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Seismic Discrimination

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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SEISMIC DISCRIMINATION

SEMIANNUAL TECHNICAL SUMMARY REPORT TO THE DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

1 OCTOBER 1981 — 31 MARCH 1982

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LEXINGTON MASSACHUSETTS

ABSTRACT

This Semiannual Technical Summary describes the Lincoln Laboratory Vela Uniform program for the period 1 October 1981 through 31 March 1982. During this period, the Lincoln prototype Seismic Data Center has been refined and improved, prior to its transfer to its operational site at Rosslyn, Virginia. Section I describes these improvements. Section II describes a series of miscellaneous investigations.

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SUMMARY

This is the thirty-sixth Semiannual Technical Summary (SATS) report describing the activities of Lincoln Laboratory funded under Project Vela Uniform. This report covers the period 1 October 1981 through 31 March 1982. Project Vela Uniform is a program of research into the discrimination between nuclear explosions and earthquakes by seismic means, and development of the data-handling and analysis techniques that may be appropriate in the event that an international agreement on global seismic monitoring is concluded. A prototype Seismic Data Center (SDC) was completed in FY 81. The Lincoln Laboratory FY 82 program consists of refining and improving this prototype, and transferring it to its operational site in Rosslyn, Virginia.

During this period, the prototype SDC has been demonstrated to DARPA and accepted as the basis of an operational system. Substantial improvements have been made to the Seismic Analysis Station (SAS), leading to a much more flexible and useful user interface. The database management system INGRES, developed by Lawrence Berkeley Laboratory, has been installed and tested in the prototype SDC. Attempts have been made to speed up certain types of data retrieval from this system. The Communications Interface Subsystem (CIS) is being assembled under subcontract by Teledyne-Geotech. A first shipment of computer equipment to the Virginia site has been completed, and a detailed schedule has been prepared for the shipment of all remaining equipment during the second half of FY 82.

Several studies have been completed. A special experiment to test the communication facilities of the World Meteorological Organization/Global Telecommunications System (WMO/GTS) was completed during November and December 1981. Substantial discrepancies were observed in the event bulletins prepared in Sweden and the U.S. using the same data set. A detailed report on these discrepancies is in preparation. In another area, an English language interface has been constructed to permit easy interaction with the list of seismic events stored in the database management system. Further extensions of this concept will make the seismic data in the SDC much more accessible to non-computer specialists.

An investigation in the area of yield estimation research is being carried out under subcontract at M.I.T. The initial portion of this study has focused on the trade-offs between explosion source parameters and anelasticity. It has been shown that some ambiguity in interpretation arises from these trade-offs, due in large part to the difficulty in modeling the pP phase.

M.A. Chinnery

SEISMIC DISCRIMINATION

I. SEISMIC DATA CENTER DEVELOPMENT

A. OVERVIEW

As described in the previous SATS* a prototype Seismic Data Center (SDC) was completed at Lincoln Laboratory during FY 81. The purpose of this SDC will be to provide a state-of-the-art data management and analysis system for seismic data, both for the seismological research community and as may be required in international seismic monitoring agreements. The prototype SDC is capable of accepting continuous on-line digital waveform data, digital waveform data on tape and a variety of parametric data, and contains an interactive analysis and display user interface.

During the period covered by this report, some refinements and improvements have been added to the original prototype, and the system has been shipped to a new site in Rosslyn, Virginia, where it is being prepared for operational functions. In the sections that follow, we outline the changes that have been made to the system, and the progress achieved to date at the new site.

M.A. Chinnery

B. SEISMIC ANALYST STATION DEVELOPMENT

The Seismic Analysis Station (SAS) is a single-user interactive computer system for display and analysis of waveform data. A key element in the software of the SAS is an interactive waveform display program, named "DISP", which was briefly described in the previous SATS. DISP uses the Megatek 7000 refresh graphics device to display a waveform database. It allows a seismologist to interactively manipulate the waveforms using a data tablet and a joystick as peripheral devices.

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*Seismic Discrimination Semiannual Technical Summary, Lincoln Laboratory, M.I.T. (30 September 1981).

Many new user-level commands have been added to the program, as well as systems-level improvements to increase the overall efficiency of the program. Waveform decimation and filtering can now be accomplished, including filtering waveforms that have already been filtered. Waveform editing is now possible, which includes copying, moving, and deleting waveforms from the Megatek screen. The number of waveforms displayed on the screen, which was previously set at 6, can now be varied from 1 to 24. We have implemented a function which combines waveform scrolling with horizontal and vertical gain change. The scrolling part of the function allows left and right scrolling of waveforms, as well as vertical scrolling, which is used to overlay waveforms on top of one another. Vertical scaling of waveforms relative to a reference waveform can now be done. We can set an artificial maximum signal level and clip waveforms to that level, which is used to amplify low-level signals.

Another new feature is automatic alignment on the first marker in each waveform, as well as allowing individual waveforms to be aligned on any sample in that trace. A file containing a history of all commands entered during the current DISP session is maintained, which is useful in debugging and recreating the effects of a set of commands. A help command is available which describes the format of each command. The seismologist can now run independent graphics programs from within DISP. This is done by saving the contents of Megatek memory on disk, executing the program as a subprocess, and restoring Megatek memory from disk. To aid the development of other graphics programs on the Megatek, we have converted Graphpac, a set of graphics functions originally developed for the Tektronix 4014, to be used on the Megatek.

An enhanced memory management scheme was implemented which simulates the UNIX functions malloc, free, and realloc, but for Megatek display memory instead of local core storage. The previous memory management scheme allocated fixed-size chunks of the display memory based on the type of entity displayed. This approach was particularly wasteful for seismograms because when displayed in short vector format, as little as half of the preallocated space was actually required. The new approach allows the unused portion of display memory to be freed for use by other graphics entities. As a direct result of this approach it is now possible to display 24 seismograms simultaneously, where the previous maximum was 12.

