Point Methods in Linear Programming

The value of designing interior point methods for linear programming which possess the attribute of superlinear convergence is often questioned by some members of the linear programming community. In this study we present numerical experimentation which demonstrates the positive value of superlinear convergence, and also implies that the positive contribution is not merely a local phenomenon.

Amr El-Bakry
Richard Tapia
Department of Mathematical Sciences
Rice University, P.O. Box 1892
Houston, Texas 77251

Yin Zhang
Department of Mathematics and Statistics
University of Maryland
Baltimore County Campus
Baltimore, Maryland 21228

L-INFINITY ALGORITHMS FOR LINEAR PROGRAMMING

We discuss a new ℓ-infinity algorithm for finding a feasible point for a linear program. The algorithm requires the same amount of work per iteration as traditional methods that minimize the sum of infeasibilities, but has the advantage that the steepest-edge pivot selection criterion may be used. We discuss the performance of the method when applied to the problems in the *Netlib* test set.

Jerome G. Braunstein
University of California at San Diego, La Jolla, CA
Philip E. Gill
University of California at San Diego, La Jolla, CA

A New Approach for Parallelising the Simplex Method

It is well known that small changes to a code of the simplex method can lead to significantly different pivot sequences and hence a different number of pivots. We exploit this observation systematically by following different pivot sequences on different processors of a parallel MIMD computer. The progress of each processor is monitored by a master processor and if a processor performs poorly compared with others it will be assigned to another more promising vertex from the neighbourhood of the currently best processor. Different pivot strategies including hybrid strategies are examined for its efficiency in this method.

Frank Plab
Edinburgh Parallel Computing Centre
University of Edinburgh
Edinburgh, Scotland, UK

Solving Stochastic Linear Programs on a Hypercube Multicomputer

Large-scale stochastic linear programs can be efficiently solved by using a blending of classical Benders decomposition and a relatively new technique called importance sampling. The talk demonstrates how such an approach can be effectively implemented on a parallel (Hypercube) multicomputer. Numerical results are presented.

George B. Dantzig
Department of Operations Research
Stanford University
Stanford, CA 94305-4022, USA

James K. Ho
Department of Information & Decision Sciences
University of Illinois at Chicago
m/c 294, P.O. Box 4348
Chicago, IL 60680, USA

Gerd Infanger
Department of Operations Research
Stanford University
Stanford, CA 94305-4022, USA

The U.S. Coast Guard Interactive Resource Allocation Problem

Models are needed to experiment with different force-mixes to discover an optimal allocation of resources under given budgetary constraints.

Current methods used to solve these problems posit a single overall objective function which implies a single decision making entity. However, a crucial aspect of this problem is that multiple decision makers influence these allocations.

Consequently, we are forced to consider a series of models that lead to a system of nonlinear equations. These equations are solved using a Path Following approach thereby obtaining equilibria. This interdependent system model is more accurate and reflects the reality of the organization.

J. Walter Smith
U.S. Coast Guard R&D Center
Applied Science Division
Avery Point
Groton, CT 06340

Optimization Problems Arising in Multidimensional Scaling

Developed primarily by psychometricians, multidimensional scaling (MDS) is a collection of multivariate statistical techniques used for ordination and dimension reduction. Unlike most statistical techniques, no underlying stochastic model is assumed: MDS is defined by specifying a purely deterministic optimization problem. This presentation considers a variety of formulations of the most common approaches to MDS, most of which are highly nontrivial. The crucial obstacle to formulating MDS as a convex program is a constraint that a positive semidefinite matrix have rank $\le p$. Methods for managing such constraints are the subject of the presentation by Tarazaga, Trosset, and Tapia.

Michael W. Trosset
Consultant
P.O. Box 40993
Tucson, AZ 85717-0993

Pablo Tarazaga
Department of Mathematics
University of Puerto Rico
Mayaguez, Puerto Rico

and

Richard A. Tapia
Dept. of Mathematical Sciences
Rice University
P. O. Box 1892
Houston, TX 77251-1892

The Classical Newton Method for Solving Strictly Convex Quadratic Programs and Data Smoothing Problems

k-Convex Approximation and Data Smoothing Techniques

In this talk, we present new algorithms for solving the so-called least distance problem

$$\min\left\{\frac{1}{2}\sum_{i=1}^{n}(x_i-b_i)^2 : l \le Ax \le u\right\}, \qquad (1)$$

where A is an $m \times n$ matrix, $b \in \mathbb{R}^n$, and $l, u \in \mathbb{R}^m$. Of course, (1) is an old problem with important applications in many areas. We are particularly interested in the case where A is the k-th divided diference matrix defined as

$$(Ax)_j = \sum_{i=0}^{k}\binom{k}{i}(-1)^i x_{j+i}, \qquad j = 1, \ldots, n-k.$$

In this case, (1) is called the k-convex approximation probelm, if $l = 0, u = +\infty$. In general, the constraints control the magnitude of the k-th divided difference of the fitting vectors and we use (1) as a data smoothing model. The new idea is to reformulate (1) as an unconstrained minimization problem with a strictly convex quadratic spline function as the objective function. A Newton method is applied to solve the unconstrained problem. Due to the ill-conditioning nature of the k-th divided difference matrices, the data smoothing problem and k-convex approximation problem are computationally difficult problems for large n. However, our preliminary numerical tests indicate that the proposed Newton method always finds a fairly accurate solution when $n^k \le 10^9$. This provides a quite efficient way of finding a smooth fitting of noisy data. We shall also discuss some mathematical and statistical problems related to the new data smoothing technique. Especially, we shall present unconstrained reformulations of general convex quadratic programming problems.

W. Li and J. Swetits
Department of Mathematics and Statistics
Old Dominion University
Norfolk, VA 23529

Objective function conditioning with smoothness constraints

Seismic imaging of the earth's subsurface requires the alignment of multiple wavefoms. A large scale nonlinear optimization problem arises when the time perturbations for each of the thousands of source and receiver points are estimated.The multimodal objective function causes solution algorithms, such as conjugate direction methods, to become trapped at local optimum. Many workers have applied combinatorial optimization techniques to this problem, but these do not tend to scale well with problem size. I have tried to improve the behavior of the objective function by applying physically motivated constraints, such as spatial smoothness. The smoothed objective function allows computationally efficient projection algorithms to find the optimal solution reliably. Since a large fraction of the time shift measurements are erroneous, robust (l_1) estimation methods are used.

Stephen F. Elston
Department of Geological and
Geophysical Sciences
Princeton University
Princeton, NJ 08544

A New Modified Newton Algorithm for Nonlinear Minimization Subject to Bounds

We describe a new efficient method for large-scale nonlinear minimization subject to bounds. The method is very efficient in practice. We present numerical results to support this claim. We also discuss global convergence results and second-order convergence.

Thomas F. Coleman, Computer Science Department, Cornell University, Upson Hall, Ithaca, New York, 14853
Yuying Li, Computer Science Department, Cornell University, Upson Hall, Ithaca, New York, 14853

An Algorithm for Large Scale Optimization Problems with Box Constraints

We consider large scale box constrained nonlinear programming problems. This kind of problems often arise in applications, for example in discrete (and discretized) optimal control and in the numerical solution of partial differrential equations. This has motivated a considerable research effort aimed at developing efficient and reliable solution algorithms, particularly in the quadratic case. Among the most successful proposal we can mention active set methods, projection technique and trust region type algorithms. However, the solution of large and difficult problems is still a challenging task.

In this work we define a new method based on the unconstrained minimization of a smooth potential function that fully exploits the simple structure of the constraints and is computationally attractive. Employing this potential function it is possible to define a truncated Newton-type algorithm which is globally and superlinearly convergent. We report extensive numerical results showing that the algorithms considered are efficient and robust, and compare favourably with existing algorithms.

Francisco Facchinei, Laura Palagi
Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", via Eudossiana 18, 00184 Roma, Italy

Stefano Lucidi
Istituto di Analisi dei Sistemi ed Informatica del CNR, Viale Manzoni 30, 00185 Roma, Italy

A Trust Region Algorithm for Nonlinear Programming

In this talk we describe a new algorithm for bound constrained minimization. Our approach adapts the trust region to the shape of the feasible region. We also present extensions of this approach to the general nonlinear programming problem. Numerical results will be presented.

Pang-Chieh Chou
John E. Dennis, Jr.
Karen A. Williamson
Dept. of Mathematical Sciences
Rice University
P O. Box 1892
Houston, TX 77251-1892

Potential Transforms Applied to Geometry Optimization in Macromolecular Chemistry

Macromolecular structure optimization is generally approached by use of empirical force fields coupled with interparticle constraints derived from X-ray Crystallography and/or Nuclear Magnetic Resonance(NMR). As it is known on statistical grounds that the native structure of a macromolecule has a low potential energy, we formulate structure determination as a problem of constrained *global* optimization. The search for acceptably low minima in this setting made difficult by the large number of independent variables (typically in the thousands) and by the astronomically large number of local minima on the potential energy surface.

