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6. AUTHOR(S) Dr. Sia Nemat-Nasser (PI) Dr. Joseph Zarka				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of California, San Diego Dept. of AMES 9500 Gilman Drive La Jolla, CA 92093-0416			8. PERFORMING ORGANIZATION REPORT NUMBER 97PR01513-00	
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13. ABSTRACT (Maximum 200 words) The project objective is to develop formalism for assessing fatigue fracture of welded parts of ship structures based on a newly developed automatic Learning Expert System (L.E.S.), using extensive knowledge of material characteristics, experimental results, and results obtained through computational simulations. Any study of the welds on a ship structure must take into account the uncertainties and random characteristics of the loading, as well as the fatigue lifetime of the welds. Due to the stochastic nature of the loads, the available deterministic approaches are not sufficient to give a reliable evaluation of the structural safety. Although there has been some effort to fill this gap by probabilistic approaches, these are yet of limited usefulness because of the limited available databases. The research project will ultimately demonstrate the applicability and effectiveness of L.E.S to this class of engineering mechanics problems. As the first and fundamental step in this project, it is necessary to build a relevant database. Experimental and field data has secured from Navy research centers, and through collaboration with scientists working in this general area. Additional data has been obtained from literature searches.				
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TITLE: A New Approach to Structural Reliability in
Fatigue Failure

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SUBMITTED FOR PUBLICATION TO (applicable only if report is manuscript):

Sincerely,

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INTERIM PROGRESS REPORT

ONR Grant Number: N00014-96-1-0631
Period Covered by Report: April 1, 1997 - March 31, 1998
Title of Proposal: *A New Approach to Structural Reliability in Fatigue Failure*
MOD Number: P00001
PR Number: 97PR01513-00
Authors of Report: Dr. S. Nemat-Nasser (PI) and Dr. Joseph Zarka

**I. SCIENTIFIC AND TECHNICAL PERSONNEL SUPPORTED BY THIS PROJECT
AND DEGREES AWARDED DURING THIS REPORTING PERIOD**

Scientific and Technical Personnel:

Masoud Beizaie (Staff Research Associate): research focusing on the reliability of weldments, especially those used in marine structures. This activity includes extensive literature survey and search for available databases and software. (partially supported).

Joseph Zarka (Visiting Research Scientist from Ecole Polytechnique, France): the research project includes collaboration with Dr. Zarka, who spends at least three months each research year at CEAM of UCSD. The approach, to study the reliability of ship structures and particularly their welded parts, utilizing the automatic Learning Expert System (L.E.S), has been developed by Dr. Zarka.

Graduate Research Assistants:

Jun Huang (9/96 - present): research focusing on fatigue and Dr. Zarka's new approach to inelastic analysis and the use of numerical analysis software. The research on fatigue includes examination of micro-mechanisms of fatigue, the influence of non-zero mean stress, the accumulative damage theories and the use of statistics in fatigue. The main idea of the new approach is to solve the plastic problem using elasticity solutions. Extensive comparative analysis has been done utilizing the basic components of NISA.

II. BRIEF OUTLINE OF RESEARCH FINDINGS FOR THIS REPORTING PERIOD

A preliminary application of the new approach has been made based on the fatigue experiments documented in the ship structural committee report SSC-346 *Fatigue Characterization of Fabricated Ship Details for Design*, by Dr's. S.K. Park and F.V. Lawrence. A database that contains 756 examples and 50652 descriptors has been built and the automatic learning tool *Learning Expert System* has been used to extract rules from it. The learned rules demonstrate a fairly good performance compared with the experimental results.

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A special procedure to produce the intelligent descriptors has been developed. These descriptors are then used to represent the important scalar fields at the critical points of the structure. Two commercial Finite Element codes, *NISA* and *ALGOR*, are used in this procedure. After the FEM model is generated, fixed size *windows* are set up to cover the hot points in the specimen. Inside each window, the *maximal*, *minimal* and *average* values of the important scalar fields, such as I_1 and J_2 , are calculated. To reduce the influence of mesh density, five *intervals* between the minimum and maximum values of each scalar field have been set up and the percentage of the area under the scalar value within each of the five intervals is calculated to express the distribution of the scalar field in the window. A special in-house program has been written to carry out this task, an automatic procedure of assigning the regions has also been developed.