P.T. Crames
H. Lison

C. DATABASE DEVELOPMENT

The previous SATS described the design of the SDC prototype database. The database uses the INGRES database management system, and contains both parametric and waveform data. During the period of this report, database developments at Lincoln Laboratory have focused on the following areas:

(1) Implementing primitives.

(2) Creating and using experimental databases.

(3) Evaluating performance of databases when used in conjunction with the SAS.

All the primitives described in the previous SATS have been implemented in cooperation with Lawrence Berkeley Laboratory. The functionality of some of the primitives has been altered based on evaluation of their performance.

Several experimental databases have been created:

(1) The largest database consists of the IESD parametric data from 1 October through 15 October 1980, as well as segmented waveforms and detections from 2 October and 4 October. Most of the primitives were developed and tested using this database.

(2) A subset of the above database, consisting of data from 2 October was extracted and used for the SAS tutorial documentation.

(3) A yield estimation database has been assembled. This database consists of waveforms from many American and Russian explosions and has been distributed to several research groups. It has not yet been fully converted into the SDC database format.

Several experimental analyst sessions using the SDC database in conjunction with the SAS have been conducted during the development of both the SAS and the database. The organization of the relations comprising the database appears to work well, although several new data fields have been added.

Although using INGRES has allowed the prototype database to be developed quickly, INGRES has two major drawbacks. The first is that there is no convenient representation of time. Experiments have been carried out using several time representations. Some are convenient for manipulation by the computer, while others are familiar to seismologists but make searching the database difficult. The current scheme is a compromise between these two extremes. It would be better if INGRES had more computational or formatting capabilities so that it could convert between different representations.

The second drawback is that INGRES does not appear to be fast enough for the interactive analysis loop required by the SAS. This loop requires transmitting information between the SAS and the database frequently during an analysis session. The main bottleneck appears to be the time required by external programs to retrieve data from INGRES. Although throughput has been improved by changing some of the primitives, performance is still inadequate for routine use. One possible solution which is being explored is to extract data from the database for a time window and completely analyze it before sending it back to INGRES. Although this would require duplicating some of the capabilities INGRES already has, it could lead to a user interface that would be much more responsive and convenient to use than the current system.

K.R. Anderson

D. INTER-COMPUTER COMMUNICATION

In the prototype SDC, the database management system resides on one computer (a VAX 11/780), while the SAS is driven by another (a PDP-11/44). Pending the development of a local computer network (see below), the two computers were initially connected by a DMC-11 device. During the current period, this has been replaced by a DMR-11. The DMR-11 is a microprocessor-based, intelligent synchronous communication controller. It provides more features and has much better reliability than the DMC-11. Due to the hardware change, some redundant software checks have been removed to achieve better efficiency and yet still keep the same reliability. The latest bench mark shows 600-kbps point-to-point throughput and 210-kbps file-to-file transfer rate. The system load presented by file transfer process is the same as a regular process.

A remote dump algorithm has been implemented, in order to provide flexibility in the use of tape drives. We are carrying out the PDP-11/44 daily system backup via the DMR to the VAX tape drive. The performance is a little better than the regular dump, primarily because the read/write activity has been distributed between two machines.

A new communication server has been implemented to eliminate the master-slave relation between two hosts. Commands can be initiated from either host and a command queuing algorithm is employed to provide better utilization of the DMR bandwidth.

Progress in the development of a local computer network, under subcontract to Sytek Inc. has been slow. After numerous and lengthy delays in engineering checkout, Sytek delivered the local computer network hardware just before the end of the reporting period. At the end of this reporting period, there has been no delivery of the required UNIX driver software, so the checkout of the hardware, integration into the prototype system, and the development of the applications software has not begun. It is expected that the checkout of the hardware and software will begin upon receipt of the driver software early in the next reporting period.

A.G. Gann
H. Hsiung

E. COMMUNICATIONS INTERFACE SUBSYSTEM

The Communications Interface Subsystem (CIS) is being developed under subcontract by Teledyne Geotech. The contract was awarded in June 1981 and continues through the end of September 1982. Shortly after contract award, a PDP-11/44 computer was moved from Cambridge to the contractor's installation in Alexandria, Virginia.

The CIS will handle communications with all the external systems connected to the SDC. It will route data to and from the international subsystems, reorganizing and reformatting as necessary to satisfy the requirements of the internal and external uses of the data. The CIS consists of hardware to interface the external communications systems to the CIS computer, and software to control the hardware and handle the data from the Regional Seismic Test Network (RSTN), other waveform sources, and alphanumeric media such as telex and the World Meteorological Organization's Global Telecommunications System (WMO).

An immediate priority of the CIS was the establishment of a link to the WMO to permit U.S. participation in an international data exchange experiment which took place during November and December 1981. This involved the installation of a direct line to the National Weather Service in Suitland, Maryland, which functions as the U.S. connection to the WMO. This experiment, described elsewhere in this report, was successfully completed using the direct link and software developed for the purposes of the data exchange.

Hardware and software development for the satellite receiver interface has been completed and now awaits final checkout with data from the satellite terminal. The latter has been temporarily installed in Alexandria, Virginia, and should shortly be providing real-time RSTN data which will be transmitted via dedicated lines to the SDC in Arlington, Virginia.

Arrangements have been made for reception of parameter data from the Canadian network, YKA (Yellowknife, Canada, array site) the U.K. arrays in Australia, India, and Scotland, and commercial telex, as well as the WMO. Acquisition of data from Sweden and Norway via TYMNET is being investigated.

The entire CIS, with the exception of the satellite terminal, is scheduled to be moved from Alexandria to the SDC site in Arlington in late April, and shortly thereafter will be connected to the database machine via a DMR-11. CIS development will be continued at its new location. The satellite terminal will be moved to Arlington during the summer of 1982.