We give a brief overview of the biological problem of interest, and of some of the methods previously employed by chemists in its solution. This is followed by discussion of a class of potential transform methods which we believe can be useful tools for global optimization in macromolecular chemistry.

Robert A. Donnelly
Department of Chemistry
Auburn University
Auburn, Alabama 36849

Large-Scale Optimization in Computational Chemistry Problems

In the semi-empirical approach of molecular mechanics, a target potential energy function is formulated for a molecular system and parameterized to reproduce known structural and thermodynamic properties for small molecules. The input consists of a known chemical composition (i.e., primary sequence), and the output is the three-dimensional structure. The parameterized function is then used to study the structure of large biomolecules, such as proteins and nucleic acids, composed of the same chemical subgroups. Minimization is performed to locate energy minima that correspond to biologically relevant configurations. Since potential energy functions are typically complex, involving many local minima, maxima, and transition points, efficient search techniques and minimization schemes must be combined. The natural separability of these functions - into local and non-local interactions, for example - can be exploited in minimization. In this talk, we will describe an adaptation of a truncated Newton method for large separable problems in computational chemistry and its application to DNA structure. Problem structure is incorporated by using a preconditioned Conjugate Gradient method to solve approximately for the Newton search direction where the preconditioner is assembled from the lower-complexity terms. Since this preconditioner may not necessarily be positive definite, it is factored by a sparse modified Cholesky factorization.

Tamar Schlick
Courant Institute of Mathematical Sciences
and Chemistry Department
New York University
251 Mercer Street
New York, New York 10012

A Global Optimization Approach for Microcluster Systems

A global optimization approach is proposed for finding the global minimum energy configuration of Lennard--Jones microclusters of atoms or molecules. First, the original nonconvex total potential energy function, composed by rational polynomials, is transformed to a quadratic one through a convexification procedure performed for each pair potential that constitute the total potential energy function. Then, a decomposition strategy based on the GOP algorithm is designed to provide tight bounds on the global minimum through the solutions of a sequence of relaxed dual subproblems. A number of theoretical results are also presented that expedite the computational effort by exploiting the special mathematical and physical structure of the problem. Finally, this approach is illustrated with a number of example problems.

C. D. Maranas
C. A. Floudas
Department of Chemical Engineering
Princeton University
Princeton, New Jersey 08544-5263

Global Optimization Methods for Molecular Configuration Problems

Molecular configuration problems consist of finding the structure of a given molecule that minimizes its potential energy. These problems typically have large numbers of parameters, and very many local minimizers with function values near the global minimum and small regions of attraction. Thus they are very challenging global optimization problems. We discuss the application of stochastic global optimization methods to these problems. Our methods incorporate new techniques for solving large scale problems that are applicable to any partially separable objective function. The methods have successfully solved test problems with over 100 parameters, and have found a new global minimizer for at least one well-studied problem.

Richard H. Byrd
Elizabeth Eskow
Robert B. Schnabel
Department of Computer Science
Campus Box 430
University of Colorado
Boulder, Colorado 80309

An implementation of a strongly polynomial time algorithm for basis recovery

Megiddo has shown that given primal and dual optimal solutions to a linear program, there exists a strongly polynomial time algorithm to identify an optimal basis. This algorithm consists of a primal simplex-like phase and a dual simplex-like phase and requires a maximum of n pivot steps. A number of issues are discussed about an implementation of this algorithm. Computational experience with the algorithm is presented that suggests that the algorithm is feasible in practice and suggests some natural extensions of the algorithm to handle numerical issues. In addition, a number of issues related to converting a near-optimal interior point solution of a linear program to a near-optimal vertex solution of a linear program are discussed.

Irvin J Lustig
Princeton University, Princeton, NJ USA

Finite Termination in Interior Point Methods

We will present our theoretical and computational results for finite termination in linear programming. We describe an indicator function for partitioning the variables. We also show when to partition the variable. We demonstrate the practicality of our approach on problems in the netlib set.

Sanjay Mehrotra
Dept. of IE/MS
Northwestern University
Evanston, IL 60208-3119

Recovering an Optimal LP Basis from an Interior Point Solution

An important issue in the implementation of interior point algorithms for linear programming is the recovery of an optimal basic solution from an optimal interior point solution. In this paper we describe a method for recovering such a solution. Our implementation links a high-performance interior point code (OB1) with a high-performance simplex code (CPLEX). Results of our computational tests indicate that basis recovery can be done quickly and efficiently.

Robert E. Bixby
Department of Mathematical Sciences
Rice University
Houston, Texas 77251

Matthew J. Saltzman
Department of Mathematical Sciences
Clemson University
Clemson, SC 29634

On Obtaining highly accurate or basic solutions using interior-point methods for linear programming

Obtaining a basic solution or a highly accurate approximation to a solution of a linear program using an interior-point method is of practical importance and several methods for accomplishing this objective have been proposed. In this talk we discuss the advantages and disadvantages of some of these methods and propose several improvements.

Amr S. El-Bakry,
Robert E. Bixby,
Richard A. Tapia
Department of Mathematical Sciences
Rice University, P.O. Box 1892
Houston, Texas 77251.

Yin Zhang
Department of Mathematics and Statistics
University of Maryland
Baltimore County Campus
Baltimore, Maryland 21228.

Approximation Algorithms for Indefinite Quadratic programming

We consider approximation schemes for indefinite quadratic programming. We propose a definition of approximation of the global minimum suitable for nonlinear optimization. We then show that such an approximation may be found in polynomial time for fixed e and k, where e measures the closeness to a global minimum and k the rank of the quadratic term. We next look at the special case of knapsack problems, showing that a more efficient approximation algorithm exists. The feature of knapsack problems exploited here may also apply to control-theory problems.

Stephen A. Vavasis,
Cornell University

On Matroidal Knapsack Problems and Lagrangean Relaxation

Camerini et al. have introduced a class of optimization problems that involve finding an optimum base in a matroid subject to a set of knapsack constraints. While these problems are NP-hard, an optimum solution to the Lagrangean dual yields good upper bounds. A simplex-like algorithm to solve the dual performs well in practice, but is not guaranteed to run in polynomial time. We use the parametric search method of Megiddo to obtain a polynomial-time algorihm for the Lagrangean dual. Our algorithm builds and improves upon results of Aneja and Kabadi, exploiting the special characteristics of matroidal knapsacks.

Richa Agarwala, David Fernandez-Baca, and Anand Medepalli
Department of Computer Science,
Iowa State University,
Ames, Iowa, 50011

Parallel Dynamic Programming Algorithms for the 0-1 Knapsack Problem

This talk describes the implementation of two algorithms for the 0-1 knapsack problem based on dynamic programming. A standard dynamic programming algorithm was implemented on a Connection Machine CM-2 with 16K processors, and problems with hundreds of thousands of variables were solved in just over 1 minute.

Secondly, a modified dynamic programming algorithm that considers only non-dominated states was implemented on a 20-processor Sequent 581.

Renato DeLeone and Mary A. Tork Roth
Center for Parallel Optimization
Computer Sciences Department
University of Wisconsin, Madison
1210 West Dayton Street
Madison, WI 53706

Totally Unimodular Leontief Directed Hypergraphs

A Leontief directed hypergraph, LDH, is a generalization of a directed graph, where arcs have multiple (or no) tails and at most one head. We define a class of Leontief directed hypergraphs via a forbidden structure ca[illegible] odd pseudocycle, and we show that the vertex-hyperarc incidence matrices of the hypergraphs in this class are totally unimodular. Indeed, we also show that this is the largest class with that property. Consequently, the minimum cost flow problems defined on this class of LDH's yield integral optimal solutions provided the demand vectors are integral. We present examples of LDH's whose underlying matric matroids are graphic; cographic; and neither graphic nor cographic.

Dr. Peh H. Ng
Division of Mathematics,
University of Minnesota at Morris,
Morris, MN 56267

Dr. Collette R. Coullard
Department of Industrial Engineering and
Management Science,
Northwestern University,
Evanston, IL 60208

A Fast Primal-Dual Algorithm for Generalized Network Linear Programs

The primal simplex method has enjoyed a pronounced computational advantage over primal-dual and out-of-kilter methods for solving large-scale generalized network LP's. In this presentation the speaker discusses a new primal-dual algorithm based on Rockafellar's monotropic programming theory. The key characterization of this algorithm is the use of efficient directions to monotonically decrease the number of infeasible constraints while optimizing a dual program. Numerical results indicate the algorithm rivals the speed of the simplex method on randomly generated benchmark problems.

