





Centrum Cyfrowej Nauki i Technologii UNIWERSYTET KARDYNAŁA STEFANA WYSZYŃSKIEGO W WARSZAWIE





# Anniversary Panel Session (The Next) 40 Years of Rough Sets



UPPSALA UNIVERSITET



Jan Komorowski, Witold Pedrycz Andrzej Skowron, Roman Słowiński & Dominik Ślęzak

PP-RAI'22









#### **Rough Sets**

Zdzisław Pawlak<sup>1</sup>

Received June 1981; revised Semptember 1982

We investigate in this paper approximate operations on sets, approximate equality of sets, and approximate inclusion of sets. The presented approach may be considered as an alternative to fuzzy sets theory and tolerance theory. Some applications are outlined.

**KEY WORDS**: Artificial intelligence; automatic classification; cluster analysis; fuzzy sets; inductive reasoning; learning algorithms; measurement theory; pattern recognition; tolerance theory.

Apart from the known and the unknown, what else is there? Harold Pinter (The Homecoming)

#### 1. INTRODUCTION

The aim of this paper is to describe some properties of rough sets, introduced in Ref. 7 and investigated in Refs. 1, 2, 4, 5, 6, 8, 9, and 11.

The rough set concept can be of some importance, primarily in some branches of artificial intelligence, such as inductive reasoning, automatic classification, pattern recognition, learning algorithms, etc.

The idea of a rough set could be placed in a more general setting, leading to a fruitful further research and applications in classification theory, cluster analysis, measurement theory, taxonomy, etc.

The key to the presented approach is provided by the exact mathematical formulation of the concept of approximative (rough) equality of sets in a given approximation space; an approximation space is understood as a pair (U, R), where U is a certain set called universe, and  $R \subset U \times U$  is an indiscernibility relation. We assume throughout this paper that R is an equivalence relation.



# Zdzisław Pawlak 1926-2006 Rough Sets 1982-2022

<sup>&</sup>lt;sup>1</sup> Institute of Computer Sciences, Polish Academy of Sciences, P.O. Box 22, 00-901 Warsaw, PKiN.

# FIRST MEETING



THEORY OF COMPUTING

AUTOMATED THEOREM PROVING



- APPLICATION ORIENTED RESEARCH
  - SIMPLICITY OF SOLUTIONS
- EXTRAORDINARY TALENT IN INFECTING
   OTHERS WITH THE CONDUCTED BY HIM
   RESEARCH

#### A Skowron

# BEGINNING OF ROUGH SETS (RS)

### CLASSIFICATION OF TOYS



# FIRST APPLICATIONS OF RS

CONTROL OF A ROTARY CLINKER KILN IN A CEMENT PLANT

# My first encounter with Rough Sets

- Introduced to RS by Professor Andrzej Skowron in 1992.
- Professor Zdzisław Pawlak visited Trondheim in Winter 1993 and stayed in my house. Had lots of illuminating discussions. Decided that implementations of rough sets are key to success.
- With contributions from Prof. Skowron's team implemented ROSETTA.
- Using ROSETTA the first significant publication in 2003 (Genome Research, IF 10); predicting gene function from expression data.

# The first international workshop on rough sets in Kiekrz near Poznań, 1992

#### The First **International Work**shop on Rough Sets State of the Art and Perspectives

#### Wojciech Ziarko

The First International Workshop on Rough Sets: State of the Art and Perspectives was held on 2-4 September 1992 in Kiekrz, Poland. To stimulate the discussion, the participation was limited to 40 researchers who are involved in fundamental research in rough set

practitioners. This mixture is what made this workshop exciting, with

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INTELLIGENT **DECISION SUPPORT** Handbook of Applications and Advances of the Rough Sets Theory

Edited by Roman Słowiński

knowledge is understood here as an theoretical papers interleaved with ability to characterize all classes of application reports demonstrating the classification, for example, in the utility of the presented methodterms of features of objects belonging ologies. Applications presented durto the domain. Objects belonging to p included data preneural net training,

the same category are not distinguishable, which means that their ng, medicine, fault membership status with respect to an diagnosis, drug arbitrary subset of the domain might processing, and digi-

Workshop Report

Pawlak in the 1970s as a result of a

long-term program of fundamental research on logical properties of information systems that was carried

out by him and a group of logicians from the Polish Academy of Sciences and the University of Warsaw in

Poland. The methodology is concerned with the classificatory analysis of imprecise, uncertain, or incomplete information or knowledge

expressed in terms of data acquired from experience. The primary notions of the theory of rough sets are the approximation space and lower and upper approximations of a

set. The approximation space is a classification of the domain of interest into disjoint categories. The classification formally represents our knowl-

edge about the domain; that is, the

ROUGH SETS. STATE OF THE ART AND PERSPECTIVES

1992



Rough Sets and Soft Computing (RSSC), San Jose, 1994

Rough Sets, Fuzzy Sets and Machine Discovery (RSFD), Tokyo, 1996

Dr HC PP, 2002

Rough Sets & Current Trends in Computing, Banff, 2000

- Early research on fuzzy sets Silesian University of Technology, Gliwice
- Around 1981 first acquittance with rough sets through reports published by Polish Academy of Sciences
- Meetings at conferences on fuzzy sets; interesting and insightful discussions



W Pedrycz

### Transactions on **Rough Sets XXII**

James F. Peters · Andrzej Skowron Editors-in-Chief



ACM Transactions on Intelligent Systems and Technology Annals of Pure and Applied Logic Applied Intelligence Applied Soft Computing Artificial Intelligence Artificial Intelligence Review **BMC Bioinformatics** Communications of the ACM **European Journal of Operational Research** Expert Systems with Applications Fundamenta Informaticae Fuzzy Sets and Systems Group Decision and Negotiation IEEE Transactions on Computational Social Systems **IEEE Transactions on Evolutionary Computation** IEEE Transactions on Fuzzy Systems IEEE Transactions on Geoscience and Remote Sensing IFFE Transactions on Image Processing

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IEEE Transactions on Knowledge and Data Engineering **IEEE Transactions on Neural Networks** IEEE Transactions on Systems, Man and Cybernetics IEEE/ACM Transactions on Audio, Speech, and Language Processing IEEE/ACM Transactions on Computational Biology and Bioinformatics **Information Sciences** International Journal of Approximate Reasoning International Journal of Computational Intelligence Systems International Journal of Machine Learning and Cybernetics International Journal of Molecular Science International Journal of Science and Engineering Neurocomputing Journal of Applied Non-Classical Logics Pattern Recognition Journal of Biomedical Informatics Pattern Recognition Letters **Knowledge and Information Systems** Pharmaceutics Knowledge Based Systems Sensors **Neural Computing and Applications** Studia Logica Neural Networks Theoretical Computer Science Neural Processing Letters Web Intelligence and Agent Systems