These procedures will be used to further expand and refine the database. We are expecting a new experimental report from the naval laboratory very soon, which contains test results of the structural details. Data about welded and notched specimens will be extracted from literature and if necessary, targeted experiments will be performed in CEAM to generate specific and tailored data.

III. OTHER ACTIVITIES

Two intensive Workshops "New Approach to Inelastic Analysis of Structures" and "Intelligent Optimal Design of Materials and Structures" was conducted November 3-14, 1997, at UCSD's CEAM, La Jolla, CA. The Workshop's were taught by Dr. J. Zarka (workshop coordinator) and Dr.'s J. Frelat, and P. Navidi, from the Laboratoire de Mécanique des Solides, Ecole Polytechnique, France. The workshop's was attended by participants from industry and well as academia.

The Aim of the Workshop's:

New Approach to Inelastic Analysis of Structures: The designers of structural systems often have to take into account the inelastic behavior of their materials, involving work-hardening and creep. For this, the classical mathematical theory of plasticity has been used over the past several decades. Many contributors have helped to provide correct formulations and useful tools to solve technologically important problems. Such formulations are usually given in terms of rates or increments of the field quantities with unilateral constraints, and require long and expensive computer calculations. In such formulations, it is necessary to define a stress field which is statically and plastically admissible throughout the entire structure.

A new approach has been proposed in the Laboratoire de Mécanique des Solides of the Ecole Polytechnique (France). This approach is based on the introduction of a change of variable, leading to an efficient method to calculate bounds on the response of the structure. The method can be implemented using *quasi-static elastic analysis*, even for dynamic loadings of the structure. The method dramatically decreases the amount of time required for the complex inelastic analysis, even during dynamic loadings, such as seismic or contact-rolling loadings.

The purpose of this intensive Workshop was to show how it is possible to transform the classical formulations to make them much clearer, leading to easier and more direct solution of the problems. This transformation involved two fundamental steps: i) *the constitutive modeling of*

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materials, based on continuum mechanics, and ii) *the numerical treatment of structures* made of such materials, involving solution of the global associated boundary-value problems.

The participants were provided with a thorough grounding in this new approach. This was achieved through a balance of lectures, demonstrations and discussions of problems of the students own interest.

Intelligent Optimal Design of Materials and Structures: The designers of materials and structures are often compelled to make decisions under uncertain conditions, seeking solutions to problems which do not have known solutions. These include constitutive modeling, fatigue life prediction, wear, friction, or prediction of errors of inelastic analysis of structures.

This workshop provided, with the help of explicit examples, the bases and the use of a new approach to deal with such design problems using the available expert knowledge, experimental data and computational tools. This approach has been developed at the Laboratoire de Mécanique des Solides de l'Ecole Polytechnique (France). It is based on coupling the existing knowledge of experts, numerical results, and experimental data, with special automatic learning and optimization techniques.

The workshop first reviewed some basic issues relating to materials and structures, as well as Symbolic-Numerical Automatic Learning, and Optimization Schemes. Then, small groups were formed according to the needs of the participants. These included optimization of processes and formulation of material input, direct coupling with CAD Systems, optimal design of structures for random or cyclic loading, control of processes, and non-destructive tests.