R.G. North

F. SYSTEM DOCUMENTATION

SDC documentation follows existing UNIX formats in that we have added new sections to Volumes I and II of the existing manuals to describe software generated at Lincoln Laboratory.

We have added Sec. 9 to Volume I of the Programmer's Manual. This section contains three parts:

(9c) Commands

(9s) Subroutines

(9f) File Formats

These sections reflect the state of development of SDC software as of 20 March 1982.

To Volume II of the manual we have added tutorials and "cookbooks." The tutorials serve to introduce the novice to the SDC in general and then to its separate parts. They include:

Introduction to the SDC Computer System

Design of a Database for the SDC Prototype System

An Introduction to the Vi Editor

A Description of the Megatek Instruction Set

Using the Megatek Waveform Display

Using the Tektronix Waveform Display

A Sample SAS Session

Remote Seismic Terminal User Guide

We have written each tutorial with the intent that the reader try the described sequences at the system. They also function as simple reference guides.

The "cookbooks" include short, simple sequence cards for performing general tasks. Three cookbooks cover:

The SDC in General

The Megatek Waveform Display

The Tektronix Waveform Display

As development continues, these documents will require updating. They can be found in /11/doc (tutorials and cookbooks) or /11/man (Sec. 9 entries).

The tutorials are set up to use sample databases and sample files. These will probably change and must be maintained by the development staff.

R. Treitman

G. TRANSFER OF COMPUTER EQUIPMENT TO THE VIRGINIA FIELD SITE

During FY 82, the prototype SDC system and all associated computer equipment will be transferred to the new field site in Rosslyn, Virginia. This equipment will form the basis for a new Center for Seismic Studies to be established at that site and operated by DARPA subcontractors. A site was chosen, and building alterations completed by late March 1982.

The transfer of Lincoln technology is being carried out in phase with the growth and development of the new Center. During the current reporting period a new VAX 11/780, and a PDP-11/44 (with peripheral devices) were delivered to the Center as it opened. A detailed schedule has been prepared for the transfer of all remaining equipment during the second half of FY 82.

M.A. Chinnery

H. DEVELOPMENT OF THE CENTER FOR SEISMIC STUDIES AT THE VIRGINIA FIELD SITE

An operating contractor for this facility was selected in November 1981 after a competitive bidding process. A lease has been obtained for half of the 14th floor of 1300 North 17th Street, Arlington (Rosslyn), Virginia 22209. Site preparation has taken longer than expected and both personnel and computer equipment were not moved in until the last week of March 1982.

The UNIX™ operating system is now being installed on the computers and it is expected that all the software developed for the Data Center Project will be working shortly.

The immediate project objective is the demonstration of the new facility to a group of DARPA-sponsored researchers on 28 May 1982. This demonstration will involve all subsystems, including the Database Management Subsystem, the Seismic Analyst Station, and the Communications Interface Subsystem. The last is being developed by a Washington area subcontractor and will be moved to the Rosslyn facility in early April 1982. All hardware and software for the real-time reception of Regional Seismic Test Network has been completed and await final checkout with data from the satellite receiver which is yet to be installed.

Close coordination between all SDC project contributors is being maintained and two members of the Applied Seismology Group are presently resident at the Rosslyn facility in order to assist the smooth transfer of both hardware and software.

R.G. North

II. MISCELLANEOUS

A. WMO/GTS SPECIAL EXPERIMENT

During November and December 1981 further tests were made of the capability of the World Meteorological Organization Global Telecommunications System (WMO/GTS) for the transmission and reception of Level I parameter data. Over 20 countries participated in this experiment; the results were little better than those of a similar test conducted during 1980. On average, ~85 percent of the messages transmitted were received by each country. Clearly, data losses of such magnitude can severely affect the quality and accuracy of event bulletins constructed from the input parameter data, and make the production of similar bulletins from several International Data Centers extremely difficult.

In order to determine what effect such losses would have upon event bulletin production, a special experiment was carried out by Australia, Sweden, the United Kingdom, and the United States on 2 and 3 December 1981. Level I parameter data for 12 and 13 October 1980, contributed by many nations and collected by Sweden for the International Common Data Base Experiment, were converted by the United States into the WMO telegraphic format for seismic data. Half the data for each of these two days was mailed both in hard copy form and on magnetic tape to Australia and the United Kingdom. These two countries then transmitted the data for 12 and 13 October 1980 on 2 and 3 December 1981, respectively. Upon receipt, both Sweden and the U.S. computed an event bulletin from the data received, and each then transmitted this bulletin over the WMO/GTS.

Since the amount of Level I parameter data to be sent exceeded the maximum message size allowed for WMO/GTS transmission, they had to be divided into a number of separate messages. Australia sent 6 messages on both the 2nd and 3rd of December, while the U.K. sent 13 on the 2nd and 14 on the 3rd. Both Sweden and the U.S. received all 39 messages complete, except that the last line of seismic data was missing from each of the 14 U.K. transmissions made on 3 December. The U.K. repeated their messages of 3 December on the following day (4 December) but again the last line of seismic data was not received, although the messages were terminated normally with the required NNNN string.

The event bulletins produced by the U.S. and Sweden were transmitted over the WMO/GTS On 3 and 7 December, respectively. Sweden received the U.S. bulletin; the U.S. did not receive the bulletin from Sweden. A hard copy of the letter was mailed to the U.S. and Tables II-1 and -2 show a combination of the bulletins produced.

Despite the negligible data losses and thus identical input data, there are substantial differences in the bulletins produced by Sweden and the U.S., reflecting variations in the procedures used for association and location. Both countries located 20 events for the 2 days, 12 and 13 October 1980, and of these 16 appear to be the same, though with occasional large differences in location. It is particularly noteworthy that the body wave magnitudes given by the U.S. are always larger than those for Sweden, sometimes by nearly one magnitude unit. This is due to the use by Sweden of a maximum likelihood magnitude estimation process, whereas the U.S. values are straight averages.