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R S S D	RSDS Rough Set Data	abase System		HOME CON					ТАСТ		US011301467B2			
НОМЕ	SEARCH SEND	STATISTICS		EOPLE	SOFTWARE	MAP	HELP	CONTACT	(1	) Unite Slezak	ed States Patent et al.	(10) Patent No.: U (45) Date of Patent:	US 11,301,467 B2 Apr. 12, 2022	
US © Categorie	SER MENU	Page 1 Page 2	Page 3 Page S FOR THE	4 Page 5	Page 6	Page 7	\SE SYS <sup>-</sup>	ΓEM	(5	<ul> <li>SYSTEM INTELL TRANSI DATA S</li> <li>Applican</li> </ul>	S AND METHODS FOR GENT CAPTURE AND FAST ORMATIONS OF GRANULATED IMMARIES IN DATABASE ENGINES : Security On-Demand, Inc., San Diego, CA (US)	<ul> <li>(52) U.S. CL CPC G06F 16/24539 (2019.0.1); G06F</li> <li>(58) Field of Classification S CPC</li></ul>	9 (2019.01); G06F 16/2282 16/2462 (2019.01); G06N 5/003 (2013.01) earch 1539; G06F 16/2282; G06F 16/2462; G06N 5/003 smplete search history.	
US Username:	ER LOGIN	The service has been visited <b>3363048</b> times. Number of registered users: <b>405</b> . Number of authors (in the database): <b>42859</b> . <b>What kinds of publications are included?</b>							(/	) inventors	Dominik Stežak, warstw (PL,C Richard Glick, Valley Center, CA (US): Paved Betlinski, Warsaw (PL): Pfort Synak, Vanethur (PL): Jakub Wroblewski, Lomianki (PL): Agalexiza Chadynskia-Krasowska, Swijowe (PL): Januar Dorkowski, Warsaw (PL): Januar Dorkowski, Warsaw (PL): Joel Alan Holland, Encinitas, CA (US)	(56) <b>References Cited</b> U.S. PATENT DOCUMENTS 6670.772 B1 132000 Comins et al. (Continued) FOREIGN PATENT DOCUMENTS WO 2009034219 A1 32008		
Password:		Kind of publication	n Number of publicat	ions			21,552		(7	<ul> <li>Assignee</li> <li>Notice:</li> </ul>	Security On-Demand, Inc., San Diego, CA (US) Subject to any disclaimer, the term of this patent is extended or adjusted under 35 USC 1540b by 462 dataset	OTHER PUBLI International Preliminary Report on Patent Application No. PCT/CA200 (Continu	ICATIONS Patentability for International 7/001627 dated Jan. 7, 2008. red)	
Log in O Create ne	w account	inproceedings incollection book techroport	-				15,324 1,232 176		(2	) Appl. No t) Filed:	1459,274 Jul. 1, 2019	Primary Examiner — Kris E Ma (74) Attorney, Agent, or Firm – Russell LLP (57) ABSTRA	ackes – Smith, Gambrell & ACT	
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		connectwoder	Pseudomonas aeruginosa				Tableting Process
Granular structure-based incremental updating for multi-label	A landecape and implementation framework for probabilistic	Małgorzata Przybyła-Kasperek <sup>1</sup>	Lakasz Pałkowski <sup>1, "</sup> <sup>1</sup> 0, Maciej Kanslak <sup>1</sup> 0, Jerzy Blaszczyński <sup>2</sup> , Jerzy Krysiński <sup>1</sup> and Roman Słowiński <sup>2,3</sup>	Rough-set-driven approach for attribute red	luction in fuzzy formal		Maciej Karolak <sup>1,4</sup> 0, Lukasz Pałkowski <sup>1</sup> 0, Bartlomiej Kubiak <sup>2</sup> , Jerzy Blaszczyński <sup>3</sup> ,
classification"	rough sets using promog	Published online: 11 April 2020	<sup>1</sup> Department of Pharmaceutical Technology, Faculty of Pharmary, Nacilians Corporation University, Januara 2.	concept analysis		Empirical risk minimization for dominance-based rough set	Rafal Lunio <sup>4</sup> , Wiesław Sawicki <sup>8</sup> , Roman Słowiński <sup>3,6</sup> and Jerzy Krysiński <sup>1</sup>
Yuanjian Zhang 22, Duoqian Miao 22, Witold Pedrycz 2022, Tianna Zhao 22, Jianteng Xu 2022, Ying Yu	Patrick Doherty Atta,1, Andrzej Szałas (202	© The Author(s) 2020	65-004 Bydgesen; Peland, meciej kareladi@cecumit.pl OM K3; perzykrysinki@cecumit.pl (UK3) kutitete of Computing Science, Perrant University of Excitociting, Protocol 2, 66-085 Presnat, Poland; here Bergenerating and an energy of (2) in second control of the	M. José Benítez-Caballero n1, Jesús Medina n1, Elo	sisa Ramírez-Poussa 441,	approaches	Department of Pharmaceutical rechnology, Conegutar Medicum, viccolaus Coperacos University, 85-009 Bydgoszcz, Poland; Jukaszpalkowski@cm.umk.pl (J.P.). jerzy krysinski@cm.umk.pl (J.K.)
<sup>1</sup> Department of Company Science and Entraning, Tangil University, Houghai, 20104, China <sup>13</sup> Exp (Laboratory of Cobuldad System and Enviro Company), Minary of Education, Tengs University, Daughot, 201034, China <sup>14</sup> Exp (Laboratory of Cobuldad) System and Enviro Company, Minary of Education, Tengs University, Daughot, 201034, China (Education and Education and Enviro).	"School of Intelligent Systems and Engineering, Jose Dativenity (Zhahai Compact), Zhahai Chena "Desarrower of Compactor and Information Science, Galdanine University, 67–681 40 Linkshota, Dandon	Abstract	<sup>6</sup> Systems Research Institute, Polish Academy of Summers, Newerlika 5, 01-807 Warsan, Poland Comparatonse: Industrypillowski/Blom.unik.pl (201) 466 52:505-59.27	Dominik Ślęzak <sup>1</sup>		YOSHITUMII KUSUNOKI ** , JETZY BIASZCZYNSKI *, MASANIPO INUIGUCII *, KOMAN SIOWINSKI *** *Graduat School of Nerweiters and Sestemble System Schools, Oxide Preferenz University, JJ. Caluers che, Nata-Ing, Sales, Oxide 599-8531, Japan	<sup>23</sup> Institute of Computing Science, Poznati University of Technology, 60-965 Poznati, Poland; institute of Computing Science, Poznati University of Technology, 60-965 Poznati, Poland; interphiloscoperational (III) - pomora dominikillos mut poznati no (U.S.).
Sparen Research Buckness, Haloh Asaberg of Simons, Warnes R. 1046, Passal * Software Collign, Banchang Delversity, Jiangel 20067, Chan a	"Institute of Informatics, University of Worson, Amurilu 2, 12-197 Warson, Peland	The article addresses the issues related to making decisions by an ensemble of clas- sifiers. Classifiers are built based on local tables, the set of local tables is called a	Abstract: This paper presents the results of structure-activity relationship (SAR) studies of 140	<sup>6</sup> Department of Mathematics, University of Ciddy <sup>5</sup> Involute of Informatics, University of Marson P.	; Spale Niloud	*Craduere Schoel of Dighovering Science, Osaka Divlorenty, 1-2, Markkaneysens, Tayonska shaka 560 kU23, Japan *Percent University of Perchaning, Acidence of Computing Science, Percent, Percent, Poland Science, Market Market, Acidemic Market, Science, 2010; 2010	<ol> <li>Polpharma SA, 83-200 Starogard Gdatoki, Poland; rafallunio@polpharma.com</li> <li>Denotment of Physical Chemistry, Medical University of Gdatok. 80:416 Gdatok. Poland-</li> </ol>
"Cologe of Spherer Exploreing East China Jacong University, Jangel. 320073. China	ARTICLE INFO ABSTRACT	dispersed knowledge. The paper discusses a novel application of Pawlak analysis	3.3" (a,u-dioxashan)Bir(1-alkylinidazoitum) chloridos. In the SAR analysis, the dominance-based mugh set approach (DRSA) was used. For analyzed compounds, minimum inhibitory concentration.	Received 13 May 2019; received in stringd form 9 Onuber 2019, acc	cepted 11 November 2019	-Shinara warata waratari warata wasana di Sourata' ni -44, waratari basana	<ul> <li>wiedaw awicki@gumed.edu.pl</li> <li>Systems Research Institute, Polish Academy of Sciences, 01-447 Warraw, Poland</li> </ul>
