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# **INTELLIGENT DECISION TECHNOLOGIES**

**Proceedings of the 5th KES  
International Conference on  
Intelligent Decision Technologies  
(KES-IDT 2013)**

Edited by  
Rui Neves-Silva  
Junzo Watada  
Gloria Phillips-Wren  
Lakhmi C. Jain  
Robert J. Howlett



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# Intelligent Decision Technologies

## Proceedings of the 5th KES International Conference on Intelligent Decision Technologies (KES-IDT 2013)

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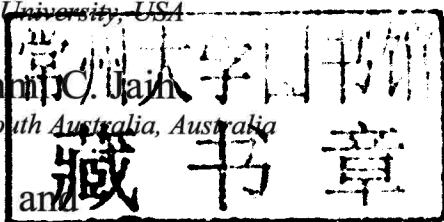
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# INTELLIGENT DECISION TECHNOLOGIES

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## Preface

The current volume includes the research results presented at the Fifth International Conference on Intelligent Decision Technologies (KES-IDT 2013) which took place in June 26-28, 2013, in Sesimbra, Portugal.

KES-IDT is a well established international annual conference, interdisciplinary conference in nature, and this edition consisted of keynote talks, oral and poster presentations, invited sessions and workshops, on the applications and theory of intelligent decision systems and related areas. It provided excellent opportunities for the presentation of interesting new research results and discussion about them, leading to knowledge transfer and generation of new ideas.

Sesimbra is a municipality lying at the foothills of the Serra da Arrábida, a mountain range between 40 km to the South of Portugal's capital, Lisbon. To the East of Sesimbra lies Arrábida Natural Park with natural caves, beaches and beautiful trails. To the West you'll find more beaches as well as Cabo Espichel with its scenic hiking trails, dinosaur footprints and ancient monastery. To the South lies Praia California and the Atlantic Ocean. Sesimbra is sheltered and the climate here is typically warmer than in most areas along the coast.

KES-IDT 2013 received many high quality submissions and all papers have been reviewed by at least two reviewers. Following a rigorous reviewing process, not all submissions could be accommodated for presentation at the conference. From these, 45 papers were accepted for presentation and included in this Proceedings. We are very satisfied with the quality of the program and would like to thank the authors for choosing KES-IDT as the forum for presentation of their work. Also, we gratefully acknowledge the hard work of KES-IDT international program committee members and of the additional reviewers for taking the time to review the submitted papers rigorously and select the best among them for presentation at the conference and inclusion in its proceedings.

We are also grateful to the KES personnel for their wonderful work in maintaining the KES-IDT 2013 website. Finally, we would like to thank the IOS Press personnel for their wonderful job in producing this volume.

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# Contents

Preface	v
International Programme Committee Members	vii
A Context-Sensitive Support System for Medical Diagnosis Discovery Based on Symptom Matching <i>Marko Knežević, Vladimir Ivančević and Ivan Luković</i>	1
A Group-Based Order Batching Method for Fruit and Vegetable's Farm-to-Door Online Retail in Metropolises of China <i>Du Mu and Hu Xiangpei</i>	11
A Hybrid RBF-ART Model and Its Application to Medical Data Classification <i>Shing Chiang Tan, Chee Peng Lim and Junzo Watada</i>	21
A study on Principal-Agent Relationship for Third-Party Reverse Logistics Based on EPR <i>Wang Xuping, Sun Zilai and Zhang Jun</i>	31
Advancing Collaborative Decision Making through Alternative Visualizations and Reasoning Mechanisms <i>Spyros Christodoulou, Nikos Karacapilidis and Manolis Tzagarakis</i>	38
An Agent Based Modelling Approach to Digital Business Models: Through a Literature Review of Three Complementary Research Areas <i>Aneesh Zutshi, Antonio Grilo and Ricardo Jardim-Goncalves</i>	48
An Analysis of Extended Absolute Measurement Method and Dominant Standard Method <i>Takafumi Mizuno and Eizo Kinoshita</i>	58
An Extension of the Method for Fuzzy Rules Extraction by Means of Artificial Neural Networks <i>Jan Górecki, Roman Šperka and Marek Spišák</i>	65
Approach for Decision Support for Energy Savings and Emissions Trading Based on Industrial Requirements <i>Maria Marques and Rui Neves-Silva</i>	74
Building a New Portfolio Selection Model with Technical Pattern-Based Fuzzy Birandom Returns <i>You Li, Bo Wang and Junzo Watada</i>	84