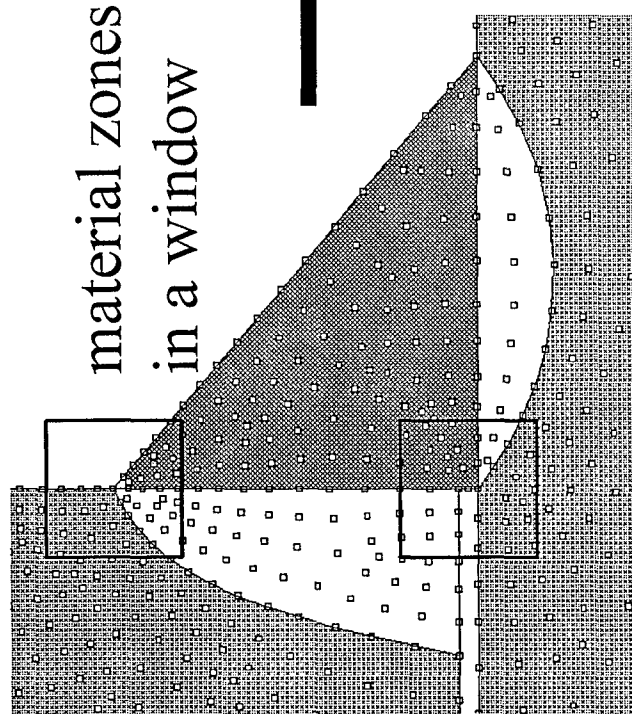
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IV PUBLICATIONS

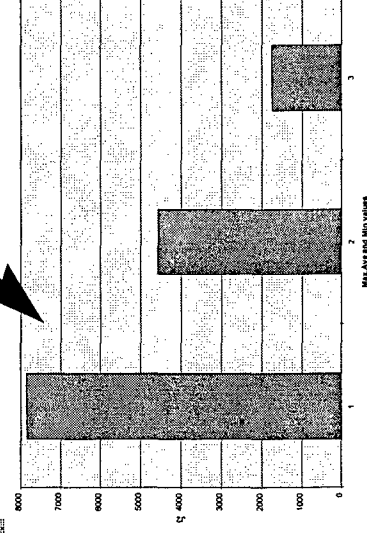
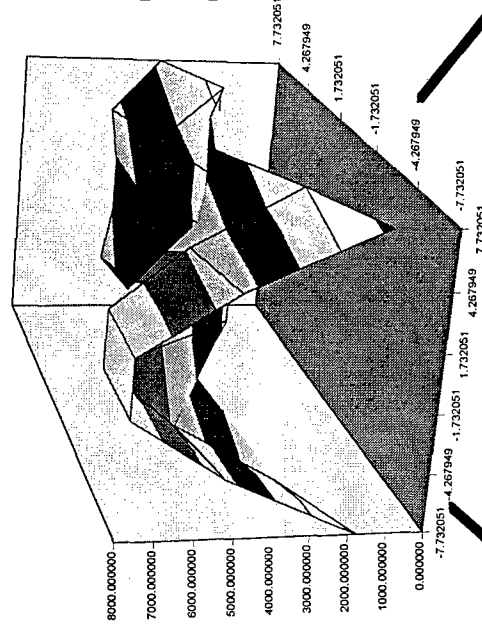
Huang, J., J. Zarka and P. Navidi, "A New Approach in Reliability of Welded Structures," Proceedings of the ASCE Engineering Mechanics Conference, May 1998, La Jolla, CA. (in press).

Zarka, J., J. Huang, and P. Navidi, " A New Approach in Reliability of Welded Structures," Proceeding s of the 6th International Conference on Nuclear Engineering, ICONE, May 1998, San Diego, CA. (in press).

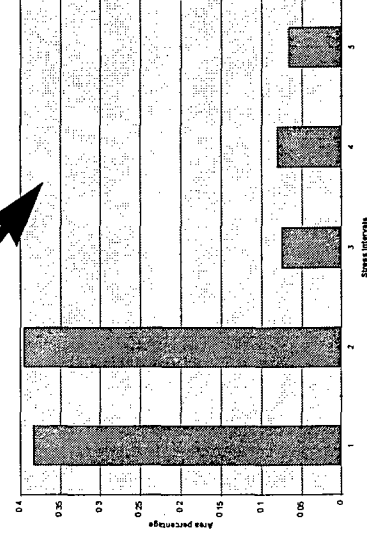
Representation of Scalar field in the window