The large discrepancies between the two bulletins clearly indicated the need for standardized methods and algorithms in potential International Seismic Data Centers. A detailed comparison of the two bulletins and the procedures used to produce each is being carried out and will be reported on at a later date.

M.A. Tiberio
R.G. North

B. AN ENGLISH LANGUAGE INTERFACE FOR SEISMIC EVENT DATABASES

Seismic researchers rely on large historical databases in many research tasks. One such database is the Preliminary Determination of Epicenters (PDE) published by the National Earthquake Information Service. It provides

TABLE II-1

EVENT LOCATIONS GENERATED BY SWEDEN (SW)
AND THE UNITED STATES (U.S.)
12 OCTOBER 1980

Time	Latitude	Longitude	Depth (km)	N	m_b	Country
00:36:54.0	36.48 N	1.63 E	038	(7)	4.1(3)	U.S.
00:36:59.7	36.73 N	1.69 E	076	(4)	3.7(4)	SW
00:39:10.8	49.80 N	171.15 W	000	(8)	4.9(4)	U.S.
00:39:15.9	50.02 N	170.93 W	033	(6)	4.1(6)	SW
03:34:13.6	49.92 N	79.10 E	000	(59)	5.9(42)	U.S.
03:34:18.5	50.03 N	79.17 E	033	(24)	5.6(24)	SW
04:02:14.2	36.33 N	1.45 E	000	(36)	4.2(4)	U.S.
04:02:44.2	37.18 N	1.99 E	033	(7)	4.0(7)	SW
04:04:03.5	29.39 N	70.15 E	000	(5)	4.5(2)	U.S.
04:04:44.1	35.38 N	71.18 E	033	(4)	3.9(4)	SW
04:29:24.9	39.69 N	21.25 E	067	(9)	4.3(3)	U.S.
04:29:25.6	36.74 N	21.30 E	067	(7)	4.1(7)	SW
07:46:34.8	15.90 S	166.10 E	033	(4)	4.1(4)	SW
11:20:01.1	61.44 S	153.88 E	033	(4)	4.8(4)	SW
13:31:55.2	12.88 N	143.79 E	045	(4)	4.1(4)	SW
16:03:34.1	44.17 N	81.59 E	033	(7)	4.2(7)	SW
16:03:38.3	44.57 N	81.29 E	033	(14)	4.7(7)	U.S.
17:49:30.2	47.78 N	158.99 E	033	(3)	3.8(3)	SW
17:49:53.2	52.60 N	160.60 E	000	(4)	4.7(3)	U.S.
19:59:25.9	47.39 N	151.57 E	000	(21)	4.9(10)	U.S.
20:00:15.5	48.49 N	152.03 E	413	(5)	4.0(5)	SW
22:21:15.6	0.43 N	123.85 E	160	(5)	4.7(5)	SW
22:21:38.6	1.42 N	123.26 E	332	(12)	5.1(4)	U.S.

TABLE II-2

EVENT LOCATIONS GENERATED BY SWEDEN (SW)
AND THE UNITED STATES (U.S.)
13 OCTOBER 1980

Time	Latitude	Longitude	Depth (km)	N	m_b	Country
01:07:58.3	54.32 N	17.79 E	000	(5)	4.6(2)	U.S.
01:16:35.1	40.12 N	124.61 W	000	(7)	4.5(1)	U.S.
01:16:41.1	40.20 N	124.29 W	033	(5)	3.9(5)	SW
03:43:05.5	32.03 N	14.06 E	033	(6)	4.2(6)	SW
03:44:50.5	39.82 N	12.80 E	501	(33)	3.9(3)	U.S.
04:11:24.3	30.19 N	138.67 E	406	(5)	4.6(4)	U.S.
06:37:36.6	36.35 N	1.55 E	000	(59)	5.1(14)	U.S.
06:37:42.1	36.28 N	1.80 E	033	(19)	4.9(19)	SW
08:58:50.7	37.16 N	71.47 E	163	(26)	4.9(15)	U.S.
08:59:01.0	36.83 N	70.53 E	273	(7)	4.3(17)	SW
10:55:41.7	36.58 N	138.16 E	055	(4)	4.0(4)	SW
10:55:45.0	36.03 N	138.81 E	119	(6)	4.9(3)	U.S.
11:19:02.3	30.80 S	178.66 W	000	(7)		U.S.
14:33:40.5	36.43 N	1.64 E	000	(42)	4.7(5)	U.S.
14:33:44.6	36.24 N	1.34 E	033	(10)	4.3(10)	SW
18:34:50.0	21.92 S	169.84 E	000	(4)		U.S.
20:25:36.2	29.19 N	2.66 E	033	(3)	3.5(3)	SW

TABLE II-3

EVENT DESCRIPTION IN THE PDE DATABASE

Field	Description
TIME	origin time
LAT	latitude (degrees)
LON	longitude (degrees)
DEPTH	depth (km)
MB	body wave magnitude
MS	surface wave magnitude
NSTA	number of stations reporting the event
REG	seismic region number

a summary of global earthquake activity since 1964 and currently contains over 100,000 seismic events. Table II-3 shows some of the information that the PDE provides for each event. Although there are several database tools available for accessing such data, such as the relational database system INGRES, they require some familiarity and a casual user may find them difficult to deal with.

It would be better if generally useful databases could have more convenient interfaces. To this end, an English-like query language for INGRES databases, called INGRISH, is under development. The user types the query without punctuation and ends it with a question mark or an exclamation point. (Queries can be in mixed upper or lower case.) The following list shows the range of requests INGRISH is capable of responding to:

- What events have occurred since March?
- What events occurred between 1/12/80 and 20 April 1980 in regions 190 191 and 192?
- Print events with magnitude greater than 5.5 since July!
- Show me events deeper than 300 km in the southern hemisphere!
- Which events have depth greater than 300 km occurred between August 1980 and dec 1982?