Child Vehicle Safety Simulation Using Regression Analysis and Predictive Data Mining <i>Ritwick Gupta, Ziad Kobti and Robert D. Kent</i>	94
Comparative Study of Correlations in Financial Markets <i>Takeo Yoshikawa, Yuta Arai and Hiroshi Iyetomi</i>	104
Complex Principal Component Analysis of Dynamic Correlations in Financial Markets <i>Yuta Arai, Takeo Yoshikawa and Hiroshi Iyetomi</i>	111
Concept of the Intelligent Energy Technology Integration to Support Sustainable Development of Energy Utilities, Energy Savings and CO <sub>2</sub> Reduction in the Complex Environment <i>Ales Podgornik, Boris Sucic and Ljubisa Urosevic</i>	120
Context Sensitive Solution for Collaborative Decision Making on Quality Assurance in Software Development Processes <i>Oliver Kotte, Aitor Elorriaga, Dragan Stokic and Sebastian Scholze</i>	130
Context-Sensitive Decision Support for Improved Sustainability of Product Lifecycle <i>Sebastian Scholze, Oliver Kotte, Dragan Stokic and Cristina Grama</i>	140
Coping with Disruptions in Public Tram Systems: Cases in Germany, China and the United States <i>Yan Fang, Christian F. Durach, Amy Z. Zeng and Jing Hou</i>	150
Decision Making on Strategic Investment: How to Determine the Specification of BTO Products <i>Yuji Sato</i>	158
Decomposition of a Term-Document Matrix Representation for Faithful Customer Analysis <i>Jianxiong Yang and Junzo Watada</i>	168
Design and Development of Central Knowledge Repository for Innovation Platforms <i>Martin Ziarati, Lakhvir Singh and Reza Ziarati</i>	178
Development of A Decision Support System for Hybrid and Cloud Computing <i>Bala M. Balachandran</i>	187
eTRIZ a Portal for Design Creativity <i>Paul Prickett and Ivan Aparicio</i>	197
Evaluation Principles between AHP/ANP and Dominant AHP/CCM <i>Eizo Kinoshita, Takafumi Mizuno and Shin Sugiura</i>	207

Finding Good and Considerate Strategies in the Iterated Prisoners Dilemma <i>Mieko Tanaka-Yamawaki and Ryota Itoi</i>	216
Fuzzy Portfolio Selection based on Index Tracking and Value-at-Risk <i>Qianli Xing, Bo Wang and Junzo Watada</i>	225
Hybrid Approach for Control Loop Performance Assessment <i>L. Brito Palma, J. Francisco Moreira, P. Sousa Gil and F. Vieira Coito</i>	235
Information Sharing Decisions in a Dual-Channel Supply Chain with Demand Disruption <i>Zichao Zhang, Haiyan Wang and Xiaoling Xu</i>	245
LARG Interoperable Supply Chains: From Cooperation Analysis to Design <i>Pedro Espadinha-Cruz, Izunildo Cabral and António Grilo</i>	255
Mathematical Model of Hit Phenomena as a Theory for Collective Motion of Human Mind in Societies <i>Akira Ishii, Kouichi Furuta, Tomoaki Oka, Hidehiko Koguchi and Koki Uchiyama</i>	267
Methodology for AmI-Based Data Acquisition and Context-Aware Processing to Enable Decision Support Related to Energy Efficiency in Manufacturing Industry <i>Gunnar Grosse-Hovest, Christian Wolff and Stefan Faltus</i>	277
Mining Twitter Data: Discover Quasi-Truss from Bipartite Graph <i>Yanting Li, Tetsuji Kuboyama and Hiroshi Sakamoto</i>	287
MobiS - Personalized Mobility Services for Energy Efficiency and Security through Advanced Artificial Intelligence Techniques <i>Ruben Costa, Paulo Figueiras, Pedro Maló, Mitja Jermol and Kostas Kalaboukas</i>	296
Modeling the Forecasting Process in Supply Chain Management and Advanced Planning System <i>Sijie Li</i>	307
Non Classical Techniques in Decision Support Systems <i>Sylvia Encheva</i>	325
Outliers Accommodation in Fuzzy Control Systems over WSN <i>F. Januário, A. Santos, C. Lucena, L. Palma, A. Cardoso and P. Gil</i>	334
Randomness as the Security Levels of Investments <i>Mieko Tanaka-Yamawaki, Xin Yang and Yuuta Mikamori</i>	344
SA-E: Sentiment Analysis for Education <i>Nabeela Altrabsheh, Mohamed Medhat Gaber and Mihaela Cocea</i>	353

