Alexander Nikov

Neuro-Fuzzy Methods and Systems for Evaluation and Design in Ergonomics and Human-Computer Interaction

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Foreword

The development of the theories of fuzzy logic and neural networks was motivated in large measure by the need for a computational framework for dealing with humanistic systems, that is, with systems in which human judgment behaviour and emotions play a dominant role. Viewed in this perspective, it is hard to understand why so few of the many books on the theory of fuzzy logic and neural networks deal with its applications to humanistic rather than mechanistic systems. A possible explanation is that the mathematical apparatus of the theory of fuzzy logic and neural networks is very different in spirit from the traditional mathematics of human factors and behavioural sciences, which is rooted for the most part in statistics.

As humans, we tend to view with scepticism and suspicion what is strange and unfamiliar. There are limited number of papers on fuzzy logic and neural networks in the literature of human factors and psychology, even though it is obvious that the theories of fuzzy logic and neural networks can provide a much better model for human cognition than traditional approaches.

By focusing its attention on the application of fuzzy logic and neural networks in ergonomics (E) and human-computer interaction (HCI), the present book serves an important function of presenting to an audience of E/HCI scientists an overview which gives an idea of what the theory is about and how it can be applied. What can be a particular advantage of the book is the broad spectrum of applications of neuro-fuzzy methods in ergonomics and in human-computer interaction.

Content

Abstract

The book treats the neuro-fuzzy-based knowledge acquisition, modeling and study of complex human-machine systems in ergonomics and human-computer interaction. For solving problems in both areas two neuro-fuzzy-based models were developed: fuzzy-knowledge-based evaluation mechanism and fuzzy backpropagation algorithm. The mathematically proved theoretical studies and their prototypical implementations are tested by case studies and empirical field studies. Four applications in different design objects in *ergonomics* like framework for human factors analysis of office-automation-systems, tool for quick ergonomic screening of workplaces, adaptable tool for ergonomic evaluation and design of workplaces, intelligent toolkit for creation and support of workshop production structures and four applications in *human-computer interaction* like method for user interface adaptation, control structure for interactive systems adaptation, usage and user modeling of user-adaptive systems, intelligent system for usability evaluation of hypermedia user interfaces are presented.

Preface

The world in which we live and work is not perfect. The problems we attempt to solve are not always clearly defined, simple, or deterministic. We live in an uncertain and complex world. The problems we face often have imprecise descriptions or are fuzzy and not easily quantifiable.

Ergonomics (E) and Human-Computer Interaction (HCI) experts attempt to make more comfortable the living in this technological world for humans. We are continually challenged by problems of increasing complexity and ambiguity of relationships between people and devices they produce, and the environments in which such devices are used. The ever present uncertainty of our complex world demands appropriate scientific treatment. Recognition of the fact that fuzziness does exist and is critical for human-machine system analyses, although still slow, is getting more and more attention in the scientific community, particularly in the field of E/HCI. I hope this book could be recognized as a significant step in that direction.

The book contains 10 chapters grouped into three topical parts (cf. Figure 1):

(1) Neuro-fuzzy models: fuzzy knowledge-based evaluation mechanism (FKE) and fuzzy backpropagation algorithm (FBP);

(2) Application specific methods and systems in ergonomics: framework for human factors analysis of office automation systems, a tool for quick ergonomic screening of workplaces, adaptable tool for ergonomic evaluation and design of workplaces, an intelligent toolkit for creation and support of workshop production structures.

(3) Application specific methods and systems in human-computer interaction: method for user interface adaptation, control structure for interactive systems adaptation, framework for usage and user modeling of user-adaptivity systems, intelligent system for usability evaluation of hypermedia user interfaces.

One of the perceived problems with dissemination of neuro-fuzzy theoretical knowledge in E/HCI areas seems to be not only insufficient mathematical preparation of some of the researchers, but more importantly, the belief that the application of statistical analysis is the only way to analyze experimental data. One must, therefore, learn about fuzzy sets and neural networks theory and accept the fact that fuzziness and randomness, as theory of fuzzy logic, neural networks and statistics, are complementary, not contradictory tools for theoretical and experimental research. I trust that this book can encourage our colleagues to seek an understanding of neuro-fuzzy methodologies and their application in explaining human thought processes and behaviour at work, and ultimately in designing human-machine systems to accommodate characteristics expressed in fuzzy terms.