- Print events for which depth was greater than 200!
- Today is 15 oct!
- Which events in july were reported by more than 5 stations?
- Print out events that occurred between january and april!
- Which events occurred in new england during 1980?
- What were the shallow large events in the area of interest during 1980?
- Print the 12 july events!
- Of those which occurred in japan!
- Put them in file event.data!

INGRISH operates as a front end to INGRES that translates English requests into QUEL (the INGRES query language), as shown schematically in Fig. II-1. Through the INGRISH interface, one can make requests to INGRES either in English or in QUEL. The results of each query are held in a temporary table. This table can be used in further queries such as

Of those which are above magnitude 6.0?

or

Of those which are deeper than 500 km?

The temporary relation can also be copied to a file using a request of the form

Copy them to file "FILE-NAME"!

Thus with INGRISH, a seismologist can easily collect a subset of the PDE that he is interested in.

The input to INGRISH is passed sequentially through three modules, the pattern matcher, the parser, and the QUEL translator, as shown schematically in Fig. II-2. To understand how INGRISH works, the sentence

S1: Show me the events that have occurred since July in the Southern Hemisphere that are deeper than 300 km and were recorded by at least 50 stations!

will be traced through the system.

1. Pattern Matcher

The pattern matcher attempts to simplify the input sentence by replacing patterns in the input sentence with alternative sentence fragments. Preprocessing the sentence in this way significantly reduces the complexity of the parser, and provides a number of useful features that are difficult without it. Replacement patterns are used in several ways:

(a) Noise words such as "please" or "me" that can occur in several positions in a sentence and contribute nothing to its meaning are simply ignored.

(b) Common patterns such as "greater than or equal to" or "body wave magnitude" are replaced by more compact patterns that preserve their meaning such as ">=" or "mb," respectively.

(c) Common contractions such as "jan" for "january" or "mag" for "magnitude" are translated into their canonical form.

(d) Colloquial expressions, such as seismic region names, that would otherwise require their own grammar rules, can be replaced by an expression that is already recognized by the grammar. For example, "southern hemisphere" is replaced by "latitude less than or equal to 0.0."

(e) Users can add their own favorite phrases by using the replace function. For example,

    (replace deep (depth greater than 300))

would allow request such as

    Print the deep events in March!

to be correctly answered.

Currently, there are over 100 replacement patterns in use.

After replacement, sentence S1 becomes:

    since july lat > 0.0 depth > 300 >= 50 sta

All that remains is a compact representation of the restrictive clauses of the query.

2. Parser

Most of the work in understanding the input is done by the parser. The parser takes the output of the pattern matcher and breaks it into its component clauses based on a number of grammar rules. The grammar is not a general grammar for English, but a "semantic grammar" that knows a great deal about its particular application. For example, rather than knowing about traditional syntactic categories such as "noun" or "verb" it knows about categories such as "parameter" and "month" that are important to its task. Such information is kept in the lexicon of words. Although semantic grammars accept a narrow range of English, they can be quite capable in the domain they are designed for. The grammar rules of INGRISH are written as an Augmented Transition Network (ATN) grammar using the language SEISMOGRAMMAR, that has been used to analyze seismic waveforms.[1-3]

Since the grammar is currently capable of answering questions about only a single kind of relation, most of the grammar is concerned with restrictive clauses such as "magnitude greater than 4.5" or "since january." Typically, a user may want to specify such clauses in a number of ways and the grammar must allow for this. For example, there are several ways to write a date:

	Format	Example
1.	MONTH/DAY-OF-YEAR/YEAR	10/2/80
2.	YEAR DAY-OF-YEAR	80276
3.	DAY-OF-MONTH MONTH YEAR	2 oct 1980
4.	MONTH YEAR	october 1980
5.	YEAR	1980
6.	TODAY	today
7.	YESTERDAY	yesterday

The current data can be set by a request of the form

Today is DATE!

so that yesterday and today can be used as valid dates.

Time intervals also come in a variety of forms

	Format	Example
1.	between DATE and DATE	between july and september
2.	before DATE	before 12 march
3.	since DATE	since 1972
4.	in DATE	in june
5.	on DATE	on 10/12/80

Such restrictive clauses are translated into a functional notation of the form

```
(restriction time (range T1 T2))
```

which means that the origin time of the event should be between T1 and T2.

Restrictions on other parameters, such as latitude and longitude are translated similarly. Some parameters have discrete values, and restrictive clauses on them can be in terms of set membership. For example, the phrase

from regions 181 182 or 183

becomes

```
(restriction reg (list 181 182 183))
```

The parser transforms its input into an intermediate functional notation. For example, the output for the sentence S1 is

```
(quel-request pde
  (and (comparison time >= 331257600.0)
       (and (comparison lat < 0.0)
            (and (comparison depth >= 300)
                 (comparison nsta >= 50)))))
```

When evaluated, this LISP expression produces the appropriate QUEL query by the QUEL translator.

3. QUEL Translator

The QUEL translator takes the intermediate expression produced by the parser and translates it into the appropriate QUEL query. Although the parser could produce the query directly, it is good practice to allow this to be done separately.[4] In this way, the details of the database are hidden from the grammar. The database and even the database system can be replaced without altering the grammar.

The output of the QUEL translator for the sentence S1 is:

```
range of p is pde
destroy result
retrieve into result
(p.date, p.hms, p.lat, p.lon, p.depth, p.mb, p.ms, p.nsta, p.reg)
where p.time >= 331257600.0 and
p.lat < 0.0 and p.depth >= 300 and p.nsta >= 50
print result\g
```

which can be directly interpreted by INGRES. This query extracts the requested events from the PDE table, puts them into a table called "result," and prints it.