Solving Dynamic Emergency Distribution Scheduling Problems in Practice <i>Yiping Jiang and Lindu Zhao</i>	363
Solving Imbalance Data Classification Problem by Particle Swarm Optimization Support Vector Machine <i>Zhenyuan Xu, Mingnan Wu, Junzo Watada, Zuwarie Ibrahim and Marzuki Khalid</i>	371
Stability of Financial Market: The Introduction to the JAVA Simulation of Agent-Based Model <i>Roman Šperka, Marek Spišák and Jan Górecki</i>	380
Super Pairwise Comparison Matrix with the Logarithmic Least-Squares Method <i>Takao Ohya and Eizo Kinoshita</i>	390
Temporal Change of Community Structure in the Japanese Credit Network <i>Yuki Matsuura, Takashi Iino and Hiroshi Iyetomi</i>	399
The Measurement of Exit Strategy Impact in Fuzzy Portfolio-Based Investment <i>Bo Wang, You Li and Junzo Watada</i>	409
Towards Optimal Solutions in a Constantly Changing Environment <i>Sylvia Encheva</i>	419
Towards Practical Tabled Abduction Usable in Decision Making <i>Ari Saptawijaya and Luís Moniz Pereira</i>	429
Subject Index	439
Author Index	443

# A Context-Sensitive Support System for Medical Diagnosis Discovery based on Symptom Matching

Marko KNEŽEVIĆ<sup>a,1</sup>, Vladimir IVANČEVIĆ<sup>a</sup> and Ivan LUKOVIĆ<sup>a</sup>

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**Abstract.** In this paper, we present a prototype of a clinical decision-support system. This prototype relies on a two-phase algorithm that is based on the differential diagnosis method from medical diagnostics and predictive models for disease occurrence in a subpopulation. The algorithm requires a data set containing information about diseases and their corresponding symptoms, and a data set with registered disease cases. The main output of this algorithm is a ranked list of diagnoses that might explain the manifested symptoms. The ranking is influenced by the patient's context, i.e., disease trends within a subpopulation to which the patient belongs. In the context of medical diagnosis discovery based on symptom matching, we present a short rationale for developing such a system, brief review of similar systems, algorithm for diagnoses ranking, and ideas for future research. Furthermore, we elaborate on the required data sets and illustrate the application of the proposed solution with a typical use scenario.

**Keywords.** clinical decision support system, symptom checker, data mining, medical diagnosis, health informatics

## Introduction

With the increased availability of databases containing vast knowledge regarding diseases and medical conditions, new possibilities arise for non-expert users who are interested in obtaining information about illnesses that they constantly face. However, the use of Web search as a diagnostic procedure, where queries describing symptoms are input and the resulting information, together with the associated rank, is interpreted as a diagnostic conclusion, may lead users to believe that common symptoms are likely the result of a serious illness. Such escalation from common symptoms to serious concerns may cause unnecessary anxiety, investment of time and expensive engagements with healthcare professionals [1]. Therefore, there is a strong need for trusted health and medical information about a set of manifested symptoms. Any software-based solution for such a requirement should also take into the account the fuzzy and incomplete nature of user queries and the lack of precise knowledge regarding symptom names in the general population. What complicates this issue even more is the fact that the relationship between symptoms and diseases is of the “many-

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to-many” type in which one symptom may be linked to many disorders and vice versa. In addition, the symptoms of disease may vary between individuals or disease subtypes.

Our goal is to create a pilot version of a software-based solution that could support, at least partially, one way symptoms-to-diseases matching while satisfying the aforementioned criteria. Moreover, as the Serbian healthcare system is undergoing extensive and significant modernization [2], this solution should primarily motivate stakeholders to more seriously regard IT solutions as an indispensable component in the modern provision of health services in Serbia. The proposed software system needs to support a scenario in which a user provides the list of present symptoms and relevant personal information, in order to obtain a list of potential diagnoses. What sets this solution apart from many other similar systems is its reliance on a broader patient context. This context sensitivity may be observed in the refinement of the initial ranked set of diagnoses that match a set of symptoms according to medical knowledge: the ranking of a matching diagnosis is increased if such diagnosis is often observed in the subpopulation to which a patient belongs and decreased if the diagnosis is rare (or not present) in the subpopulation. In this manner, medical diagnosticians could utilize the system to more rapidly evaluate potential diagnoses in individual cases. Tasks that need to be carried out during the implementation of such system include: (i) collection of medical knowledge about diseases and their symptoms; (ii) collection of data that could help narrow down the search space of diseases by containing a valid excerpt of registered cases for different subpopulations; (iii) formulation of an algorithm that forms a list of possible diagnoses matching a list of symptoms by utilizing information from the two abovementioned data sets; and (iv) implementation of the algorithm and its integration into a software that is also designed for non-expert users.