Norman D Curet
Anderson Graduate School of Management
UCLA
Los Angeles, CA 90024-1481

NETWORK ASSISTANT to Construct, Test and Analyze Network Algorithms

NETWORK ASSISTANT is a system of portable C program modules to support the construct of efficient graph and network algorithms with capabilities to generate structured random networks and analyze test results. The system is designed for large-scale problems and includes high level constructs and various data structures for graphs, networks, trees, stacks, queues and heaps. It includes various algorithms for graph coloring, minimum spanning trees, shortest paths, maximum flows and minimum cost network flow that demonstrate the use of the system and the efficiency of the resulting programs. These algorithms have been tested on thousands of random networks.

Gordon H. Bradley
Operations Research Department
Naval Postgraduate School
Monterey, CA 93943, USA

Homero F. Oliveira
Centro Tecnico, Aerospacial
S. Jose dos Campos
S.P. CEP 12225, Brazil

Advanced implementation of the dantzig-wolfe decomposition applied to transmission networks

The routing problem in a transmission network at medium term planning of telecommunication network is studied with an optimization model with non linear and non differentiable objective function and multicommodity-reliability conditions.

The mathematical model is transformed in a large-scale linear with reliability, equilibrium and capacity linear conditions but with implicit network structure. The model may be solved using Dantzig-Wolfe decomposition considering the reliability and the equilibrium linear conditions in the subproblem and the capacity conditions in the master problem.

An advanced implementation of the above decomposition has been necessary to can solve real problems in personal computers. Real test networks has been used to test the decomposition. Thus is possible obtain interesting conclusions and study the advantages of exact methods in front to classical heuristic ones.

Fátima G. Ayllón
Telefónica Investigación y Desarrollo,
Emilio Vargas, 6, 28043 Madrid, Spain.

Jorge Galán, Angel Marín and Angel Menéndez
Departamento de Matemática Aplicada, E.T.S.
Ingenieros Aeoronáuticos, Madrid 28040, Spain.

Algorithms for Solving the Large Quadratic Network Problems

In this article, an active set algorithm based on the Lagrangian dual formulation is proposed for the minimization of quadratic network flows problems. The dual problem is an unconstained maximization problem with differentiable costs. Therefore, a conjugate gradient algorithm can be applied. However, when the problem size is large, an active set strategy is necessary to solve the problem efficiently. We show that the new algorithm is finite when the line search is exact and the dual function has a bounded level set. An extensive computational study is presented to evaluate the performance of this approach.

Chi-Hang Wu and Jose A. Ventura
Department of Industrial and Management
Systems Engineering
The Pennsylvania State University
207 Hammond Building
University Park, PA 16802

Minmax Problems Arising in Optimal m-stage Runge-Kutta Differencing Scheme for Steady-state Solutions of Hyperbolic Systems

In order to construct the optimal m-stage Runge-Kutta differencing scheme for solving steady-state solutions of hyperbolic systems, it is necessary to solve the minimax problem of the form

$$\min_{z \epsilon R^m, x > 0} \; \max_{z \epsilon S} \; |f(z,x)|$$

where S is a compact region in C, and f is a mth degree polynomial of z and is continuously differentiable in x. In this talk, we will first show that for each m, this minmax problem is equivalent to a convex programming problem and therefore it has a unique solution Then we will present a numerical scheme which solves this minmax problem when S contains finite many complex numbers and approximates an optimal solution of this minmax problem when S is a compact region: $\{z; a \leq |z| \leq b\}$. Some testing results will also be discussed.

Mei-Qin Chen
The Citadel, Charleston, SC
Chichia Chiu
Michigan State University, Eastlansing, MI

A Method for Generalized Minimax Problems

We consider the following generalization of the finite minimax problem:

$$\min_x f(y_1(x), \ldots, y_m(x)), \qquad x \in R^n,$$

where

$$y_i(x) = \max_{j \in I_i} \phi_{ij}(x),$$

I_i is a finite index set and ϕ_{ij} is a smooth function.

Problems of this form can be solved by employing methods of nondifferentiable optimization, but superlinearly convergent algorithms are not available.

Under suitable assumptions, we show that the problem is equivalent to the unconstrained optimization of a smooth function. Thus Newton-type methods can be employed.

Gianni Di Pillo, Luigi Grippo
Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza", via Eudossiana 18, 00184 Roma, Italy

Stefano Lucidi
Istituto di Analisi dei Sistemi ed Informatica del CNR, Viale Manzoni 30, 00185 Roma, Italy

Convergence Conditions for the Regularization Methods that Solve the Min-Max Problem

To solve the finite min-max problem, the authors have presented in earlier papers, first and second order regularization methods, that solve the non-differentiable problem, using a sequence of first order differentiable approximations. A dual vector parameter is used to generate these approximations. Conditions for several updating formulae for this parameter are given, to achieve global convergence to a Kuhn-Tucker point. Also second order conditions ensure convergence to a local minimum of the original problem, and a second directional derivative of the regularized function is then needed. The relation between the regularization function and augmented Lagrangeans has also been presented before, but conditions for the penalty parameter to achieve convergence will be given.

Cristina Gigola
ITAM
Mexico

Susana Gomez
Department of Numerical Analysis
IIMAS - Universidad Nacional de Mexico
Apdo. Postal 20-726 Mexico
DF 10200 Mexico

The Phase-Problem in Crystallography

The problem is to compute the shape of a crystal, i.e. a function p(x) on the unit-cube (the electron density). Only the moduli of the Fourier coefficients of p are known, via X-ray diffraction; a possible formulation is to maximize an entropy function of p, subject to the moduli-constraints. We present a hierarchical approach, giving birth to a minimax problem: in the inner maximization, the phases are fixed (and we actually minimize with respect to the Lagrange multipliers); then, the unknown phases solve the outer maximization problem.

Andrée Decarreau
Département de Mathématiques Université de Poitiers.
40 avenue du Recteur Pineau, 86022 Poitiers (France).

Danielle Hilhorst
Laboratoire d'Analyse Numérique. CNRS & Université de Paris-Sud,
91405 Orsay (France).

Claude Lemaréchal
INRIA, BP 105, 78153 Le Chesnay (France).

Jorge Navaza
Centre pharmaceutique. Université de Paris-Sud,
92290 Châtenay-Malabry (France).

An Optimization Problem on Subsets of the Symmetric Positive Semidefinite Matrices.

The optimization problems associated with multidimensional scaling (MSD), described in the presentation by Trosset, Tarazaga and Tapia have the added difficulty of dealing with rank restrictions.

Here we consider the problem of minimizing a strictly convex function over the set of symmetric positive semidefinite matrices with rank less than or equal to k. This problem is not convex when k is less than the order of the matrix. We discuss a transformation of the problem and some characteristics of this setting.

Pablo Tarazaga
Department of Mathematic
University of Puerto Rico
Mayaguez, Puerto Rico 00709-5000.

Michael Trosset
Consultant
P.O. Box 40993
Tucson, AZ 85717-0993

Richard Tapia
Department of Mathematical Science
Rice University
Houaton, TX 77251-1892.

Minimization of Nonlinear Functionals over Finite Sets of Matrices

The main purpose of this work is to minimize the number of arithmetic operations necessary to minimize a nonlinear functional F defined on sets of matrices. The basic problem is as follows:

$$\underset{G}{\text{Minimize}}\ F(G,G^t) = [\text{trace}(GG^t)^{-1}]^{\frac{1}{2}}$$

where the real n by n matrix G is given by $G = (e_{i+1,1}e_{i+1,2}\cdots e_{i+1,n}1)$, where $(i = 0,1,2,\ldots,n)$ subject to the set of constraints given by

$$(e^2_{i+1,1}+e^2_{i+1,2}+e^2_{i+1,3}+\cdots+e^2_{i+1,n} = 1), \text{ where}$$
$$(i = 0,1,2,\ldots,n)$$

Applications of this type of problem will be given. For the case of large matrices use is made of parallel processing and supercomputers.

John Jones, Jr.
Department of Mathematics and Statistics
Air Force Institute of Technology
Wright-Patterson AFB, Ohio 45433
and
The George Washington University
Washington, D.C.

WEDNESDAY PM

Positive Definite Constrained Least Square Estimation of Matrices

This paper presents a method for positive definite constrained least square estimation of matrices. The approach is to transform the positive definite constrained least square problem into an equivalent convex quadratic program with infinitely many linear constraints and solve the latter by generating and solving a sequence of ordinary convex quadratic programs. By specifying a parameter the method will find a sub-optimal solution in a finite number of iterations or an optimal solution in the limit.

H. Hu
Department of Mathematical Sciences
Northern Illinois University
DeKalb, IL 60115

An Interior-Point Method for Minimizing the Largest Eigenvalue of a Linear Combination of Symmetric Matrices

We consider the problem (P) of minimizng the largest eigenvalue of the matrix $A(x) = A_0+x_1A_1+\dots+x_mA_m$ for $x \in R^m$ and given symmetric matrices A_i. The problem arises e.g. in the stability analysis of dynamical systems. Classical methods for solving (P) based on algorithms for nondifferential optimization exhibit a rather slow convergence behaviour. Recently, Overton proposed a locally quadratically convergent method for solving (P). The method presented here is globally linearly convergent, and numerical experiments indicate that the method may be efficient in practice. In our talk we will outline a primal interior-point algorithm for solving (P) and present some theoretical and numerical results.