In summary, INGRISH is quite capable of answering a wide range of questions that seismologists ask about historical databases. The seismologist needs to know very little about the actual database. He can simply form his request in natural English.

Since INGRISH deals with a large variation in time formats and parameter names the seismologist need only know the generic type of information contained in the database rather than know exactly what data are stored there and what the parameter name is. For example, a typical request is about events in a certain magnitude range. The PDE specifies both m_b and m_s magnitudes and if the generic term "magnitude" is used, the query is made on m_b.

Another example is queries with time constraints. Time is stored in the PDE table both as "mm/dd/yy hh:mm:ss.s" and as "seconds since 1970." The former is what seismologists are familiar with, but it is awkward to express some queries using it. The latter makes queries easier, but is difficult for the seismologist to interpret. INGRISH solves the problem by allowing queries using a number of time formats and translates them into the "seconds since 1970" form in the internal form of the query.

Once a user becomes familiar with the system, he can streamline many of his requests. For example, rather than saying

Body wave magnitude greater and or equal to 5.5

he can say

mb >= 5.5

Also, with the replacement function he can tailor his own set of standard queries.

The overhead involved in using INGRES through INGRISH rather than using INGRES directly is small. Translating the request into QUEL typically takes less than a second of real time, a fraction of the time it takes INGRES to respond to the query.

K.R. Anderson

C. THE TRADE-OFFS BETWEEN EXPLOSION SOURCE PARAMETERS AND ANELASTICITY

P waveforms from underground nuclear explosions at the Eastern Kazakh test site were matched using the spectral shape parameters of the explosion source model of von Seggern and Blandford.[5] These parameters consist of a long-period spectral level ψ_∞, a corner frequency parameter k that scales as the inverse cube root of yield Y, and an overshoot parameter B related to the difference between the peak spectral value and the long-period spectral level. These shape parameters can be empirically related to the physical constants in the explosion source model of Mueller and Murphy,[6] which specifies the time function of the pressure profile acting over a spherical surface surrounding the explosive source at a radius r_e; r_e is the radius at which the elastic behavior of the medium begins. In addition to the spectral shape parameters, the synthesis of seismograms requires the assumption of an attenuation operator specified by a t^*_α value, a P-pP delay time for a buried source, and the application of a suppression factor to the elastic pP reflection coefficient at the free surface. The suppression factor is found to be necessary to account for the amplitude of pP relative to P observed teleseismically in the band 0.25 to 5 Hz (Ref. 7) and is consistent with finite difference models incorporating the formation of spall in the near field of the source.[8] Synthetics were constructed for a range of shape parameters, P-pP times, t* values, and R_{pP} suppression factors in order to match the waveform data by trial and error. The waveform data consisted of both narrowband short-period data and broadband data. The broadband data were derived from the digital short-period data by deconvolving the instrument response and applying a high-pass filter with a corner at 0.1 to 0.3 Hz to remove microseismic noise. The results for an Eastern Kazakh test recorded by the WWSSN station LON are shown in Figs. II-3 and -4.

Figure II-3 illustrates that the short-period data can be fit by drastically different combinations of source parameters and t* values. The short-period data alone are thus insufficient to infer much about the source properties or the attenuation operator other than a relation of amplitude to yield through empirically derived magnitude-yield relations. Figure II-4, however, shows that the broadband waveform can eliminate some of the source parameter and t* combinations. An additional constraint that must be satisfied is the amplitude ratio of the short period to broadband waveforms. Table II-4 summarizes the fit of the different combinations of source and

TABLE II-4

FITS OF OBSERVED TO SYNTHETIC EXPLOSION P-WAVES

Source Parameters, Attenuation	Observation Satisfied		
	BB Waveform	SP/BB Ratio (Obs=0.67)	SP Waveform
High k, high t*, normal B, R_{pP}	X	X	X
High k, high t*, normal B, 0.5 R_{pP}			X
High k, high t*, abnormal B, 0.5 pP	X	X	X
Low k, low t*, normal B, 0.5 pP	X	X	X

attenuation parameters to the short period and broadband data. The B parameter is noted to be normal or abnormal according to whether it satisfies the B value determined from source spectral observations of explosions in granite at the Nevada Test Site (NTS) at distances of 200 to 800 m. The notation "high k" refers to the results for k = 23, "low k" to k = 7.7, "high t*" to t* = 1.0, and "low t*" to t* = 0.6. The reflection coefficient R_{pP} was either taken to be the elastic value of $R_{pP} = 1.0$ or was suppressed by a factor of 0.5. The result for high k, high t*, normal B, and suppressed R_{pP} does not satisfy the observed broadband waveform or the amplitude ratio of short to broadband. All other combinations of parameters in the synthetics satisfy all observations. The results having an abnormal B value, however, can be excluded by physical considerations. The B value can be related to the peak shock pressure P_{os} and the elastic transition pressure P_{oc} acting at the elastic radius by the relation:[5]

$$\frac{(P_{os} - P_{oc})}{P_{oc}} = 2B \quad . \qquad \text{(II-1)}$$

Using Eq. (II-1) and the constants and empirical scaling relations for P_{os} and P_{oc} given in Mueller and Murphy,[6] B can be related to the scaled depth h_s of an underground explosion. h_s is the depth necessary to contain a 1-kt explosion. The containment depth for an event having a yield Y is given by the scaling relation

$$h = h_s Y^{1/3} \quad . \qquad \text{(II-2)}$$

P_{os} has been measured to be approximately 1.5 ρgh for shots at NTS, which are normally buried at the scaled depth. Thus by setting $P_{os} = 1.5\ \rho g h_s$, using the empirical relations for P_{oc} in Mueller and Murphy,[6] and the scaling relations for the corner frequency k given by von Seggern and Blandford,[5] a relation between B and the scaled depth may be obtained. For granite the result is given by

$$h_s = 45\ (2B + 1)^{0.785} \qquad \text{(II-3)}$$

where h_s is in meters. von Seggern and Blandford take B = 2 for granite, which in Eq. (II-3) gives h_s = 159 m. This agrees closely with the correct average value of h_s of 122 m at NTS, and suggests that scaling of the shape parameters and the relations taken between these and Mueller and Murphy's source parameters are approximately correct. If B is taken to be 5, the scaled depth would need to be nearly twice as deep as in a tuff, rhyolite, or granite medium in order to insure containment. Thus, the synthetic match using the abnormal B value can be excluded from consideration if the shot medium of the Kazakh event can be considered to be an "average" medium.