I thank Prof. J.-H. Kirchner of TU Braunschweig, Dr. S. Stoeva of Bulgarian National Library, Dr. D. Elsler of German Federal Institute for Occupational Health and Safety, Mr. T. Georgiev of TU Sofia for manuscript preparation.

Finally, I must recognize continuous support of my family, especially my deceased wife Maria Nikova and children Nadia and Svetoslav, who made my research work possible.

Alexander Nikov
St. Augustine, Trinidad and Tobago
May 2007

Book Objectives

The book treats the acquisition and modelling of implicit knowledge in the areas of ergonomics (E) and human-computer interaction (HCI). For solving real E/HCI problems, methods based on fuzzy logic and neural networks should be developed. They should be implemented as software tools and used in E/HCI case studies.

On Figure 1 the book areas and topics are presented in the following three groups:

(1) Neuro-fuzzy models;

(2) Application specific methods and systems in ergonomics;

(3) Application specific methods and systems in human-computer interaction.

For solving problems from the E/HCI practice the following theoretical neuro-fuzzy-based models should be developed: a fuzzy knowledge-based evaluation mechanism (FKE) and a fuzzy modification of the most popular in neural networks - a backpropagation algorithm called a fuzzy backpropogation algorithm (FBP). These theoretical studies should be proved mathematically and tested by case studies in E/HCI area.

The second group of topics are 4 application specific methods and systems in which the theoretical methods from the first group have to be implemented in the area of ergonomics. The FKE mechanism may be implemented in a framework for human factors analysis of office automation systems and in a tool for quick ergonomic screening of workplaces (QuickErgoScreening). The FBP algorithm may be implemented in an intelligent disposition toolkit for creation and support of workshop production structures WEDIS and in an adaptable tool for ergonomic evaluation and design of workplaces ATERG. Each method should be compared with other comparable methods by case studies using the developed intelligent software tools.

The third group of topics are 4 application specific methods and systems in which the theoretical methods from the first group should be implemented in the area of human-computer interaction. The FKE mechanism may be implemented in an intelligent system for usability evaluation of hypermedia interfaces ISSUE. The FBP algorithm may be implemented in a system for user interface adaptation SOFIA, in a control structure for adaptive interactive systems CBAUM and in a framework for usage and user modelling for user-adaptive systems MBAUM. Each method may be compared with other comparable methods by case studies using the developed intelligent software tools.

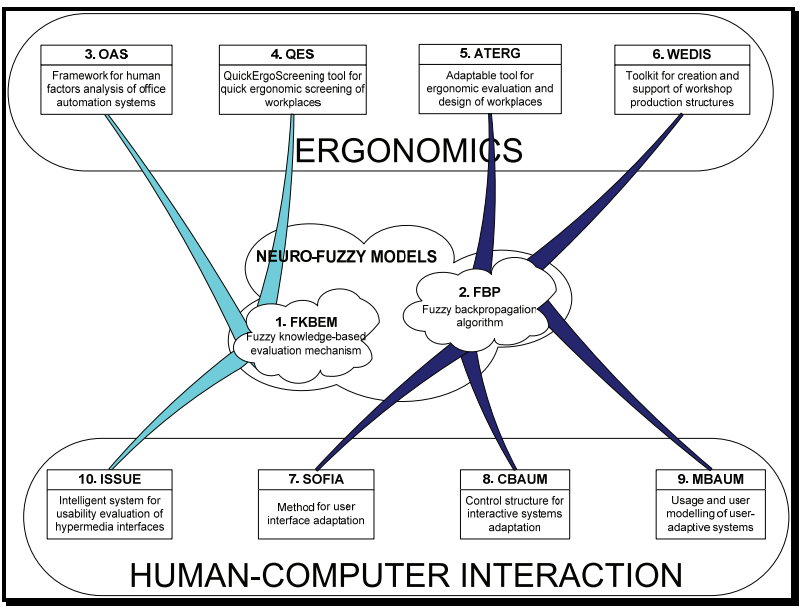

Figure 1: Book areas and topics.

The intelligent system for usability evaluation of hypermedia user interfaces ISSUE can be applied for usability evaluation of hypermedia educational

software. The framework for human factor analysis of office automation systems can be used in a case study of more than 4000 workplaces in Italian Telecom. SOFIA algorithm can be implemented for user interface adaptation of the information system of Bulgarian parliament. Using CBAUM and MBAUM models case studies of user interface adaptation in the electronic research funding system ELFI developed by the German National Centre for Information Technology can be carried out.