Florian Jarre
Institut für Angewandte Mathematik
Universität Würzburg, Am Hubland
W-8700 Würzburg, Germany

Genetic Algorithms in Combinatorial Optimization

Genetic algorithms (GAs) are search procedures based on the mechanics of natural genetics and selection. GAs iteratively use Darwinian survival-of-the-fittest principle along with a structured recombination operator on a population of artificial chromosomes representing the problem parameters. Because of GAs' simplicity, global perspective, and implicit parallel information processing, they have been successful in a wide variety of problems including science, commerce, and engineering.

However, despite their empirical success, GAs have been criticized for their inherent linkage problem that causes GAs to converge to a false optima in a class of problems called deceptive problems. A more flexible GA called a messy GA has been devised and tested for this purpose. Messy GAs work by first searching tight linkages in a problem and then combining them together to form the optima in a way that mimics nature's processing of simple organisms to form more complex life forms. Theoretical analyses supported by empirical evidence have shown that messy GAs solve a problem of bounded deception in a time that grows only as a polynomial function to the number of decision variables on a parallel machine. These findings are interesting and encourage GA's application to difficult combinatorial optimization problems that remained unsolved for the want of suitable solution techniques.

Kalyanmoy Deb
University of Illinois
Urbana, Illinois 61801

Parallelization of Probabilistic Sequential Search Algorithms

We compare some strategies for the parallelization of probabilistic sequential search algorithms. We are concerned with those probabilistic sequential search algorithms which generate a sequence of candidate solutions where each solution is generated from the previous one by the application of a probabilistic local improvement operator. Two good examples of such algorithms are Lin's 2-opt strategy for the Travelling Salesman Problem and Simulated Annealing. We explore the concept of searching by a pool of candidate solutions.

In this work we compare some strategies of parallelization of Lin and Kernighan's 2-opt operator for the Traveling Salesman Problem. In particular, we study tradeoffs between processors working independently and processors communicating at regular intervals. We show that a good strategy of parallelization is one that involves communication at fairly regular intervals. We also explore the selection strategy, of Holland's Genetic Algorithms as a strategy for information exchange.

Prasanna Jog
DePaul University
Chicago, IL 60614

A Genetic Algorithm For The Set Partitioning Problem

The Set Partitioning Problem is a difficult combinatorial optimization problem with many applications, a particularly important one being airline crew scheduling. Because it is a highly constrained problem, Set Partitioning is difficult for Genetic Algorithms. In this talk we discuss a method for computing approximate solutions to Set Partitioning Problems based on a Genetic Algorithm augmented with a local search heuristic. We use several specialized data structures that are advantageous for solving Set Partitioning Problems. Computational results are presented for several test problems.

David Levine
Argonne National Laboratory
Mathematics and Computer Science Division
9700 Cass Avenue South
Argonne, IL 60439

A Hybrid Genetic Approach to Energy Minimization in Layered Superconductors

This presentation describes a hybrid genetic approach to the solution of energy minimization problems that arise in the study of layered superconductors. The underlying problem is to understand the behavior of flux vortices in such materials in the presence of external magnetic fields.

Multiple instances of a deterministic optimization procedure run in parallel from different starting points in order to find local minima. A genetic algorithm selects successive generations of starting points based on the fitness of solutions found by these local methods.

David Malon
Argonne National Laboratory
9700 Cass Avenue South
Argonne, IL 60439

On Minimizing the Largest Generalized Eigenvalue of an Affine Family of Hermitian Matrix Pairs

We consider the quasi-convex optimization problem:

$$\inf_{x_l \leq x \leq x_u} \overline{\lambda}\left(A_0 + \sum_{i=1}^{m} x_i A_i,\ B_0 + \sum_{i=1}^{m} x_i B_i\right) \qquad (1)$$

where A_i's and B_i's are Hermitian matrices, $\overline{\lambda}$ denotes the largest generalized eigenvalue, and, for any feasible x, the matrix $B_0 + \sum_{i=1}^{m} x_i B_i$ is assumed to be positive definite. We show that the solution of (1) can be obtained by estimating the solutions of a sequence of convex optimization subproblems, which will be solved by a proposed cutting plane based algorithm. Special considerations are given to utilize information between the subproblems. it is also shown that, with a technique of removing nonactive constraints in the LP problems involved in the cutting plane algorithm, the LP problems can be often solved very efficiently.

Michael K.H. Fan Batool Nekooie
School of Electrical Engineering
Georgia Institute of Technology, Atlanta, GA 30332

On the Variational Analysis of All the Eigenvalues of a Symmetric Matrix

Let A(.) be a real symmetric matrix-valued function of $x \in X \subset R^p$ and $\lambda_1(x) \geq \lambda_2(x) \geq \cdots \geq \lambda_n(x)$ be its eigenvalues arranged in the decreasing order. The main purpose of this paper is to study two closed related problems, namely, the sensitivity analysis of <u>any</u> eigenvalue, say $\lambda_m(x)$, for $1 \leq m \leq n$, and the sensitivity analysis of $f_m(x)$, the sum of the m greatest eigenvalues, under some mild assumption such as A(.) is strictly differentiable. Based on the Ky Fan's variational principle and some chain rule of calculus, we derive a formula for the generalized gradient of f_m and a computationally useful formula for the directional derivative of f_m. Using this latter formula and the relation $\lambda_m = f_m - f_{m-1}$, we then obtain the directional derivative of λ_m.

Jean-Baptiste Hiriart-Urruty and Dongyi Ye
Université Paul Sabatier
Laboratoire d'Analyse Numérique
Toulouse, FRANCE

Optimality Conditions and Duality Theory for Minimizing Sums of the Largest Eigenvalues of Symmetric Matrices

This paper gives max characterizations, in terms of the Frobenius inner product, of the sum of the largest eigenvalues of a symmetric matrix. These max characterizations show that if the matrix is a smooth function of a vector of parameters then the sum of the largest eigenvalues is a regular locally Lipschitz function of these parameters. The elements which achieve the maximum provide a concise characterization of the generalized gradient in terms of a dual matrix. The dual matrix provides the information required to either verify first-order optimality conditions at a point or to generate a descent direction for the eigenvalue sum from that point, splitting a multiple eigenvalue if necessary. A model minimization algorithm is outlined, and connections with the classical literature on sums of eigenvalues are explained. Sums of the largest eigenvalues in absolute value are also addressed.

M. L. Overton
Courant Institute of Mathematical Sciences
New York University

R. S. Womersley
School of Mathematics
University of New South Wales

Variational Properties of the Spectral Abscissa and Spectral Radius Maps

Variational properties for the spectral radius and spectral abscissa of an analytic matrix valued mapping $A : C^s \rightarrow C^{n \times n}$ are considered. A notion of directional differentiability is introduced that allows us to exploit the perturbation results of Newton, Puiseux, Kato, and Arnold. Lower bounds for the directional derivative are established which yield formulas for the directional derivative when a natural nondegeneracy condition is satisfied. These formulas are interpreted in the extreme cases where the eigenvalues attaining either the spectral radius or the spectral abscissa are nonderogatory or semisimple (nondefective). We conclude by investigating the relationship with the proximal normal subdifferential.

James V. Burke
Math. Dept., GN-50
University of Washington Seattle, WA 98195

Michael L. Overton
Computer Science Department
Courant Institute of Mathematical Sciences
New York University
251 Mercer St.
New York, NY 10012

A Mathematical Programming Approach for Optimal Control of Distributed Parameter Systems

A class of optimal control problem for a damped distributed parameter system is considered. The proposed approaches approximate each control force of the system by a Fourier-type series. In contrast to standard linear optimal control approaches, this method is an optimal approach in which the necessary condition of optimality is derived as a system of linear algebraic equations. The proposed approach is easy to apply to a large class of control problems. A vibrating beam excited by an initial disturbance is studied numerically in which the effectiveness of the control and the amount of force spent in the process are investigated in relation to the reduction to the dynamic response.

M. Nouri-Moghadam
Department of Mathematics
Penn State University
Lehman, PA 18627

I. S. Sadek
Department of Mathematical Science
University of North Carolina at Wilmington
Wilmington, NC 28403

WEDNESDAY PM

Optimal Control of Distributed Parameter Systems: Exact and Approximate Methods

A maximum principle is employed to solve analytically a linear-quadratic optimal control problem of a certain class of elastic vibrating structures. The main characteristic of these techniques is reducing this problem to that of solving systems of algebraic equations, thus greatly simplifying the problem and making it computationally plausible. An illustrative example of an optimal control is given, and the computational results are compared with those of exact solution.