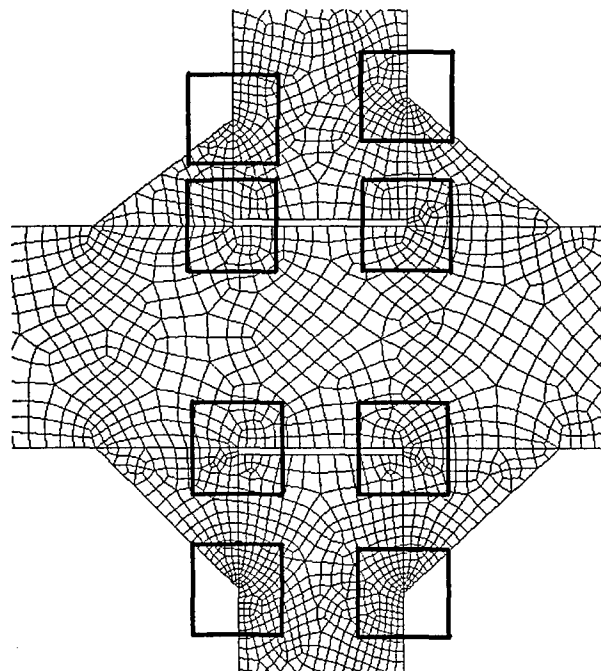
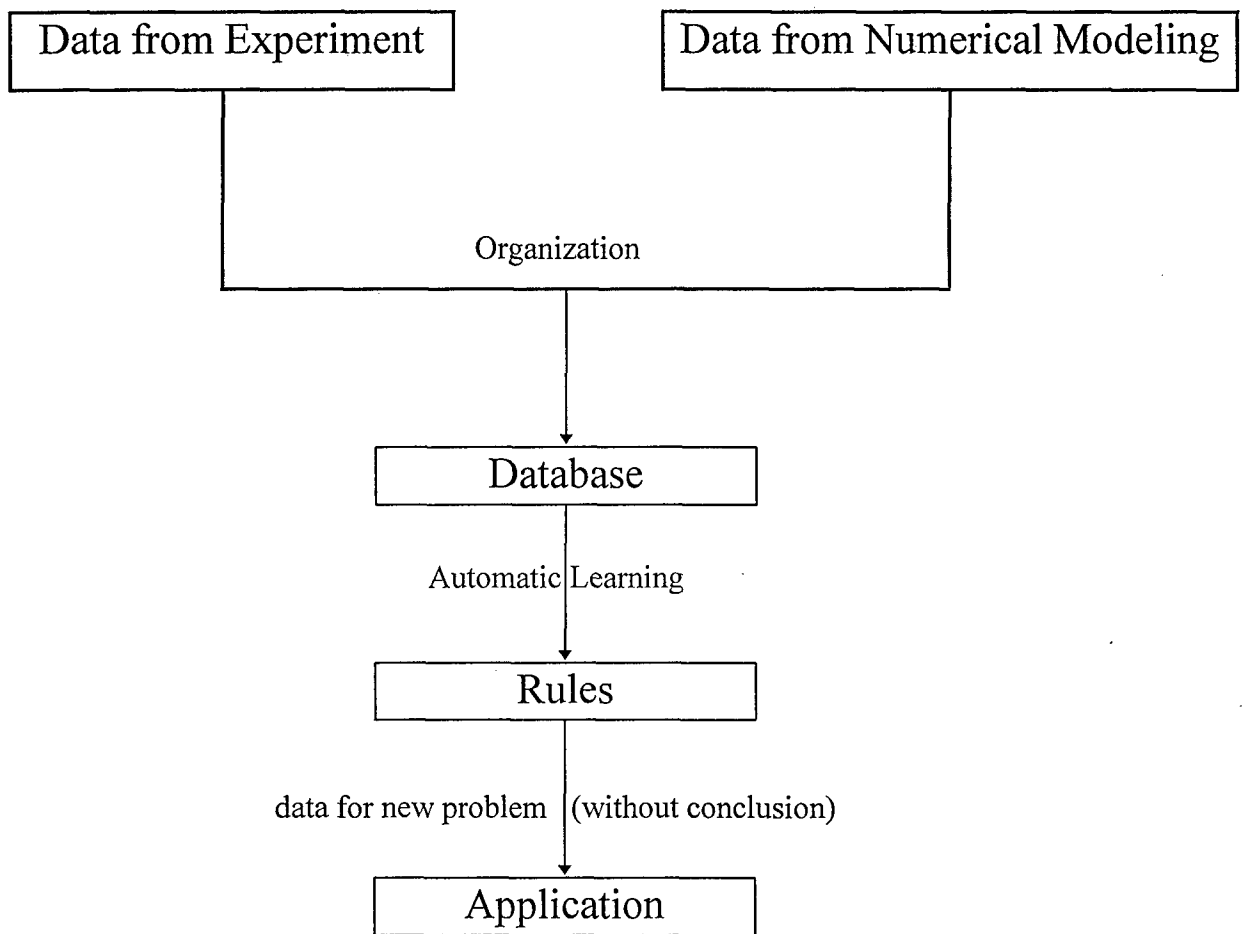
scalar field
distribution