ARTICLE INFO ABSTRACT	Article Money: Reasoning about uncertainty is one of the main conversioner of Knowledge Representation.	model to examine the relations between classifiers and to create coalitions of classi- fiers. Each coalition has access to some aggregated knowledge on the basis of which	(MIC) against strains of Stephylececca aarns and Petskiniones emploies was determined. In order to perform the SAR analysis, a tabular information analysis was formed, in which tested compounds were	Available owned to however 2019		ARTICLE INFO ABSTRACT	<ul> <li>Correspondence: maciej.karolak@cm.umk.pl; %1: +48-52-585-3927</li> </ul>
White knows: Incremental tearning is an efficient comparational paradigm of acquiring approximate knowledge of data in dynamic environment. Must of the research focuses on knowledge updating for single-	Beerivel 16 April 2011 Beceived an interest 10 December 2021 Mere recently, combining lingle with probability has been of major interest. Bough set methods have been proposed for modeling incompleteness and imprecision based on	joint decisions are made. Various types of coalitions are formed-a strong coalitions	O such to support of the second se			Article Manay Bostined 5 Marc 2020 Bostined 5 Marc 2020	Received: 25 September 2020; Accepted: 24 October 2020; Published: 26 October 2020
Accepted 22 September 2019 Accepted 22 September 2019 Assisted watters 15 October 2019 Institute watters 15 October 2019 Institute watters 15 October 2019	Austable online 20 December 2021 More recently, the classical theory has been generation to be angle only or work in the direction. More recently, the classical theory has been generation to include probabilistic rough out muthed of which there are also a must variety of memory.	sisting of insignificant classifiers. The new contributions of the paper is a systemati-	Contexe Personist 1. Karvisk M. with respect to values of MIC. DISA allows to induce decision make from data describing the memorials 1. Kywtols 1	Abstract The reduction of the set of attributes is an important preliminary challenge in	order to obtain information from knowledge	Received in revised from 13 October 2000 Accepted 18 February 2021 DDSA (VC-DISA) They were introduced to cope with classification data encountered in particle for which the enricond definition of parent and the encountered in particle for which the enricond definition of parent and the encountered in the encountered in the encountered in the encountered in particle for which the enricond definition of parent and the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountered in the encountere	Abstracti Multiple-unit pellet systems (MUPS) offer many advantages over conventional solid dosage forms both for the manufactures and nationic Control pellois can be efficiently communed into
Approval system is bottom up way periodes a systematic view on label-specific based cassification. We becommandly demonstrate that the there-way selective miserable (TSIN) model, a state-of-the-art solution for	Environt: Probabilistic rough set: Bold on is lacking. It is the purpose of this paper to fill in that gap where the licus will be on prob-	cal investigation of the weights of coalitions that influence the final decision. Four different method of calculating the strength of the coalitions have been applied. Each	Sociali, I. Sociali, Astrony to relevance using a Bayesian confirmation measure. Decision rules present the most important Resemblys of the Industrian and University and University and University of the community, or one hand, and their	systems. Two remarkable formal tools for extracting such information are Rough Se (FCA) to well to their force amendications. This such introduces a new method to a	t Theory (RST) and Formal Concept Analysis educe attributes in Fures FCA considering the	Austable roline 20 Peterusy 2021 these extensions allow as augmentation of lower approximations, which is controlled parametrically in different ways. We give statistical interpretations for VP-ORSA and VC-	MUPS in classic tableting process and enable controlled release of active pharmaceutical ingrectient
Musi-laber classification, is comparable with CS in granularion. An incremental inechanism of CS is     cannot encoded in both laber opecific feature generation and optimization, and incremental frequency     multi-laber classification, is comparable under the second processing     decision encoded in the both laber opecific feature generation (MINTRA) is     measure interpreted classification.	resolutions programming abilitis rough set methods. A landscape of (probabilistic) rough set reasoning methods and Knowledge representation the variety of choices involved in specifying them is surveyed first. While doing this, an	of these methods consider another aspect of the structure of the coalitions. Gener-	Composed on Authorities of Implacement and Predemonal antibacturing encourse of the other hand. They also indicate directions of synthesizing more efficient antibacturing encourse of antibacturing encourse of a synthesizing more efficient antibacturing composed and for an antibacturing encourse of a synthesizing more efficient antibacturing encourse of a synthesizing enco	reduction philosophy given in RST and studies its main properties. This method allow between these two theories. Moreover, the proposed methodology has been compare	vs us to carry out a deeper study of the relation al with other existing induction mechanisms.	Repends: DBSA from the perspective of empirical risk minimization typical for machine learning. Doubt not construct the memoratum Coven families of classification problems which	(APIs). For patients MUPS are divisible without affecting drug release and convenient to swallow. However, maintaining API release profile during the compression process can be a challenge. The
completed on six datasets show that the proposed algorithm can maintain considerable classification performance while significantly accelerating the biswindige (CIS) updating.	hale-based languages abstract generalization of all the considered approaches is derived which subsumes each of the methods. One then shows how, via this generalization, one can specify and reason of the methods.	fies the relations between base classifiers, the use of coalitions weights improves the	sergiose bit 2.466 Sci 200, 27, 7907. https://doi.org/10.2007.	© 2019 Elsevier B.V. All rights reserved.	a sur cure county reaction in commun.	Vaciable consistency dominance-based relate directly VP-DRSA and VC-DRSA to redinal classification. Then, we characterize the parametrically augmented lower approximations of both approaches as optimal solutions	aim of this work was to explore and discover relationships between data describing: composition, properties, process parameters (condition attributes) and quality (decision attribute, expressed as
© 2010 Ebevier B.Y. All rights reserved.	about any or these methods using remote, a popular and watery used probabilities topic programming language based on mixes. The paper also considers new techniques in this constant such as the action of modulation larger and draining methods and then use	quality of classification. More specifically, it has been statistically confirmed that the best results are generated by the weighting method that is based on the size of the	guagettowr Keywoode: gemini-inidaacilians chloridas; antimicrobial activity; molecular descriptors; SAR; downoochand much act promote (2025).	Execute Faces sets Attribute reduction: Roket Facead concert analysis: Rouch set theory		Variable precision developments have reaght ant approach of associated empirical risk minimization problems. As a consequence, a connection between parametric DRSA and statistical learning to established. Moreover, new character- insteament of the summary statistical learning to established.	similarity factor (2) of MUPS containing pellets with verapamil hydrochloride as API, by applying a dominance-based rough net approach (DRSA) mathematical data mining technique. DRSA generated