This leaves two possible combinations of source parameters and t* values that fit the waveform observations: (1) high k, high t*, normal B, and normal pP; and (2) low k, low t*, normal B, and suppressed pP. Type (1) is representative of the modeling done by Helmberger and Hadley[9] and type (2) is representative of the modeling done by Shumway and Blandford.[7] Helmberger and Hadley show that a type (1) model can be made to satisfy velocity measurements at distances of 5 to 10 km from the source, but did not attempt to see if a model with a reduced R_{pP} gave an equally acceptable fit to the local data. If the evidence for reduced R_{pP} in the frequency band 0.2 to 5 Hz is accepted, then the type (2) model is preferable. Additional evidence that favors the type (2) or low t* model is provided by observations of P- and S-wave spectra in the band 2 to 5 Hz. The spectral content in this band is difficult to satisfy by an absorption band model of anelasticity that gives t^*_α = 1 in the 0.2- to 2-Hz band[10] because intrinsic anelasticity allows t* to decrease with increasing frequency at a rate no faster than ω^{-1}. These results suggest that t* must be generally less than 1 in the band 0.2 to 2 Hz. In waveform modeling studies, this conclusion heavily depends on the suppression of the R_{pP}. Further studies at distances 5 to 20 km from the source may be necessary to confirm R_{pP} suppression and its frequency dependence.

V.F. Cormier

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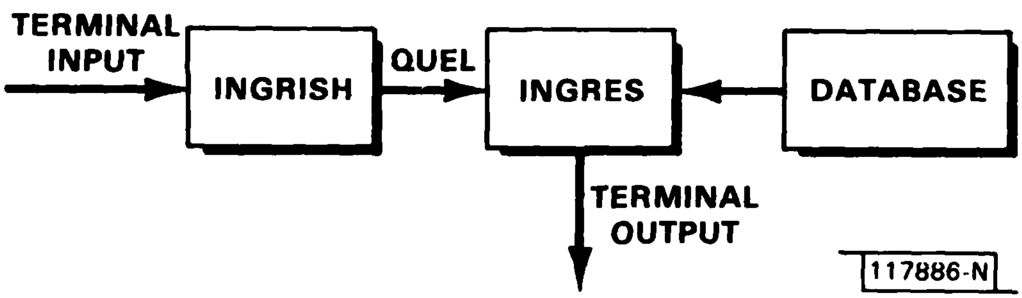

Fig. II-1. Schematic of the INGRISH interface to INGRES.

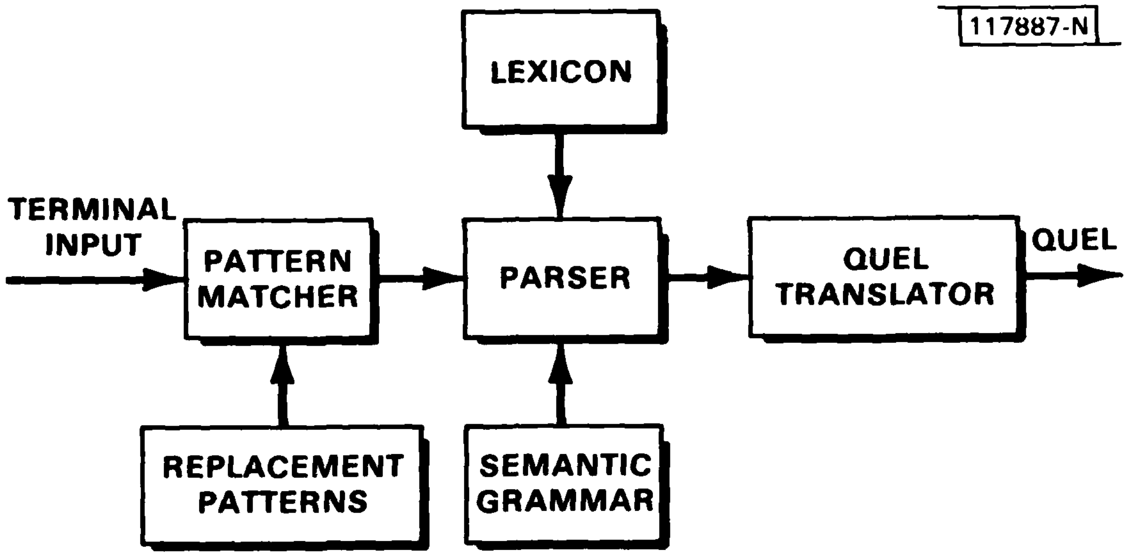

Fig. II-2. Block diagram of INGRISH.