extreme values



Area intervals



Mesh and Windows

A New Approach in Reliability of Welded Structures

Jun Huang¹, Joseph Zarka² and Pirouz Navidi

Abstract

We are concerned by the reliability of a general inelastic structure which is subjected to a general complex cyclic/random static or dynamical loading. Hereby we propose a new approach to deal with this problem. Realistic description of the material and structure is required and the new technology of Machine Learning is applied in this new approach. In this paper, we shall review it and we shall show its particular application to welded structures.

Introduction

There are two classical approaches towards the reliability assessment of a given structure. Deterministic approach requires exact representation of material properties, geometric characterization and the loading, as well as errorless simulation of loading history. The probabilistic approach deals with several incidents without reference to the underlying causes and the produced numbers can not be verified experimentally.

With the help of the new technology of Machine Learning, We propose a new approach for the solution of this problem. At first, we make a rather simple and fast finite element analysis of the structure. Then we will bring in the material properties, the nominal loading, the important geometric parameter, etc., along with the stress fields value from the FEM calculation. We organize the data into a well tailored database and present it to the Learning Expert System to extract the rules. Within this approach, we try to include all the information that may influence the structural failure.

In this paper, we shall present the important elements of this approach with the example of the weld details used in shipbuilding and other structural engineering projects.

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A NEW APPROACH IN RELIABILITY OF WELDED STRUCTURES

Joseph Zarka, Pirouz Navidi¹ and Jun Huang²

Abstract

The constitutive modeling of materials, which takes inelastic behavior, creep, damage, rupture into account, is still a no-ended problem. There are many industrial finite element codes that can simulate numerically the response of inelastic structures to various loading, but none is still able to assure the real accuracy of the solution. The real initial geometry and initial state of a structure as well as its real loading are not perfectly known. The tests on large-scale models are expensive and the results are often difficult to interpret. In many other vital areas, there are also serious limitations in our knowledge. A new framework was proposed by Zarka et al (1994) to overcome these difficulties.

In this paper, we shall present a new approach for the reliability of welded structures, which is based on this new framework.

The main point is that for various problems, it is possible to organize the results of numerical simulation, and if it is desirable, along with experiment and field observation into a dedicated database and extract valuable rules from it by using the machine learning technology. We will use the particular analysis of fatigue problems to illustrate this method.

At first, a part of an old database for fatigue characterization of fabricated ship details by Park et al (1988) will be reviewed. The primitive description (geometry, material, loading including initial bending due to the grips) of each case will be coped with an intelligent description that utilizes the actual expertise on weld, numerical simulation and fatigue. One important feature of the intelligent description is that the details are treated as general structures what allows the fusion of data from various sources and from various types of test.

Then, with the help of machine learning tools (LES from Ecole Polytechnique, Neuro-Shell from Wards Systems...), the rules will be automatically extracted in a clear form and with a known degree of confidence. At last, we shall show it is possible to apply these rules to some other parts of the database and also to any general structure as well.

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