1 Introduction of female maintains endates descent of the set the location character	of partially specified base relations that are also probabilistic. Additionally, probabilistic approaches using tolerance spaces are proposed. The paper includes a rich set of examples	coalitions and the method based on the unambiguous of the decisions.	Added Lifest Signation			Latities between VP-DRSA and VC-DRSA.	decision rules representing cause-effect relationships between condition attributes and decision attribute. Similar API advance motion from relate before and after tableting can be ensured by monor
Example of the second s	and provides a furnework based on a library of generic source, relations that make speci- fication of any of these methods, straightfreward, officient and compact. Complete, ready to	Keywords Conflict analysis - Dispersed knowledge - Multiple classifiers - Coalitions	Resident 21/Jane 2021	1. Introduction			polymer coating (Eudragit® NE, absence of ethyl cellulose), compression force higher than 6 kN,
solving methodology. It simulates human-centric operations to alized in the presence of multifaceted data, and embraces a accomenodate information variations. For single-label learning,	ran musco code in included in the Appendix for all examples considered. © 2021 The Author(s), Published by Elsevier in: Thit is an open acress article under the CC.		Parameter 27 (sity 2021 Cationic surfactants, including bis-imidazollum chlorides (also called gemini-compounds), au able to based the surface tension while keeping result antimicrobial activity. This activity is a	The study of the knowledge stored in databases is one of the most import	ant enals in several research fields, which		for analysis of complex technological data. Decision rules with high values of confirmation measures
plethora of techniques which minimize uncertainty. The generic composent, information granule, in (ch in semantics and reflects) ing can be induced by variations of objects, attributes, values,	as score (add //remotionistrolly/usite//remotionistrolly/usite//remotionistrolly/usite//remotionistrolly/usite//	1 Introduction	Publisher's Note: MCM supressesting with ward to Edition of the cationic surfactant with the cell membrane of the microsoganism, with ward to Editional three is	has produced the necessity of developing mathematical tools to manage the	collected information. In addition, to deal	1. Introduction	can help technologist in optimal formulation development.
set theory (RST), established by Pawlak [2] in 1982, is capable of dealine which arbitraneously [6]. Lette et al. [7] investigated a fuzzy model-based control for nonlinear dynamic systems given object	I. Introduction	An important problem in today's world is the dispersion of knowledge. Many units,	pathloot request waterlood and interesting and waterlood and in addition of an interesting and the mechanism of antimicrobial effect interesting and the mechanism of antimicrobial effect	and Rough Set Theory (RST) [47] are two widely studied mathematical the	ories, devoted to obtain information from	In data analysis, we often encounter objects which are inconsistent with respect to our prior knowledge. Rough set theory [17,21] provides mathematical foundation for reasoning about the inconsistency. It concerns a data set given in the form of a	Keywords: tablets; multiple-unit pellet system; pharmaceutical technology; DRSA; data mining; knowledge discovery; machine learning
strety applied in various domains including sentiment analysis (e.g. [1]), social optimetic (e.g. [4]) and siden analysis (e.g. [5]).	1.1. Probabilistic rough sets	dealing with the same subject and operating in the same field, gather the knowledge to which they have access. This knowledge can be the mult of various factors-	concentration of other ions. Quaternary ammonium salls (containing quaternary nitrogen in its model) as a subject of the second se	<ul> <li>relational databases that contain uncertainty.</li> <li>Although it is easy to notice that both theories have several common a</li> </ul>	spects, the philosophy that underlies the	decision table, where rows correspond to objects of interest and columns correspond to attributes describing the objects. The attributes are divided into condition attributes and a decision attribute. The decision attribute specifies a target classification	
Previous studies usually assume a large collection of object with all information is known in advance. However, the emerge- taken incremental mechanism with the consideration of decision right advance sources from the consideration of the c	Formal theories for approximate reasoning are numerous and highly varied due to different types of approximate con- cepts intended to be modeled such as vagueness, imprecision and incompleteness. Rough set theory [27,19,25,38,47,48]	experience, history, analyzed cases, sensors. Very popular form of saving knowledge	tee to be backeria are less susceptible to those salts, which results in a tendency to acquire resistance to this	information management strategy employed by each theories is well differ the knowledge in small pieces, colled concepts, which contain a subset of	rentiated. On the one hand, FCA groups	of objects by partitioning the set of objects into decision classes. A major task for data analysis is to find descriptions of deci- sion classes in terms of condition attributes, and to make it possible to infer decision classes of objects based on their	1. Introduction
ing features occur unexpectedly in a dynamic environment. To name a few examples, senses continuously monitor the status inconvertibility undating the membership fuerities. Xu et al. [13]		is a decision table. However, if the knowledge contained in local decision tables is the result of different stimuli or analysis, the form of the tables can be very different,	Lanser MDR Back, Sectoring, Das ankle is an open access that an effective antikangal activity, and ability to indust the growth of yeast by industriant the ankle is an open access with the sector access and the sector access access access and the sector access	attributes by that objects. All these information pieces can be ordered, obta	ining the algebraic structure of a concept	descriptions. This setting is called supervised learning, and is a part of the field of machine learning. Because available condition attributes are limited both in number and in their value sets, some objects may be indis-	Pellets, microcapsules, as well as other solid particles can form multiple-unit dosage forms. By a