Ibrahim Sadek
Department of Mathematical Sciences
University of North Carolina at Wilmington
Wilmington, NC 28403

Optimal Control of Thin Plates by Point Actuators and Sensors

The optimal control of a class of self-adjoint distributed parameter systems (e.g., vibrating thin plates) using a combined open-closed loop control mechanism is considered. In particular, the proposed method involves the application of a finite number of actuators and sensors to actively dampen the undesirable transient vibrations of rectangular plate.

This method gives an explicit optimal open-loop control as a function of the prescribed closed-loop control. The effectiveness of the proposed control is illustrated by a numerical example on a simply-supported plate subject to specific initial conditions. Moreover, the sensitivity of the method in conjunction with the locations of the actuator and sensor is examined by numerical simulations.

Mark Blanton
Department of Mathematics
University of North Carolina at Wilmington
Wilmington, NC 28403-3297

Optimal Control of Non-Classically Damped Distributed Structures

Optimal control of a large class of distributed systems is investigated. The behavior of such systems is governed by partial differential equations with an appropriate boundary condition where the damping is non-proportional.

In controlling distributed systems with non-proportional damping, it is customary to express the equation in its state-space form and proceed with the available methods for lumped-parameter systems. However, a new, computationally efficient, iterative technique was introduced and shown to converge to the exact solution, requiring less operations than that needed for the larger state-space equations. Applicability, as well as robustness of this iterative method will be studied in detail. The proposed method will be applied to several physical systems and numerical results and simulations will be presented subsequently.

Ramin S. Esfandiari
Department of Mechanical Engineering
California State University
Long Beech, CA 90840-5005

Simultaneous Design - Control Optimization of Composite Structures

The optimal layer thickness and optimal feedback control function are determined for a symmetric, cross-ply laminate. The objectivies of the optimization is to maximize the fundamental frequency (design objective) and to minimize the dynamic response to external disturbances (control objective) subject to a constraint on the expenditure of control energy. The design/control problem is formulated as a multiobjective optimization problem by employing a performance index which combines the design and control objectives in a weighted sum. Numerical results are given for a laminate made of an advanced composite material. Comparisons of controlled and uncontrolled laminates as well as optimally designed and non-optimal laminates indicate the benefits of treating the design and control problems in a unified formulation.

Sarp Adali
Department of Mechanical Engineering
University of California at Santa Barbara
Santa Barbara, CA 93106
(On leave from the University of Natal Durban, South Africa).

On the Complexity of Approximately Solving LP's Using Minimal Computational Precision

Complexity theory has assumed problem instances are encoded with exact data, and algorithmic efficiency has been measured in terms of the (bit) length of the encoding. This is appropriate for combinatorial problems, but less so for numerical problems where the goal is to approximate a solution. For numerical problems it makes more sense to measure a problem instance in terms of the stability of its solution under data perturbations. (If the solution is stable then crude data accuracy is sufficient and hence the bit length of the exact data is irrelevant.)

The speaker will discuss some highlights of research on linear programming which attempts to address these issues.

James Renegar
School of Operations Research and Industrial Engineering
Cornell University
Ithaca, NY 14853

Pre-Selection of the Phase I - Phase II Balance in a Path-Following Algorithm for the "Warm Start" Linear Programming Problem

In solving a linear program from an infeasible "warm start," it is useful to pre-select the tradeoff between infeasibility (Phase I) and non-optimality (Phase II). This paper presents a path-following algorithm that will follow a path from a given infeasible "warm start" to an optimal solution along a path with a pre-specified balance of infeasibility and nonoptimality. The algorithm obtains a fixed improvement in both objectives in O(n) iterations using Newton's method, with no assumptions regarding foreknowledge of primal or dual solutions.

Robert M. Freund
M.I.T., Sloan School of Mgmt.
50 Memorial Drive
Cambridge, Mass. 02139

Global Convergence of a Primal-Dual Exterior Point Algorithm for Linear Programming

We propose an algorithm for solving a primal-dual pair of linear programming problems. The algorithm starts from any point at which nonnegative variables are positive. At each iteration of the algorithm, we compute the Newton direction for a system defining a center. The next iterate moves to the direction by different step sizes in primal and dual spaces. We show that in a finite number of iterations, the algorithm computes an approximate optimal solution or finds that the primal-dual pair has no interior feasible points in a wide region given in advance.

Masakazu Kojima
Departments of Information Sciences and Systems Science
Tokyo Institute of Technology
Meguro-ku, Tokyo 152, Japan

Nimrod Megiddo
IBM Almaden Research Center
650 Harry Road, San Jose, California 95120-6099
and School of Mathematical Sciences
Tel Aviv University, Tel Aviv, Israel

Shinji Mizuno
The Institute of Statistical Mathematics
4-6-7 Minami-Azabu, Minato-ku, Tokyo 106, Japan

Polynomial Complexity vs. Fast Local Convergence for Interior Point Methods

All interior methods for linear programming are basically iterative methods of a nonlinear flavor. At each iteration the original objective function, or the primal-dual gap, or a certain potential function, is decreased. The best complexity results show that the distance to the optimal value become less than 2^{-L} in at most $O(\sqrt{n}L)$ iterations. This translates into linear convergence rate with global factor $1-c/\sqrt{n}$. In practice much faster convergence is observed , especially when we are close to the solution. We discuss the relationship in between global convergence, local convergence, and finite termination criteria. New efficient algorithms that have optimal global and local properties are presented.

Florian Potra.
University of Iowa, Iowa City, IA.

Implicit Functions and Lipschitz Stability in Control and Optimization

The talk is concerned with Lipschitz properties of maps, defined implicitly by generalized equations. We discuss several known implicit functions and metric reularity results and present a new implicit function theorem for pseudo-Lipschitz maps. As applications we examine various stability problems in control and optimization, focusing in particular on the stability of the feasible sets and the optimal solutions.

A.L. Dontchev
Mathematical Reviews
Ann Arbor, MI 48107

W.W. Hager
UNiversity of Florida
Department of Mathematics
Gainesville, FL 32611

Applications of structured secant approaches in Hilbert space

Some problem classes of general importance like e.g. integral equations, parameter estimation problems and control problems possess special structure in their derivatives. To exploit these problem dependent properties we discuss applications of structured and totally structured secant approaches in the framework of Hilbert space problems. We show how problem dependent structure can be used to construct approximations of the Jacobian and the Hessian, respectively. We comment on the convergence theory for the given methods, discuss implementational issues and we present numerical results obtained for the discussed applications.

J. Huschens
Universität Trier
FB IV - Mathematik
Postfach 3825
D-W-5500 Trier
Federal Republic of Germany

Optimization in Impulsive Stochastic Control: Time Splitting Approach

Usually in stochastic control models the successive impulsive actions are meant to be separated by positive time intervals. However, in reasonable models with random outcomes of impulses, the precise optimum is attained only if controls with several instantaneous repetitions of impulses are also allowed. For a rigorous treatment of optimal control in such models, we introduce here a new notion referred to as stochastic process with time splitting. In this framework, optimality conditions in the form of quasivariational inequalities are shown to hold. To illustrate, we present an example of a continuous-time two-armed bandit problem (studied in detail by D. Donchev).

Alexander A. Yushkevich
Department of Mathematics
University of North Carolina at Charlotte
Charlotte, NC 28223

H^∞-Optimization with Decentralized Controllers

Even though the H^∞-optimal control of linear systems with centralized controllers has reached a level of maturity during the past decade, little is known on extensions of this theory to decentralized systems, where different controllers acting on the same system have access to different output measurements. A major difficulty here is the establishment of the existence of globally optimal solutions, as well as their characterization, as opposed to that of person-by-person optimal solutions.

In this paper, we obtain such a globally optimal solution for a discrete-time linear-quadratic disturbance rejection problem with a decentralized control/measurement structure. The approach uses the framework of zero-sum dynamic games, in which context we prove the existence of and obtain a characterization for a decentralized saddle point for a related soft-constrained game.

Garry Didinsky and Tamer Başar
Decision and Control Laboratory
Coordinated Science Laboratory
University of Illinois
1101 West Springfield Avenue
Urbana, IL 61801 / USA

A Comparison of Barrier Function Methods with Lagrangian Method for Nonlinear Programming

The problem of minimizing nonlinear functions often arises in practice. In the past few years there have been significant developments in different approaches used to solve these types of problems. However, of recent, since the introduction of Karmarkar's Interior-Point method for solving linear problems, a lot of interest has been renewed in using similar approaches for solving large nonlinear programming problems. In this work large scale nonlinear problems are solved using Barrier and Potential functions, and the results compared with results from those obtained using Lagrangian methods. The classes of problems considered arise from:- VLSI placement, electricity generation and oil refinery production planning.

