Studies in Computational Intelligence

Volume 735

Series editor

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Intelligent Medical Decision Support System Based on Imperfect Information

The Case of Ovarian Tumor Diagnosis

Springer

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ISSN 1860-949X ISSN 1860-9503 (electronic)
Studies in Computational Intelligence
ISBN 978-3-319-67004-1 ISBN 978-3-319-67005-8 (eBook)
https://doi.org/10.1007/978-3-319-67005-8

Library of Congress Control Number: 2017951167

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

I dedicate this book to my Family: my wife Anna, sons Kuba and Michał, and to my Parents

Preface

This monograph is the result of scientific research conducted between 2012 and 2016 by an interdisciplinary team of scientists from the Department of Imprecise Information Processing Methods at Faculty of Mathematics and Computer Science of Adam Mickiewicz University (AMU) in Poznań and The Division of Gynecologic Surgery of the Poznań University of Medical Sciences (PUMS). The AMU team includes prof. dr hab. Maciej Wygralak, dr inż. Anna Stachowiak, dr Patryk Żywica, and mgr Andrzej Wójtowicz. The PUMS team is composed of: prof. dr hab. n.med Dariusz Szpurek, dr hab. n.med. Rafał Moszyński, and dr n.med. Sebastian Szubert. The author of this monograph is the project leader.

Medical diagnosis and the proper differentiation of ovarian tumors are very important issues. Every year, about 2500 women die in Poland due to this type of cancer and over 14,000 in the USA. Poland is at the top of the list with the highest mortality due to this cancer. In addition, these tumors are difficult to diagnose because they give too few unambiguous symptoms in the early stage. Differentiating this form of tumor is in many cases difficult and requires a physician with extensive experience, advanced medical equipment, and repeated use of imprecise and incomplete data.

Physicians specializing in this type of disease have noted the need for a computerized system to support the diagnosis of such tumors, which would help the less-experienced physicians in the diagnosis and differentiation of tumors. There is also a need for a central database for standardized gathering of medical information on cases of patients treated in different centers in Poland, which would allow us to improve the developed diagnostic algorithms in the future.

The book outlines the theoretical foundations and the description of the *OvaExpert* system created by our team. The system supports the physician in the diagnosis of ovarian tumors using computational intelligence methods with particular focus on the problem of data incompleteness. The first part of the book introduces basic information on medical diagnosis and the diagnosis of ovarian tumors. The statistics concerning this disease have also been presented. In the next part of the book, we have introduced the necessary elements of fuzzy set theory and its extensions such as IVFSs and IFSs. The key part of the monograph is the description of original algorithms based on the cardinalities of IVFSs. The algorithm descriptions are supplemented with the analysis of the efficacy of the presented algorithms, performed on the data of patients treated in the Poznań medical center. The last chapter describes the *OvaExpert* system, its key elements, and technologies and analyzes the prediction efficacy of algorithms used in the system against other existing methods. The book ends with a brief description of the ongoing and planned research and development works connected with the system.

I would like to thank the whole team involved in the project, without whom this book could not have been written. In particular, I would like to thank prof. dr hab. Maciej Wygralak for supporting me throughout the years, for pointing me in scientific directions and motivating to do further research. I extent my gratitude to colleagues from my Department: dr Anna Stachowiak, dr Andrzej Wójtowicz, and dr Patryk Żywica for their daily cooperation and hard work, commitment, as well as conceptual and technical support. I am grateful to the doctors from the Poznan University of Medical Sciences who cooperated with us, and especially to dr hab. Rafał Moszyński and dr n.med. Sebastian Szubert whom I would like to thank for introducing me to the medical realm of knowledge and for tremendous support during the creation of the system, and to prof. dr hab. Dariusz Szpurek, for his interest in the subject and creating favorable conditions for cooperation between our teams.

Finally, I would like to thank my beloved wife, Anna, for her understanding throughout the whole time which I devoted to my research and for her unwavering support in difficult times.

Poznań, Poland Krzysztof Dyczkowski
April 2017

Contents

Acronyms and Abbreviations

Acc	Accuracy
ADNEX	The Assesment of Different Neoplasis in the adneXa
Alc	Alcazar's model
AUC	Area under an ROC curve
BI-RADS	Breast Imaging Reporting Data System
BMI	Body Mass Index
CBR	Case-Based Reasoning
CEE	Central and Eastern Europe
COG	Center of Gravity
DBMS	Database management system
Dec	Decisiveness
EBM	Evidence-Based Medicine
FCS	Family of all Crisp Sets
FDA	Food and Drug Administration
FE	FECount
FFS	Family of all Fuzzy Sets
FG	FGCount
FIGO	International Federation of Gynecology and Obstetrics
FL	FLCount
FN	False Negative
FP	False Positive
FSC	*Ovaexpert* decision method based on counting
GDM	Group Decision Making
GFE	Family of all generalized cardinal numbers
GI-RADS	Gynecolologic Imaging Reporting and Data System
GP	General Practitioner
IFS	Atanassov's Intuitionistic Fuzzy Set
IOTA	International Ovarian Tumor Analysis Group
IVFC	OvaExpert decision method based on Interval-Valued Fuzzy Classifier
IVFS	Interval-Valued Fuzzy Set

LR	Logistic Regression
LR1	IOTA Logistic regression-based model 1
LR2	IOTA Logistic regression-based model 2
Max	Maximum
Min	Minimum
MSK	Memorial Sloan-Kettering Cancer Center
MVC	Model-View-Controler
NICE	National Institute for Health and Care Excellence
OEA	OvaExpert decision method based on aggregation
OECD	The Organization for Economic Cooperation and Development
ORM	Object-Relational Mapping
OWA	Ordered Weighted Averaging
PACS	Picture Archiving and Communication System
PBD	Percent Breast Density
PDI	Polytomous Discrimination Index
PPV	Positive Predictive Value
Prec	Precision
RIS	Radiology Information System
RMI	Risk of Malignancy Index
ROC	Receiver Operating Characteristic
ROMA	Risk of Ovarian Malignancy Algorithm
SaaS	Software as a Service
SD	Doppler Index
SDR	Standardized Death Rate
Sen	Sensitivity
SM	Sonomorphological Index
Sneg	Family of all strong negations
Spec	Specificity
SR	IOTA Simple Rules diagnostic model
Supp	Support of a fuzzy set
Tim	Timmerman's logistic regression model
TN	True Negative
TNR	True Negative Rate
TP	True Positive
TPR	True Positive Rate
USG	Ultrasonography

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Abstract

This book deals with a computer-supported medical diagnosis with particular focus on ovarian tumor diagnosis. The book presents theoretical foundations (both medical and mathematical) of the intelligent *OvaExpert* system which supports the decision-making process in tumor diagnosis. The main purpose for creating *OvaExpert* was to support a gynecologist in the process of predicting the malignancy of ovarian tumors by applying the existing diagnostic models and using modern methods of computational intelligence which allow for imprecision and imperfection of the medical data, both of which are common features of the everyday medical practice. We had good reasons to focus on this particular cancer. Ovarian cancer is difficult to diagnose and has high mortality, especially in the Central and Eastern Europe. The book presents novel methods based on interval-valued fuzzy sets and the theory of their cardinalities. The algorithms applied have been verified by analyzing their efficacy on real data.