* No author incremental mechanism to stream computing * No author incremental mechanism to stream computing field. Yang et al. [12] explained the principles of attribute re-	<ul> <li>Corresponding author at Department of Computer and Internation Science Londoring University, 52-581 KE Londoning Sources, E-netl addresses; particular/invigiblesses (P. Doberty), and republication (C. Statke).</li> </ul>		distributed under the terms and conditions of the Control Commons Staphylicoccccis aspects (SAU) and Pseudowornas arringioosa (PAE) are microbial strains conditions of the Control Commons This is done to the	10-0-0		cernible, that is, they have identical values of all considered condition attributes. This idea is a mathematical basis of rough set theory. We suppose that indiscernible objects should be classified into the same decision class. Otherwise, the classifi-	proper modification, such forms allow a modified or constant release rate, whereby the concentration of the drug is maintained within therapeutic limits for a longer period of time. An appropriate release
persent similar wear sig or pended to have repending million with this weak, for hill disclosure summers over to have part interpretent wear and the similar persented a matrix based approach for updating 2011 (1000).	Storing's Research SSP Citizet Systems Propert RTIS 00071 (2004) problems grant from (inauthorizet story and an Respect Program Carel 20208313030088 from the Gaugeforg Department of Information and Technology, Clina.	1-0 Małgorzata Przybyła-Kasperek małgorzata przybyła-kasperek@us.edu.pl	Ambeion (C. W) liesse brip(// imitecommon/jknow/ty/ of themical comparation of the cell wall. Hence, the parameters affecting antibacterial activity of themical comparation of the original methods are alfored that	E-mail addresses manajors beamst was as OLJ. Beaker-Caballeroj, jenn modurettara (E. Bandrez-Penna), sheak Onzinew oly pl (B. Storak).	es (J. Medina), china, samiree Waca, es	T funnessing after	profile allows controlled absorption of active pharmaceutical ingredients (APIs) in the specific part of the gastrointestinal tract, providing a desirable therapeutic effect and reduces side effects. A special
<ul> <li>Corresponding autor.</li> <li>Found autors: dynamic matrices, Jing et al. [14]</li> </ul>	* This work has been supported by gaint 2017/27/M276/02018 of the National Science Centre Poland.	<sup>1</sup> Institute of Computer Science, University of Silesia, Bedzintska 39, 41-200 Sosnowiec, Poland	400	<sup>1</sup> Partially supported by the State Research Agency (AEI) and the European Regional Develo	openent Fund (PEDER) project TIN2016-76653-P.	E-mail addresses yorkitani kuroniki kurolakata wai, jo (Y. Kasanski ), jorg blassogniki (Kopat, porangi (J. Masaryshki), isognit (kyar.maka w z. jo (M. majachi), sonanjakataki (Kr. pat, porangi (R. Savatski),	type of multiparticulate drug delivery systems is a multiple unit pellet system (MUPS) in which microparticles or pellets are compressed to obtain a tablet. Tableted pellets demonstrate faster passage
https://doi.org/10.1111/j.htmps.2010.100000 0055-3503/0-2010 Dawlor BV. All inglite controll.	0020.0255/co.2021 The Auchiel (c) Published by Diserver Inc. This is an operatorial and the first COV/Lanne (http://creativerenena.a.org/instance/bg/420).	A	To 7 Mail Criwels 19 Bart Anno 7 August In Maintain William	https://doi.org/10.1016/j.fm.2019.31.009 0165-0114/02 2019 Elsevier B.V. All rights reserved.		https://doi.org/10.1016/j.j.ws.2021.02.042	The second s
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				Barbara Pekala <sup>1,2,4</sup> , Teresa Mmczek <sup>2</sup> , Dorota Gil <sup>2</sup> and Michal Keps	M 10		PATRICK G. CLARK*, Department of Electrical Engineering and Computer
Auto loan fraud detection using dominance-based rough set approach	Data meaning and knowledge discovery: Semantical aspects of	Heuristic-based feature selection for rough set approach		Institute of Constatus Science, University of Research, 2	6-300 Researcher, Polandi miketreki@sandis.cl	Rough Set Based Description of	Science, University of Kansas, Lawrence, KS 66045, USA.
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Jerzy Błaszczyński", Adiel T. de Almeida Filho <sup>5</sup> , Anna Matuszyk <sup>c.d</sup> , Marcin Szeląg <sup>A.*</sup> , Roman Słowiński <sup>og</sup>	Marcin Wolski <sup>a,*</sup> , Anna Gomolińska <sup>b,*</sup>	<ol> <li>Staticzyk ***, B. Z JEROSKO ***</li> <li>* Depresent of Gaptics. Compare Vision and Dated Systems. Resilty of Astronace Control Decremics and Computer Statese. Similar</li> </ol>		* Consepondence hpskaløfbezede.pl		1 Institution 11 opagation	University of Kansas, Lawrence, KS 66045, USA.
*Institute of Computing Science, Research Oniversity of Environments, Research Related *Control de Efferendition, Universitate Federal de Remanshero, Recipi, Brazil	4 Moria Carlo-Gibidinesia (Monesia): Department of Logic and Cognitive Science /R Mark Carlo-Silindowship 4, 20-031 Lablin, Poland	Delovniky of Testanikog, Akademicka 16, 46, 500 Glovicz, Palcad <sup>10</sup> Isostanie of Computer Science, Deloveniky of Silesia in Scienceice, Bedrichska 20, 41-200 Scienceice, Poland	I ANTACT	Abstract: Considering that the population is aging to borns, which can provide whatks, unobtrustive month	spidly, the demand for technology for aging at- toring of human activity, to expected to expand.	EXPLOSIVE BANCHER <sup>4</sup>	IERZY W GRZYMALA-BUSSE <sup>†</sup> Department of Electrical Envineering and
<sup>1</sup> Minuma Schwart gl. Zimmenni, Callighen of Menagement and Thinnes Minume, Paland <sup>6</sup> Anie Took Garaventig, 1038th Austranus Johns, New Yang, 1038 <sup>6</sup> Symmer, Zinzenh Toolskor, Vallan Austrop of Schwarts Watson, Paland	* Dationsky of Palgonisk Institute of Eglomatics, al Konstantogo Chilkowskiege (ML 15-245 Balgonisk, Palaul)			This research focuses on improving the solution of the full detection system. Fall detection, using depth may	e postum detection problem, which is a part of problained by the Microsoft Kinect sensor, is a	REFISEIOF PARCERE	Computer Science, University of Kansas, Lawrence, KS 66045, USA and
	ABTICLE INFO ABSTRACT	ARTICLE INFO ABSTRACT		two-stage method. We concentrate on the first stage doubt man. For hims none detection, a new hybrid	of the system, that is, pose recognition from a IRNeders is represed. In the restore, two rule	College of Natural Sciences, University of Rzeszów, Poland	Department of Expert Systems and Artificial Intelligence, University of
ARTICLE INFO ARSTRACT	Amir hover: Data tables provide the standard means of representation of qualitative or quantitative information about objects of interest. They also form a starting point for the task	Received in project (1997) and (1		arbs are investigated, the first one created based on based on the much art theory. Additionally two int	a domain knowledge and the second induced	Received January 6, 2019. Accepted: May 2, 2020.	Information recinology and management, 55-225 Rzeszow, Polana.
Received 35 (among 202) Received 35 (among 202) Received 36 (among 202)	Beaked is proved from 30 December 2019 Accepted 1 January 2022 or information processing: an operation of passing from raw dats or information to semantically processed knowledge. The fundamental issue here is the question about the	Anoped 13 July 2020 Invaluate center 4 August 2020 Set approach. Operations process for induction of decision rates with Classical rough set approach. Operations were precising over index data sets discretioned by several		with and without the knowledge measure. The result	Its indicate that the new axiomatic definition of	In plasmodium propagation, some ambiguous behaviour can be observed. To describe it, a rough set approach based on neighbour-	TERESA MROCZEK <sup>††</sup> , Department of Expert Systems and Artificial Intelligence,