WEDNESDAY PM

Amarinder Singh
University of Waterloo, Waterloo,
On. N2L 3G1, Canada.
Kumaraswamy Ponnambalam
University of Waterloo, Waterloo,
On. N2L 3G1, Canada.
Telephone: (519) 885 1211 ext 3825.
Fax : (519) 746 4791

Recent Improvements on FSQP

Feasible Sequential Quadratic Programming (FSQP) has been studied for several years by the authors and their colleagues. Recent progress has been made in enhancing the efficiency of the method and applying it to the solution of engineering problems. A Fortran package has been developed and extensively tested.

In this talk we first review the basic FSQP scheme: tilting and bending of the search direction and possible use of a nonmonotone line search; the latter permits to avoid the Maratos effect at the sole expense of (possibly) a few additional function evaluations in early iteration (initialization). We then observe that, under mild assumptions, initialization is not necessary. Finally, we report numerical experiments on standard test problems as well as on control system design problems.

Jian L. Zhou and André L. Tits
Department of Electrical Engineering
and Systems Research Center
University of Maryland
College Park, MD 20742

An Affine-Scaling, Nonsmooth Newton Hybrid for Constrained Optimization

We present a hybrid of affine-scaling and local Newton's method for nonsmooth equations, aimed at large-scale constrained optimization problems. Problems of interest include those of discrete time optimal control with inequality constraints on state and/or control variables. Convergence properties, computation, and potential for parallelism will be discussed.

D. Ralph
Department of Computer Science, Upson Hall
Cornell University
Ithaca, NY 14853.

A Primal-Dual Interior Point Method for Large Scale Linear and Nonlinear Programming

A globally convergent primal-dual interior point method for general nonlinear optimization problem is considered. The method solves the parameterized Karush-Kuhn-Tucker conditions for optimality by Newton or quasi-Newton iterations from an arbitrary initial point. The parameter attached to the complementarity conditions is used as a barrier parameter and tends to zero as the search proceeds. To obtain the global convergence of the iteration the barrier-penalty function with respect to the primal variable is used. A code for large scale linear programming is implemented and it solves all the netlib problems with total iterations which is almost same as that of OB1. A code for dense nonlinear problems is also implemented and it solves all the available (112) test problems of Shittkowski successfully with total iterations of about 2100 and 2600 function evaluations.

Hiroshi Yamashita
Takahito Tanabe
Mathematical Systems Institute, Inc.
6F AM Bldg. 2-5-3, Shinjuku,Shinjuku-ku
Tokyo, Japan 160

Algorithms for the Production and Vehicle Routing Problems with Deadlines

Two new algorithms are presented for an extension of the well known delivery vehicle routing problem with time constraints. The extension involves the presence of a production process determining the rate of availability of the product being delivered. The vehicle dispatch order is therefore important and must be determined in conjunction with the routes to be used. One of the algorithms is a hybrid route construction and improvement algorithm , while the other uses set partitioning. Numerical experience with the algorithms is discussed.

M.A. Forbes, J.N. Holt, P.J. Kilby and A.M. Watts
Centre for Industrial and Applied Mathematics and
Parallel Computing, Department of Mathematics, The
University of Queensland, Queensland 4072, Australia

ADDENDUM

An Algorithm for Solving the Cost Optimization Problem in Precedence Diagram Network

In the first part of the performance, we extend the cost optimization problem solved by Kelley Walker and Fulkerson to the precedence diagramming network.

We allow the next precedence relationship between activities which are represented by nodes.

SSt: start-start-t
SFt: start-finish-t
FSt: finish-start-t
FFt: finish-finish-t

We briefly discuss the main differences between CPM and precedence diagram network, from the aspect of cost optimization problem.

Finally we show and explain the basic idea of the algorithm which is based on a network flow approach.

Miklos Hajdu
Technical University of Budapest
Department of BUilding Organization and
Management
Muegyetem rkp. 3. K. II. 17.
Budapest, 1111.
Hungary

Redistribution Transport Means the Traffic in the Area of Subway is Shut

The task redistribution of the ground passengers transport means for the transport of passengers in the area of subway where the traffic is temporarily shut are under consideration.

The ground transport of the passenger according to the corresponding route from the another routes, which are situated near the part subway above-mentioned. The redistribution of the ground passenger transport means take place according to criterion of minimisation additional loss time passenger for the waiting transport service. The stability of the received decision for the case of alteration of the passenger correspondences are under consideration.

Mishenko Aleksndr
Plekanov Acad. National Economy
Dep. Econ. Cybernetics
Stremyanii Pereyloc 28
113054 Moscow U.S.S.R.

Projective Interior Point Methods O(sqrt(n)L) Step-Complexity

We develop a projective interior point method that is path-following and, hence, has a step-complexity of O(sqrt(n)L). We also show how to modify Karmarkar's and several other projective interior point methods so that their step-complexities are also O(sqrt(n)L), and relate these modified methods to potential reduction methods.

Donald Goldfarb
Department of Industrial Engineering
and Operations Research
Columbia University
New York, NY 10027

Dong Shaw
Rider College
Lawrenceville, NJ 08648

On the Convergence of Pattern Search Methods

We present a general convergence theory for a class of direct search methods, which we call pattern search methods. Direct search methods are methods for solving unconstrained optimization problems without computing, or even estimating derivatives. We define pattern search methods to be direct search methods for which the search strategy at every iteration is predetermined by a particular pattern, or template. Examples include the multidirectional search algorithm of Dennis and Torczon, the factorial design algorithm of Box, and the (original) pattern search method of Hooke and Jeeves; each is distinguished by the choice of pattern used to drive the search procedure.

The theory we will present is the most general of the known convergence results for these methods. The theory is also unusual in that pattern search methods require only strict decrease in the value of the objective function; no assumption of sufficient decrease is required to prove convergence.

Instead, an interesting appeal to discrete mathematics is used to complete the argument.

Virginia Torczon
Department of Mathematical Sciences
Rice University
Houston, TX 77251-1892

A Trust Region Method for Nonsmooth Programming

The classical trust region algorithm for smooth nonlinear programs is extended to the nonsmooth case where the objective function is only locally Lipschitzian. At each iteration, an objective function that carries both first and second order information is minimized over a trust region. The term that carries the first order information is an iteration function that may not explicitly depend on subgradients or directional derivatives. We prove that the algorithm is globally convergent. This convergence result extends the results of Powell for minimization of smooth functions, the results of Yuan for minimization of composite convex functions, and the recent model of Dennis, Li and Tapia for minimization of regular functions. In addition, compared with the recent model of Pang, Han and Rangaraj for minimization of locally Lipschitzian functions via line search, this algorithm has the same convergence property without assuming positive definiteness and uniform boundedness of the second order term. Applications of the algorithm to various nonsmooth optimization problems are discussed.

Liqun Qi
University of New South Wales, Kensington, NSW, Australia

Jie Sun
Northwestern University, Evanston, IL, USA

Adaptive Filtering in Nonlinear Parameter Estimation with Serially Correlated Data Structures

Underwater detection and tracking is a complex, nonlinear state estimation problem. Previous work has demonstrated an efficient and flexible approach to the problem using compressed data sets. In this approach time segments of measured data are represented by sufficient statistics. It has been shown that tracking performance may be enhanced by exploiting the bias/noise variance tradeoff and adaptively selecting the rank of the statistic used for segment representation. Correlated noise structures, however, can cause severe modeling and estimation anomalies. This paper extends the methods developed for adaptive rank selection to include the issue of serial correlation in the measurement noise structure. Monte Carlo simulation results for a trajectory estimation problem using noisy angle-of-arrival measurements are presented.

Frank O'Brien
Marcus L. Graham
Kai F. Gong
U.S. Naval Underwater Systems Center
Code 2211, B 1171-1
Newport Laboratory
Newport, RI 02841-5047

Quadratic Programming with Approximate Data: Ill-Posedness and Efficient Algorithms

We present algorithms for Quadratic Programming problems specified with approximate data. This is important when rounding errors prevent the use of exact numbers or only estimates or the real data are available. The algorithms are efficient from the point of view of computation and data needed, requiring an excessively precise approximation and excessive computation only for nearly ill-posed instances. This work is a continuation of the research we have done for Linear Programming, presented at ICIAM91, and points towards the understanding of ill-posedness in optimization and the formulation of a complexity theory of problem solving with approximate data.

Jorge R. Vera
Department of Operations Research
Cornell University
Ithaca, NY 14853

Experiments with the Broyden Class of Quasi-Newton Methods

In this talk we use a new rule to summarize numerical results required to solve a set of standard unconstrained optimization problems by new quasi-Newton methods. The new methods switch among several available methods and belong to a new class of methods proposed within the Broyden class on the basis of estimating the size of the eigenvalues of the Hessian approximation. The rule measures the improvement percentage of the methods against the BFGS method. The results show that the performance of the new methods is better than that of the BFGS method and almost similar to that of the idealized method of Byrd, Liu and Nocedal (1990) (which requires the calculation of the Hessian matrix at each iteration).