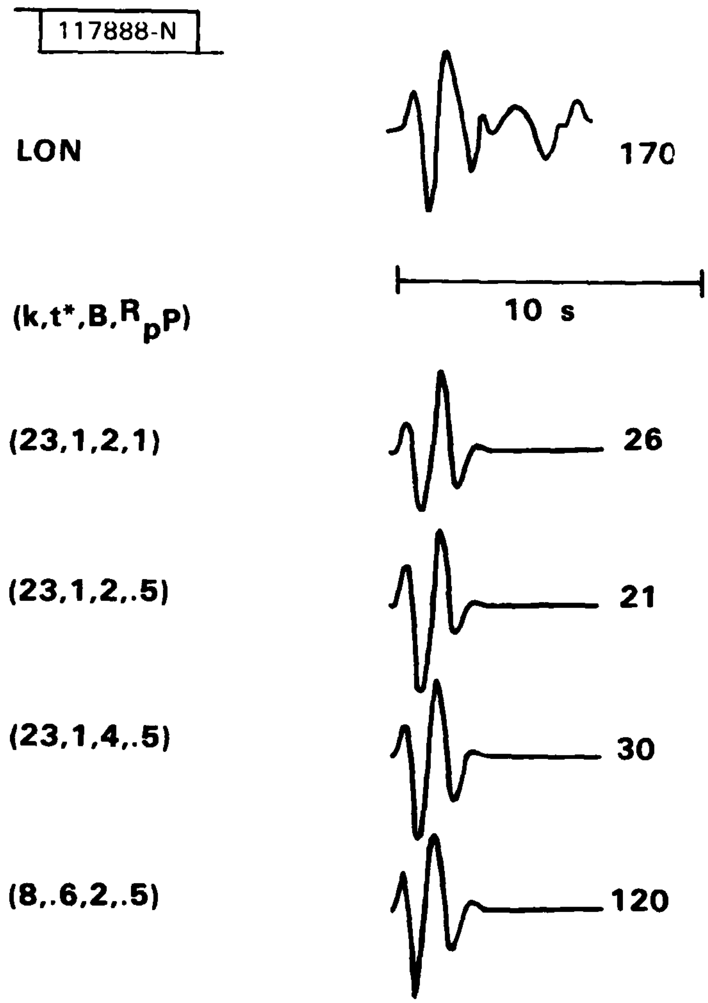

Fig. II-3. Observed and synthetic P waveforms at the WWSSN station LON for an underground nuclear test at the Eastern Kazakh test site on 12 October 1980, 03:34:14.0 GMT, located at 49.91 N, 79.01 E. All records are for a short-period WWSSN instrument. The P-pP delay time = 0.7 s in all synthetics.

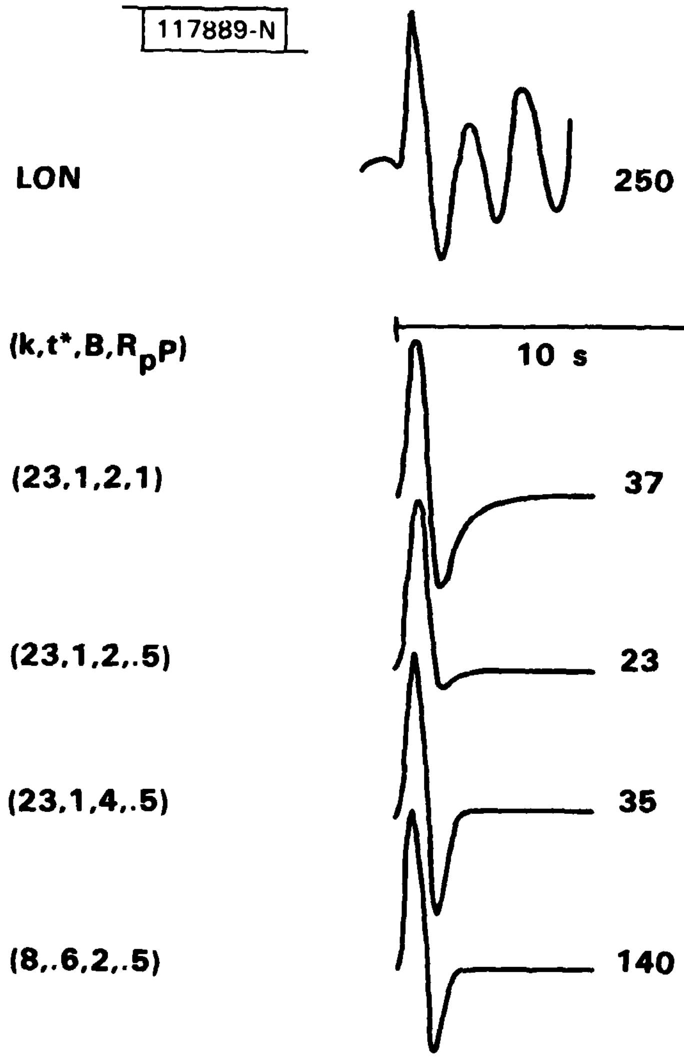

Fig. II-4. Observed and synthetic broadband displacements at LON for the event described in the caption of Fig. II-3.

III. PUBLICATIONS LIST

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187. Seismic Discrimination Semiannual Technical Summary, Lincoln Laboratory, M.I.T. (30 September 1979), DDC AD-A082615/6.

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GLOSSARY

ATN	Augmented Transition Network
CIS	Communications Interface Subsystem
DARPA	Defense Advanced Research Projects Agency
FY	Fiscal Year
GTS	Global Telecommunications System
IDCE	International Data Collection Experiment
IESD	International Exchange of Seismic Data
m_b	Body Wave Magnitude
NTS	Nevada Test Site
PDE	Preliminary Determination of Epicenters
RSTN	Regional Seismic Test Network
SAS	Seismic Analysis Station
SATS	Semiannual Technical Summary
SDC	Seismic Data Center
WMO	World Meteorological Organization
WWSSN	World-Wide Standardized Seismograph Network

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seismology	LASA	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This Semiannual Technical Summary describes the Lincoln Laboratory Vela Uniform program for the period 1 October 1981 through 31 March 1982. During this period, the Lincoln prototype Seismic Data Center has been refined and improved, prior to its transfer to its operational site at Rosslyn, Virginia. Section I describes these improvements. Section II describes a series of miscellaneous investigations.