Accessed 9 July 2020 resolution of the second secon	Research in the data table actually tell us about objects? It mitable another question: How should the meaning be further processed? The primary	Reports: methods, Experimental results show that elimination of less relevant attributes through the proposed methodology led to inferring rule sets with reduced cardinalities, while		the rule induction method reducing the number of re-	uko in a set maintaine it.	hood systems is proposed. The rough set approach enables us to con- sider plasmodium propagation in terms of three situations: behaviour is	University of Information Technology and Management, 35-225 Rzeszow, Poland.
Rependi Institute and there and there and the analysis and the analysis and the analysis of th	Data meaning and the article is an attempt to answer these two questions. To this end we are Internation system going to employ conceptual scales from formal concept analysis, an important theory	Ceedy hearings in a statistic of the sta	TOR ROUGO	Keywoods: precedence indicator; knowledge mean	sare: fuzzy inference; rule induction; posture	certain, behaviour is possible, behaviour is impossible. The presented approach is focused on ambiguities of connections, made by protoplas-	RAFAL NIEMIEC <sup>1</sup> , Department of Expert Systems and Artificial Intelligence,
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Incluse rules distantially used for predicting financial fault, finds that the proposed approach has several advantages Rankow Funct over the coalitional over.	Our main idea is to regard multivatured information systems as the remainies or meaning of the original tables. This idea allows us to describe and combine classical rough set	- Annual Control of Co		Citation Polatic R. Marcock, F. GL. D. Kepiki, M. Application of Flazzy and Annual Annual Polatic Polatics.		Keywords: Plasmodium propagation, rough sets, approximation, ambiguity,	Allestand
e 20 tane di Argin Nerve.	theory, dominance-based rough set approach, and formal concept analysis within the single transework of readilocaland information systems, which is rich enough to cope with a	1. Introduction	-	aut Rough Logic in Protein Becapition in hit Descence (pains). Futury [1] and rough [2] sets provide tools if	for the analysis of significant imperfections	neignsournood system	Advantact
	member of semantical mances that may accur during the process of days androis			immer 2022, 22, tiest. 164pm // of data and knowledge. The former allows of	dassification of objects as belonging to a		tables and 'do not com' conditions. For rule induction, we are characteristic and amendiated maximal consistent blocks
	© 2020 Published by Elsevier Inc.			storing: th 1000 s2000 is given degree to a set or relation. The latter pro-	wides approximations in cases where the		Therefore we apply all different approaches for data mining. As follows from our proving experiments, where we used as
<ol> <li>Introductions repart of this problem, gives the high increase in the figures, which source to about \$2-4 billion in 2015.</li> </ol>	© 2000 Published by Rovier Inc.	In rough set perspective [1,2] the universe is seen as granular, with data points grouped in space into equivalence classes, imposed by indiccembility reason. When two injects have the same values of considered features, they cannot be		docreg 10.3000-2203002 Anatomic Idame Conceptions Anatomic Idame Conceptions	wides approximations in cases where the monstrate how the mentioned theories can solution of the posture detection problem,	1 INTRODUCTION	Therefore, we apply six different approaches for data mining. As follows from our previous experiments, where we used an error rate evaluated by tws-fold cross validation as the main criterion of quality, no approach is university the bent. Thus, we decided to commerce our six mersuches using commercive or mining the bent. Thus, we
<ol> <li>Interduction         <ul> <li>Interduction</li> <li>Interduction</li> <li>Interduction statistics</li> <li>Interduction statis</li> <li>Interductin statis</li>             &lt;</ul></li></ol>	© 2000 Published by Elsevier Inc.	In rough set perspective [1,2] the universe is icen as granular, with data points prouped in space into equivalence classes, imported by indirecentinity retains. When two eleptrics have the same values of considered features, they cannot be discreted, Detection of patients in granules loads to inferring decision rules. Based on conditions on attribute introduced in the permises, but rules assign class shafes to examples. A support of a rule, encrementary to its constructions, and the permises but rules assign class shafes to examples. A support of a rule, encrementary to its constructions, the	Sat Danars	thong: 10.306/2243000 Andreak liker Georgelines Restort Useruption Restort Version Restort Version	wides approximations in cases where the monetrate how the menticesed theories can solution of the postase detection problem, upidly, the demand for assistive technology	1 INTRODUCTION A Blowaruse machine is a programmable amorphous biological computing	* Hand may us not care to determine the interaction we take databased recomparisons approximate extension of the second secon
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L terrelation Set of the particle, parts the gamma data of the particle, parts the gamma data of the gamma dat	<ol> <li>2005 Hottendry Dever In-</li> <li>Introduction</li> <li>Data Latter product a simple, per efficient means of representation of quantitative priors of data () Interna-</li> </ol>	In maps we projection [11] the senseries is not accurate, went and a point property in space time spacebook times, mapping the properties by the sense time is not provide the sense time and increases the description of patterns are parameters to all the sense time is not provide the sense time and the sense is not provide the sense time and the sense is not provide the sense time and the sense is not provide the sense time and	Set Papers	force TLOBOC-CROOL Andreas Hanne Gonzgellen Montan Linear (Senzgellen Montan Linear (Senzgellen Mon	wides approximations in cases where the ministrate how the mentioned theories can adultion of the posture detection problem, spidly, the demand for assistive technology instructions of the posture of numan activity in sintre technology is to provide problemed ment without changing everyday literytic, graging population. Many efforts have	<ol> <li>INTRODUCTION</li> <li>A Physicarum machine is a programmable amorphous biological computing device, experimentally implemented in the plasmodium of Physicarum poly- cephalum, ais called true silmer model (1). Physicarum polycephalum is a sim-</li> </ol>	Therefore, we apply its different specases for data mining. As follows their or persons expections, where we used as the person of the second
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# The Strongest Assets of Rough Set Theory