M. Al-Baali
Department of Systems
University of Calabria
87036 Arcavacata (Cosenza)
Italy

On the Performance of a Trust Region Newton Method for Large-Scale Problems

We are concerned with the solution of large-scale optimization problems with sparse Hessians. A trust region Newton method is used in which the trust region subproblems are solved by the preconditioned conjugate gradient method. In particular, we use an improved sparse incomplete Cholesky factorization as a preconditioner. The new algorithm is compared with several existing algorithms for unconstrained minimization. Convex and nonconvex (indefinite) problems from the MINPACK-2 test problem collection are used for these comparisons.

Brett M. Averick
Army High Performance Computing Research Center
University of Minnesota, Minneapolis, MN 55415

Richard G. Carter
Army High Performance Computing Research Center
University of Minnesota, Minneapolis, MN 55415

Jorge J. Moré
Mathematics and Computer Science Division
Argonne National Laboratory Argonne, IL 60439

Iteration Functions in Nonsmooth Optimization and Equations

Some globally convergent model algorithms have been proposed for solving nonsmooth optimization problems. These algorithms do not explicitly depend on subgradients, but are based upon some iteration functions of two arguments. Iteration functions or pointed-based approximations were also introduced in algorithms for solving nonsmooth equations to reach global or superlinear convergence. The existence of iteration functions depend upon the original function in the nonsmooth optimization or the nonsmooth equation problem. In nonsmooth optimization, Poliquin and Qi proved that a necessary condition for existence of iteration function in the sense of Pang-Han-Rangaraj or Qi-Sun is that the original function is pseudo-regular in the sense of Borwein, and a sufficient condition for existence of iteration function in the sense of Pang-Han-Rangaraj is that the original function is subsmooth (lower C^1) in the sense of Rockafellar and Spingarn. It was also shown that such an iteration function is not unique in general and is a certain kind of "continuous" approximation of the upper Dini directional derivative of the original function.

Liqun Qi
University of New South Wales, Kensington, NSW, Australia

Trust Region Methods for Large Constrained Optimization

We begin by considering bound-constrained problems and focus on two crucial questions: (i) how can we use negative curvature information, in particular, second derivatives? (ii) how can we keep the iteration cost to minimum? We propose an approach well-suited for large problems.

We then consider the general nonlinearly constrained problem and discuss an adaptation of an algorithm proposed by Byrd and Omojokun, designed to be efficient when the number of variables is very large. Numerical tests will be described.

Marucha Lalee and Jorge Nocedal
Northwestern University

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Gould, N.	Mon AM	10:50	11:10	CP1	A2-3	Belmont Room
Gould, N.I.M*	Wed AM	08:30	09:15	IP7	15	Regency A/B
Graham, M.L.	Tue PM	06:00	07:30	Poster 2	A47	Regency A/B
Grandine, T.A.*	Tue AM	11:10	11:30	MS11	A19	Regency A/B
Grandinetti, L.	Tue PM	03:10	03:30	CP15	A24	Water Tower Room
Griewank, A.*	Tue PM	01:30	02:15	IP6	11	Regency A/B
Grigoriadis, M.*	Wed PM	01:30	02:15	IP9	16	Regency A/B
Grino, R.	Tue AM	11:30	11:50	CP11	A20	Toronto Room
Grippo, L.	Wed PM	02:50	03:10	CP25	A41	Acapulco Room
Grippo, L.*	Tue PM	02:50	03:10	CP15	A24	Water Tower Room
Guler, O.*	Mon PM	03:10	03:30	MS6	A6	Water Tower Room
Guptill, J.D.*	Mon AM	11:10	11:30	CP1	A3	Belmont Room
H						
Haddad, E.*	Mon PM	06:00	07:30	Poster 1	A14	Regency A/B
Haeberly, J.P.*	Mon PM	05:00	05:20	MS9	A10	New Orleans Room
Haftka, R.T.	Tue PM	06:00	07:30	Poster 2	A31	Regency A/B
Hager, W.W.	Wed PM	04:20	04:40	CP28	A45	Gold Coast Room
Haidar, S.M.*	Mon PM	06:00	07:30	Poster 1	A17	Regency A/B
Hajdu, M.*	Mon PM	06:00	07:30	Poster 1	A47	Regency A/B
Hallman, W.	Mon AM	11:30	11:50	CP1	A3	Belmont Room
Han, S.-P.	Tue PM	03:10	03:30	CP16	A25	Gold Coast Room
Hao, J.	Tue PM	03:30	03:50	MS12	A22	Belmont Room
Hao, J.*	Tue PM	03:10	03:30	MS12	A22	Belmont Room
Harrell, A.W.*	Mon PM	06:00	07:30	Poster 1	A15	Regency A/B
Hartvigsen, D.*	Mon AM	11:10	11:30	MS2	A1	Water Tower Room
Hattori, T.*	Tue PM	06:00	07:30	Poster 2	A31	Regency A/B
Hemmer, G.M.*	Tue AM	10:30	10:50	CP10	A19	Belmont Room
Hernandez, S.*	Mon PM	06:00	07:30	Poster 1	A13	Regency A/B
High, K.A.*	Tue PM	06:00	07:30	Poster 2	A29	Regency A/B
Hilhorst, D.	Wed PM	03:30	03:50	CP25	A41	Acapulco Room
Hipolito, A.*	Tue AM	11:10	11:30	CP10	A19	Belmont Room
Hiriart-Urruty	Wed PM	04:40	05:00	MS24	A43	Belmont Room
Hirshfeld, D.S.*	Tue AM	10:30	10:50	MS10	A18	Water Tower Room
Ho, J.K.*	Tue AM	11:30	11:50	CP20	A37	Belmont Room
Hochbaum, D.*	Wed AM	10:30	10:50	MS20	A36	Acapulco Room
Hossain, A.K.M.	Mon PM	03:30	03:50	CP6	A8	Gold Coast Room

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Hu, H.*	Wed PM	03:10	03:30	CP26	A42	Gold Coast Room
Hu, Y.H.	Mon AM	10:30	10:50	CP2	A3	Gold Coast Room
Huang, S.*	Tue PM	04:40	05:00	CP19	A28	Gold Coast Room
Huschens, J.*	Mon PM	04:40	05:00	CP7	A45	Gold Coast Room
I						
Infanger, G.	Wed AM	11:30	11:50	CP20	A37	Belmont Room
Isac, G.*	Tue PM	06:00	07:30	Poster 2	A33	Regency A/B
Iusem, A.N.*	Mon PM	06:00	07:30	Poster 1	A14	Regency A/B
J						
Jarre, F.*	Wed PM	03:30	03:50	CP26	A42	Gold Coast Room
Jaumard, B.	Tue PM	05:00	05:20	MS16	A26	New Orleans Room
Jelinski, L.W.*	Tue PM	02:30	02:50	MS13	A22	Regency A/B
Jensen, D.	Tue AM	11:30	11:50	CP10	A19	Belmont Room
Jensen, D.*	Mon PM	06:00	07:30	Poster 1	A14	Regency A/B
Ji, J.	Tue AM	10:50	11:10	CP10	A19	Belmont Room
Ji, J.	Tue PM	04:40	05:00	CP19	A28	Gold Coast Room
Ji, J.*	Tue PM	06:00	07:30	Poster 2	A31	Regency A/B
Jog, P.*	Wed PM	04:40	05:00	MS23	A42	Acapulco Room
Jones, C.V.*	Tue AM	10:50	11:10	MS10	A18	Water Tower Room
Jones, J.*	Wed PM	02:50	03:10	CP26	A41	Gold Coast Room
Judice, J.J.	Mon PM	05:00	05:20	CP8	A11	Gold Coast Room
Judice, J.J.	Tue PM	05:00	05:20	CP19	A28	Gold Coast Room
Judson, R.S.	Mon PM	03:10	03:30	MS5	A6	Belmont Room
K						
Katti, M.*	Tue PM	06:00	07:30	Poster 2	A32	Regency A/B
Kaufman, L.*	Mon AM	10:30	10:50	CP3	A4	Acapulco Room
Kearsley, A.J.*	Mon PM	05:00	05:20	CP9	A12	Water Tower Room
Kelley, C.T.	Mon PM	02:50	03:10	MS5	A6	Belmont Room
Kelley, C.T.*	Tue PM	04:20	04:40	MS15	A25	Belmont Room
Kisala, T.P.	Mon AM	11:10	11:30	MS3	A2	Toronto Room
Klinger, A.	Tue PM	06:00	07:30	Poster 2	A32	Regency A/B
Klinger, A.*	Mon PM	02:50	03:10	CP5	A7	Acapulco Room
Kodiyalam, S.*	Tue AM	10:30	10:50	MS11	A18	Regency A/B
Kojima, M.	Wed PM	05:00	05:20	CP27	A45	Regency A/B
Kojima, M.*	Mon PM	04:40	05:00	MS7	A9	Belmont Room
Kostreva, M.	Mon PM	05:20	05:40	CP9	A12	Water Tower Room
Kountanis, D.	Tue PM	06:00	07:30	Poster 2	A33	Regency A/B
Kountanis, D.	Tue PM	06:00	07:30	Poster 2	A33	Regency A/B
Kountanis, D.	Mon PM	06:00	07:30	Poster 1	A16	Regency A/B
Kovoor, N.	Wed AM	11:10	11:30	M20	A36	Acapulco Room
Kowalewska, U.L.*	Mon PM	06:00	07:30	Poster 1	A14	Regency A/B
Krishnan, R.*	Tue AM	11:30	11:50	MS10	A18	Water Tower Room
Kumar, P.R.*	Tue AM	09:15	10:00	IP5	10	Regency A/B
Kunisch, K.*	Tue PM	05:20	05:40	MS15	A25	Belmont Room
Kuperman, W.A.	Mon PM	03:30	03:50	CP5	A8	Acapulco Room
Kupfer, F.S.	Tue PM	04:40	05:00	MS15	A25	Belmont Room
Kupfer, F.S.*	Mon PM	05:00	05:20	CP7	A11	Acapulco Room
L						
La Roche, R.D.	Tue PM	06:00	07:30	Poster 2	A29	Regency A/B
Lalee, M.*	Wed AM	11:30	11:50	CP22	A48	Gold Coast Room
Lampariello, F.	Tue PM	02:50	03:10	CP15	A24	Water Tower Room
Lasdon, L.*	Mon PM	03:10	03:30	MS4	A5	Regency A/B
Launay, G.	Mon PM	04:40	05:00	CP9	A12	Water Tower Room
Leary, R.H.*	Tue PM	02:30	02:50	CP15	A24	Water Tower Room
Lemarechal, C.*	Wed PM	03:30	03:50	CP25	A41	Acapulco Room
Levine, D.*	Wed PM	05:00	05:20	MS23	A42	Acapulco Room
Lewis, R.M.*	Tue PM	05:00	05:20	MS15	A25	Belmont Room
Lewis, R.M.*	Wed AM	11:30	11:50	MS18	A35	Regency A/B
Li, G.	Tue PM	05:00	05:20	MS17	A26	Acapulco Room
Li, G.*	Mon PM	06:00	07:30	Poster 1	A15	Regency A/B
Li, G.*	Tue AM	11:10	11:30	CP13	A21	Acapulco Room
Li, W.*	Wed AM	11:10	11:30	CP21	A37	Water Tower Room
Li, Y.*	Wed AM	10:30	10:50	CP22	A37	Gold Coast Room
Li, Yong	Tue PM	04:40	05:00	MS16	A26	New Orleans Room
Liao, L.-Z.	Mon PM	04:20	04:40	CP7	A10	Acapulco Room