This paper is divided into four sections besides the Introduction and Conclusion: Section 1, which gives an overview of similar solutions; Section 2, which presents data sets utilized in the proposed algorithm; Section 3, which describes the algorithm for symptoms-to-disease matching; and Section 4, which illustrates a use scenario for the algorithm in a software system for epidemiological research and monitoring.

## **1. Related Work**

There are many clinical decision support systems (CDSSs) [3] and software systems that provide information on most common causes of provided symptoms. One group of such systems includes symptom checkers, online tools used to help educate users and suggest what condition certain symptoms could indicate. WebMD Symptom Checker [4] is one such example of a tool designed to help determine the underlying cause for a set of medical symptoms and learn about possible conditions. Different areas where discomfort or pain is being felt may be selected on the displayed human figure. Based on the selection, symptoms that are being experienced and related to that area may be further specified. Depending on the input, WebMD Symptom Checker provides information needed to determine the next steps in dealing with the symptoms, including recommendations to consult with a physician, as well as lifestyle changes. Another similar solution is the Isabel Symptom Checker [5], which takes a pattern of symptoms in everyday language and instantly computes the most likely diseases. When compared to our solution, both WebMD Symptom Checker and Isabel Symptom Checker ignore data about disease trends in a community to which the user belongs. Furthermore, they provide information only on the basis of symptoms being consistent



with a diagnosis. In this manner, those systems provide answers to such questions as: whether some symptoms might indicate a serious, perhaps chronic or fatal condition, or whether such fears are unfounded. Unlike our system, their results are not influenced by the results of an analysis that is performed over a set of registered disease cases.

The second group of such systems helps physicians to diagnose diseases. Internist [6] is one such example of a diagnostic program. It tries to explicitly capture the way human experts make their diagnoses, using a complex problem-solving strategy based on the technique of differential diagnosis that clinicians use every day. Its main strengths with respect to our solution are two parameters supplied for each finding (such as symptoms and test results), indicating the correlation between disease and finding. The first parameter represents the likelihood of the disease given that the finding occurs. The second parameter represents the likelihood of the finding given that the disease occurs. Values of both parameters for each association between disease and finding within Internist's knowledge base are a result of many man-years of effort provided by a team of physicians. On the other hand, our solution provides estimation of these parameters on the basis of number of symptoms consistent with a disease and number of diseases associated with a symptom. However, there is a conceptual difference between these two systems regarding algorithm and usage scope. Our solution is intended to be used outside the physician's office, as well. In this manner, it may be used by people other than healthcare professionals, in which case it has only informative purpose. Furthermore, it is a web-based system that may be used through a regular web browser and easily made public. As far as the algorithm is concerned, unlike Internist, our solution utilizes predictive models to refine the initial results that are based solely on observed symptoms. The user may also set how much the final score assigned to each diagnosis is going to be influenced by the results of the corresponding predictive model. The final score is dependent on the parameter that determines the ratio of scores provided by separate phases of algorithm, one of which relies on predictive models. DXplain [7] is a decision support system developed at the Laboratory of Computer Science at the Massachusetts General Hospital. It utilizes a set of clinical findings (signs, symptoms, and laboratory data) in order to produce a ranked list of diagnoses that might explain the clinical manifestation. Furthermore, it suggests what further clinical information would be useful to collect for each disease, and lists what clinical manifestations, if any, would be unusual or atypical for each of the specific diseases. However, similarly to our solution, it is not intended to be used as a substitute for professional medical advice. Another similarity is that it also offers a ranked list of diagnoses with corresponding sets of not observed symptoms. These symptoms are provided as guidance in making decisions about which laboratory test to order or which symptoms to observe. On the other hand, the principal difference lies in the ability to rank the diseases based on the epidemiological trend in the subpopulation.

The strong point of our solution when compared to the aforementioned solutions is the possibility to reduce errors caused by different probabilistic relationships between findings and diagnoses in different patient populations. The reduction is done by utilizing a data set with registered disease cases in a subpopulation. In this manner, among diseases with similar sets of symptoms, higher ranking is given to those more consistent with disease trends within the specified subpopulation. Therefore, the relationship between the symptoms and a disease to which the subpopulation is more susceptible has a greater significance. Our solution is a complex system that has traits typical of both symptom checkers and CDSSs: (i) it may provide information about the meaning of observed symptoms; and (ii) support medical diagnosis discovery.