#### • Applications: started in medicine in 1986

Z. Pawlak, K. Słowiński, R. Słowiński: Rough classification of patients after highly selective vagotomy for duodenal ulcer. International Journal of Man-Machine Studies, 24 (1986) 413-433

• Applications of RST in Operational Research – the challenge of ordinal data

Z. Pawlak, R. Słowiński: Decision analysis using rough sets. Int. Transactions in Operational Research, 1 (1994) 107-114

#### • Breakthrough adaptation of RST to reasoning about ordinal data – DRSA

S. Greco, B. Matarazzo, R. Słowiński: Rough sets theory for multicriteria decision analysis. *European J. of Operational Research*, 129 (2001) 1-47

#### • Representation of preferences using monotonic decision rules

R. Słowiński, S. Greco, B. Matarazzo: Axiomatization of utility, outranking and decision-rule preference models for multiple criteria classification problems under partial inconsistency wrt dominance. *Control & Cybernetics*, 31 (2002) 1005-1035

#### **R Słowiński**

# The Strongest Assets of Rough Set Theory

• Algebra and bi-topology of the Dominance-based Rough Set Approach

S. Greco, B. Matarazzo, R. Słowiński: Algebra and Topology for Dominance-based Rough Set Approach. [In]: Z.W. Raś, T.-S. Lin (eds.), *Advances in Intelligent Information Systems*, Springer, 2010, pp. 43-78

### • Probabilistic approach to the Dominance-based Rough Set Approach

W. Kotłowski, R. Słowiński: Statistical approach to ordinal classification with monotonicity constraints. [In]: E. Hüllermeier, J. Fürnkranz (eds.): *Preference Learning*, Proc. ECML/PKDD 2008 Workshop, Antwerp, 2008

### • Fuzzy-Rough hybridization and gradual decision rules

S. Greco, M. Inuiguchi, R. Słowiński: Fuzzy rough sets and multiple-premise gradual decision rules. *International Journal of Approximate Reasoning*, 41 (2006) 179-211

### • Statistical interpretation of VC-DRSA in machine learning terms

Y. Kusunoki, J. Błaszczyński, M. Inuiguchi, R. Słowiński: Empirical Risk Minimization for Dominance-based Rough Set Approaches. *Information Sciences*, 567 (2021) 395–417

#### **R Słowiński**

# ROUGH SETS (RS)

APPROXIMATE DEFINABILITY OF SETS RELATIVE TO PARTIAL INFORMATION ABOUT OBJECTS



Zdzisław was one of the giants who created the theory that underlies the digital revolution. Rough Sets is one of the leading paradigms

for thinking about the information, as it is provided to us at the global village through the World-Wide Web.

Victor Marek (University of Lexington)

#### A Skowron

COMPLEMENTARY NOT COMPETETIVE TO OTHER APPROACHES LIKE FUZZY SETS, FCA, BOOLEAN REASONING,

RS



COMBINATION OF RS WITH OTHER APPROACHES LEADS TO A SIGNIFICANT IMPROVEMENT OF THE QUALITY OF SOLUTIONS helps in characterizing computational building blocks (granules) that are necessary for A Skowron cognition – THE MAIN PROBLEM of AI (Leslie Valiant, Turing award winner)

### **GRANULAR COMPUTING**

- Unified and comprehensive conceptual and algorithmic platform aimed at representing and processing information granules
- Formation of a suitable level of abstraction and a knowledge representation environment
- Formalisms: sets, intervals, rough sets, fuzzy sets ... and their synergistic aggregates
- Ongoing intensive research with numerous conceptual generalizations

### CHALLENGES

- Design of information granules realized on a basis of experimental evidence
- Assessment of quality of information granules
- Quantification of performance of granular models

# Most important properties of Rough Sets (RS)

- In RS (and ROSETTA) all reducts are found, which is not the case for most of other learning systems. This is particularly important in modelling of living systems – biology is robust and redundant. Finding all reducts may show alternative pathways.
- There is an ongoing discussion about interpretable versus explainable machine learning systems (cf. C. Rudin, *Stop explaining black-box machine learning models...*, <a href="https://doi.org/10.1038/s42256-019-0048-x">https://doi.org/10.1038/s42256-019-0048-x</a>). RS can and should contribute to empowering the interpretable case. R.ROSETTA is a step in this direction.
- RS models are intuitive and legible, essentially without any training in discrete mathematics the notion of reduct is easily grasped by non-computational communities.

# Most important properties of RS's

- RS models allow studies of subgroups
  - Hierarchical clustering of rules and objects



S Younes et al, Scientific reports, 2022

#### J Komorowski

 RS rule sets have informative visualisation as rule networks – VisuNets



## PP-RAI'22 Contest for Rough Set Papers *Evaluation process and results*

- 20 articles submitted (at least one co-author with Polish affiliation)
- Each article being evaluated by 3 (out of 5) members of the Jury
- Each member recommends 3 (out of 12) articles as *excellent*
- Outcomes:

9 articles with *one or two stars of excellence* 1 article with *three stars of excellence* 