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Liren, W.*	Tue PM	06:00	07:30	Poster 2	A34	Regency A/B
Liu, J.	Tue AM	10:50	11:10	CP13	A21	Acapulco Room
Lucidi, S.	Tue PM	02:50	03:10	CP15	A24	Water Tower Room
Lucidi, S.	Wed PM	02:50	03:10	CP25	A41	Acapulco Room
Lucidi, S.*	Wed AM	10:50	11:10	CP22	A38	Gold Coast Room
Luo, Z.-Q.	Mon PM	6:00	07:30	Poster 1	A12	Regency A/B
Lustig, I.J.	Mon PM	06:00	07:30	Poster 1	A15	Regency A/B
Lustig, I.J.*	Wed PM	02:30	02:50	MS22	A39	Regency A/B
M						
Maciel, M.C.*	Mon PM	04:20	04:40	CP9	A12	Water Tower Room
Madsen, K.*	Tue AM	10:30	10:50	CP12	A20	Gold Coast Room
Magnanti, T.L.*	Mon PM	01:30	02:15	IP3	07	Regency A/B
Magnitskii, N.*	Tue PM	06:00	07:30	Poster 2	A34	Regency A/B
Mahey, P.*	Tue PM	06:00	07:30	Poster 2	A31	Regency A/B
Maier, R.S.*	Tue PM	06:00	07:30	Poster 2	A29	Regency A/B
Maier, W.R.S.	Tue PM	05:20	05:40	MS16	A26	New Orleans Room
Malon, D.*	Wed PM	05:20	05:40	MS23	A43	Acapulco Room
Mamer, J.	Mon PM	06:00	07:30	Poster 1	A12	Regency A/B
Mangasarian, O.L.*	Wed AM	10:50	11:10	MS18	A34	Regency A/B
Mansouri, A.	Tue PM	06:00	07:30	Poster 2	A30	Regency A/B
Maranas, C.D.	Wed PM	03:10	03:30	MS21	A38	Belmont Room
Marbukh, V.*	Tue PM	06:00	07:30	Poster 2	A32	Regency A/B
Marin, A.*	Wed PM	03:10	03:30	CP24	A40	Toronto Room
Martinez, J.M.*	Tue PM	06:00	07:30	Poster 2	A29	Regency A/B
Mata, J.	Mon PM	06:00	07:30	Poster 1	A13	Regency A/B
Mateus, G.R.	Mon PM	06:00	07:30	Poster 1	A15	Regency A/B
McGeoch, C.*	Tue PM	02:50	03:10	MS12	A21	Belmont Room
McKenna, M.	Mon AM	10:50	11:10	CP3	A4	Acapulco Room
McQuain, W.D.	Mon PM	03:10	03:30	CP6	A8	Gold Coast Room
Medepalli, A.	Wed PM	02:50	03:10	CP23	A39	Water Tower Room
Megiddo, N.	Mon PM	04:40	05:00	MS7	A9	Belmont Room
Megiddo, N.	Wed PM	05:00	05:20	CP27	A45	Regency A/B
Mehrotra, S.*	Mon AM	11:10	11:30	MS1	A1	Regency A/B
Mehrotra, S.*	Wed PM	02:50	03:10	MS22	A39	Regency A/B
Melman, A.*	Mon PM	06:00	07:30	Poster 1	A17	Regency A/B
Melville, R.C.	Mon PM	03:10	03:30	CP6	A8	Gold Coast Room
Menendez, A.	Wed PM	03:10	03:30	CP24	A40	Toronto Room
Mesirov, J.	Mon AM	10:50	11:10	CP3	A4	Acapulco Room
Meyer, R.R.	Mon PM	06:00	07:30	Poster 1	A16	Regency A/B
Meza, J.*	Mon PM	03:10	03:30	MS5	A6	Belmont Room
Mikhail, N.N.*	Mon PM	06:00	07:30	Poster 1	A15	Regency A/B
Mishenko, A.*	Mon PM	06:00	07:30	Poster 1	A47	Regency A/B
Mitchell, J.E.*	Mon PM	06:00	07:30	Poster 1	A15	Regency A/B
Mizuno, S.	Mon PM	04:40	05:00	MS7	A9	Belmont Room
Mizuno, S.*	Wed PM	05:20	05:40	CP27	A45	Regency A/B
Mladineo, R.H.*	Tue PM	06:00	07:30	Poster 2	A32	Regency A/B
Mongeau, M.*	Tue PM	06:00	07:30	Poster 2	A33	Regency A/B
Monteiro, R.D.C.*	Tue PM	02:30	02:50	CP16	A24	Gold Coast Room
Morales-Perez, J.L.	Tue Am	10:30	10:50	CP13	A21	Acapulco Room
More, J.J.	Tue PM	06:00	07:30	Poster 2	A48	Regency A/B
Morshedi, A.M.*	Mon AM	11:30	11:50	MS3	A2	Toronto Room
Mulvey, J.M.*	Mon PM	04:20	04:40	MS8	A9	Toronto Room
Murray, W.	Wed AM	10:50	11:10	MS19	A35	Toronto Room
Murray, W.	Wed AM	11:30	11:50	MS19	A35	Toronto Room
Musmanno, R.	Tue PM	03:10	03:30	CP15	A24	Water Tower Room
N						
Nash, J.C.*	Tue PM	06:00	07:30	Poster 2	A29	Regency A/B
Nash, S.	Mon PM	06:00	07:30	Poster 1	A13	Regency A/B
Nash, S.G.	Tue AM	10:50	11:10	CP11	A20	Toronto Room
Navaza, J.	Wed PM	03:30	03:50	CP25	A41	Acapulco Room
Nekooie, B.	Wed PM	04:20	04:40	MS24	A43	Belmont Room
Ng, P.H.*	Wed PM	03:30	03:50	CP23	A40	Water Tower Room
Nielsen S.S.*	Tue PM	02:30	02:50	MS12	A21	Belmont Room
Nielsen, H.B.	Tue AM	10:30	10:50	CP12	A20	Gold Coast Room
Nielsen, S.S.*	Wed AM	10:30	10:50	MS18	A34	Regency A/B

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