• The contest winner will be announced at the Closing Ceremony



## PP-RAI'22 Contest for Rough Set Papers *Distinctions (one or two stars)*

- Patrick Doherty, Andrzej Szałas: A landscape and implementation framework for probabilistic rough sets using ProbLog. Information Sciences 593: 546-576 (2022)
- Mateusz Garbulowski, Klev Diamanti, Karolina Smolińska, Nicholas Baltzer, Patricia Stoll, Susanne Bornelöv, Aleksander Øhrn, Lars Feuk, Jan Komorowski: R.ROSETTA: an interpretable machine learning framework. BMC Bioinformatics 22(1): 110 (2021)
- Jerzy Błaszczyński, Adiel Teixeira de Almeida Filho, Anna Matuszyk, Marcin Szeląg, Roman Słowiński: Auto loan fraud detection using dominance-based rough set approach versus machine learning methods. Expert Systems with Applications 163: 113740 (2021)
- Małgorzata Przybyła-Kasperek: Coalitions' Weights in a Dispersed System with Pawlak Conflict Model. Group Decision and Negotiation 29: 549-591 (2020)
- Łukasz Pałkowski, Maciej Karolak, Jerzy Błaszczyński, Jerzy Krysiński, Roman Słowiński: Structure-Activity Relationships of the Imidazolium Compounds as Antibacterials of Staphylococcus aureus and Pseudomonas aeruginosa. International Journal of Molecular Sciences 22(15): 7997 (2021)
- Marcin Wolski, Anna Gomolińska: Data meaning and knowledge discovery: Semantical aspects of information systems. International Journal of Approximate Reasoning 119: 40-57 (2020)
- Barbara Pękała, Teresa Mroczek, Dorota Gil, Michał Kępski: Application of Fuzzy and Rough Logic to Posture Recognition in Fall Detection System. Sensors 22(4): 1602 (2022)
- Krzysztof Ropiak, Piotr Artiemjew: On a Hybridization of Deep Learning and Rough Set Based Granular Computing. Algorithms 13(3): 63 (2020)
- Svea Stratmann, Sara A Yones, Mateusz Garbulowski, Jitong Sun, Aron Skaftason, Markus Mayrhofer, Nina Norgren, Morten Krogh Herlin, Christer Sundström, Anna Eriksson, Martin Höglund, Josefine Palle, Jonas Abrahamsson, Kirsi Jahnukainen, Monica Cheng Munthe-Kaas, Bernward Zeller, Katja Pokrovskaja Tamm, Lucia Cavelier, Jan Komorowski, Linda Holmfeldt: Transcriptomic analysis reveals proinflammatory signatures associated with acute myeloid leukemia progression. Blood Advances 6(1): 152-164 (2022)

#### **ARTIFICIAL INTELLIGENCE AND GRANULAR COMPUTING**

- AI general directions of SYMBOLIC and SUBSYMBOLIC (NUMERIC)
- A quest for explainable AI (XAI)
- Information granules: duality of representation

\*symbolic

\*numeric

Knowledge representation environment delivered by information granules

# Predictable Future of Rough Set Theory

• Associating RST with machine learning through fuzzy granularity

M. Palangetić: *Machine Learning on Inconsistent Data and its Granular Properties*. PhD thesis, Univ. Ghent, 2022 M. Palangetić, Ch. Cornelis, S. Greco, R. Słowiński: A novel machine learning approach to data inconsistency with respect to a fuzzy relation, *submitted*, 2021.

### • Monotonic decision rules as explanatory models in OR and AI

S. Corrente, S. Greco, B. Mararazzo, R. Słowiński: Explainable Interactive Evolutionary Multiobjective Optimization (XIMEA-DRSA), *submitted*, 2022

### • Applications of RST on imbalanced and partially missing ordinal data

J. Błaszczyński, A.T. de Almeida Filho, A. Matuszyk, M. Szeląg, R. Słowiński: Auto loan fraud detection using dominancebased rough set approach versus machine learning methods. *Expert Systems with Applications*, 163 (2021) 113740

### • Software development

DRSA library: ruleLearn (https://github.com/ruleLearn/rulelearn) RuLeStudio (http://www.cs.put.poznan.pl/mszelag/Software/RuLeStudio/RuLeStudio.html) RuleVisualization (http://www.cs.put.poznan.pl/mszelag/Software/RuleVisualization/RuleVisualization.html)

#### R Słowiński

# RS-models and genomic applications – the need for statistics

- Data preparation, e.g. bias removal, is a significant step prior to RS-model generation. Very few researchers, if any consider these steps.
- RS cannot directly cope with problems of 50K to 1M attributes which are charateristic of today's bioinformatics applications; there is no manual alternative to selecting the informative attributes.
- Discretization is a blessing and a curse gene expression analysis require huge care in this step.
- RS models need p-values (permutation tests), individual rules also require p-values.
- While quality of prediction is most often assessed with various forms of accuracy, cross-validation makes often inflated or even clearly wrong assessments.

# Future of RS in Al

- Need to create state-of-the-art implementation that can be customized to extensions of RS: speed, modern programming environment, interface to other computational formalisms/languages
- Move to Big Data
- Theory is first, but applications have the last word
- Major application areas:
  - Knowledge Discovery where interpretability is essential; no black-box
  - Certifiable systems: health care, law, safe systems (cf. Rudin's article)

# RS AND AI : WHAT NEXT? DEVELOPMENT OF FOUNDATIONS OF AI AND RS BASED ON INTERACTIVE GRANULAR COMPUTING

#### IS NECESSARY FOR CONSTRUCTING INTELLIGENT SYSTEMS DEALING WITH COMPLEX PHENOMENA



In the existing approach to rough sets interactions with the physical world are eliminated. Attributes are mathematical functions. Rough sets in IGrC:

- perceiving values of attributes are based on interactions with the physical world.
- attributes are not pure mathematical functions; they are realised by ic-granules.

A Skowron

# RS AND AI : WHAT NEXT?

Mathematics and the physical sciences made great strides for three centuries by constructing simplified models of complex phenomena, deriving, properties from the models, and verifying those properties experimentally.

This worked because the complexities ignored in the models were not the essential properties of the phenomena. It does not work when the complexities are the essence.

*Frederick Brooks: The Mythical Man-Month: Essays on Software Engineering. Addison-Wesley, Boston, 1975. (extended Anniversary Edition in 1995).*  The Turing test, as originally conceived, focused on language and reasoning; problems of perception and action were conspicuously absent. The proposed tests will provide an opportunity to bring four important areas of AI research (language, reasoning, perception, and action) back into sync after each has regrettably diverged into a fairly independent area of research.

*C. L. Ortitz Jr. Why we need a physically embodied Turing test and what it might look like. AI Magazine 37 (2016) 55–62.* 

RS:

DYNAMIC SPACE OF REASONING CONSTRUCTIONS OVER INTERACTIVE GRANULAR COMPUTATIONS (NOT PURELY MATHEMATICAL!) AS THE BASIS FOR APPROXIMATE REASONING, IN PARTICULAR FOR CONCEPT (CLASSIFICATION) APPROXIMATION IN INTELLIGENT SYSTEMS

A Skowron

# Dziękujemy!!!

- 2022 Int. Joint Conf. on Rough Sets (IJCRS'22)
- 19th Int. Conf. on Information Processing & Management of Uncertainty in Knowledge-Based Systems (<u>IPMU'22</u>)
  - The Anniversary Panel: Rough Sets Turn 40 – Uncertainty Management Perspective
- 17th Int. Conf. on Computer Science & Intelligence Systems (<u>FedCSIS'22</u>)
  - The Anniversary Rough Set Lecture
  - 4th Int. Symp. on Rough Sets: Theory & Applications (<u>RSTA'22</u>)
  - 30th Int. Symp. on Concurrency, Specification & Programming (<u>CS&P'22</u>)
- 2022 IEEE Int. Conf. on Big Data (IEEE BigData'22)
  - Special Session: 40 Years of Rough Sets from Big Data Perspective
  - 8th Special Session: Information Granulation in Data Science & Scalable Computing

