



Centrum Cyfrowej Nauki i Technologii UNIWERSYTET KARDYNAŁA STEFANA WYSZYŃSKIEGO W WARSZAWIE



Rough Sets Turn 40 Uncertainty Management Perspective IPMU 2022





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- 3. Jesús Medina (University of Cádiz, Spain)
- 4. Ernestina Menasalvas (Technical University of Madrid, Spain)
- 5. Andrzej Skowron (Systems Research Institute & UKSW, Poland)
- 6. Dominik Ślęzak (University of Warsaw & QED Software, Poland Security On-Demand, USA)









Rough Sets

Zdzisław Pawlak¹

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

¹ Institute of Computer Sciences, Polish Academy of Sciences, P.O. Box 22, 00-901 Warsaw, PKiN.





Sets $\operatorname{Edg}_{A}(X) = X - \operatorname{Apr}_{A}(X)$ (in short $\operatorname{Edg}(X)$) and $\operatorname{Edg}_{A}(X) = \overline{\operatorname{Apr}}_{A}(X) - \overline{X}$, (in short $\operatorname{Edg}(X)$) are referred to as an *internal* and an *external edge* of X in A, respectively.

Of course $\operatorname{Bnd}_A(X) = \operatorname{Edg}_A(X) \cup \operatorname{Edg}_A(X)$.

Fig. 1 shows the notion of an upper and lower approximation in a twodimensional approximation space consisting of a rectangle partitioned into elementary squares.

Let us define two membership functions \subseteq_A , $\overline{\in}_A$ (called *strong* and *weak* membership, respectively), as follows:

 $x \in A X \quad \text{iff} \quad x \in \underline{Apr}_{\mathcal{A}}(X)$ $x \in \overline{A} X \quad \text{iff} \quad x \in \overline{Apr}_{\mathcal{A}}(X)$

If $x \in A X$, we say that "X surely belongs to X in A," while $x \in A X$ is to mean that "X possibly belongs to X in A." Thus we can interpret approximations as counterparts of necessity and possibility in modal logic.

Of course,

 $\underline{\operatorname{Apr}}_{A}(X) = \{x : x \in X\}$ $\overline{\operatorname{Apr}}_{A}(X) = \{x : x \in X\}$

Thus we can develop our theory in terms of strong and weak membership functions or in terms of approximations. For the sake of simplicity we shall use here the approximational approach.

2.2. Approximation Space and Topological Space

It is easy to check that the approximation space A = (U, R) defines uniquely the topological space T(A) (in short T_A), where $T_A = (U, \text{Com}(A))$, and Com(A) are the family of all open sets in T_A , and U/R is a base for T_A .

It follows from the definition of (lower and upper) approximations that Com(A) is both the set of all open and closed sets in T_A . Thus, $\underline{Apr}_A(X)$ and



Approximations, their calculus and examples

Rough Sets

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Thus, we can interpret the approximation space $A = (R^+, S)$ as a measurement system, where

 $\bar{\mu}_A(i, i+1) = \mu_A(i, i+1) = 1, \ i = 0, 1,...$

is the *unit of measurement* in A, and $\eta(0, r)$ is the accuracy of (0, r) in A. For more detail see Ref. 6.

Example 2. Let V be a finite set called a *vocabulary* and let V^* be the set of all finite sequences over V. Any subset of V^* will be called a *language* over V.

Let $R \subset V^* \times V^*$ be an *indiscernibility* relation, and let $A = (V^*, R)$ be an approximation space defined by V^* and R.

A language $L \subset V^*$ is recognizable in A if $\operatorname{Apr}_A(L) = \overline{\operatorname{Apr}}_A(L)$.

The family of all recognizable languages in \overline{A} , denoted as $\operatorname{Rec}(A)$, is the topology induced by $A = (V^*, R)$ and the base of the topology is V^*/R .

That is to say that if the language L is not recognizable in A we are able to recognize only the lower and upper approximations in A.

This property can be used in speach recognition, pattern recognition, fault tolerant computers, etc.

Example 3. Let $S = \langle X, A, V, \rho \rangle$ be an information system (see Ref. 10), where

X is the set of objects

A is the set of attributes

 $V = \bigcup V_a$, V_a is the set of values of attribute $a \in A$

 $\rho: X \times A \to V$ is an information function, $\rho_X: A \to V$

 $x \in X$ is called an *information about* x in S, where

 $\rho_x(a) = \rho(x, a)$

for every $x \in X$ and $a \in A$.

We define the binary relation \tilde{S} over X in the following way:

 $x \sim_S y$ iff $\rho_x = \rho_y$

Obviously \tilde{S} is an equivalence relation and $A = (X, \tilde{S})$ is the approximation space induced by the information system S.

Any subset $Y \subset X$ is called *describable* in S iff $\underline{\operatorname{Apr}}_{\mathcal{A}}(Y) = \overline{\operatorname{Apr}}_{\mathcal{A}}(Y)$. The set of all describable sets in S, denoted as $\operatorname{Des}(S)$, is a topology induced by S on X, and the base of the topology is X/\tilde{S} .

Towards decision reducts (how

owards decision **reducts** (how approximations change when we add / remove attributes)

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 meeting with Rough Sets:

XV A.M.A.S.E.S. Conference	Grado, September 26-29, 1991
Parte I - RELAZIONI INVITATE	
<i>C. Corradi</i> Approssimazioni per difetto e per eccesso e Con operatori monotoni e applicazioni	DI SOLUZIONI DI EQUAZIONI 13
A. Montesano UN'ANALISI DI EQUILIBRIO GENERALE CON CONTII	NUITÀ DI AGENTI E DI SPAZIO 35
<i>R. Slowinski</i> ROUGH SETS: A NEW TOOL FOR ANALYSIS OF KN RIENCE	OWLEDGE GAINED BY EXPE- 53

- April 1994: I started to work at the University of Catania
- May 1994: Roman Słowiński gave a seminar in Catania
- May 1995: I went for one week to Poznań

...

 My first meeting with Professor Pawlak: 4th International Workshop on Rough Sets, Fuzzy Sets and Machine Discovery, Tokyo, 1996



From the left to the right: Jerzy Stefanowski, Shusaku Tsumoto, Lotfi Zadeh, Wojciech Ziarko, Zdzisław Pawlak and Roman Słowiński The first time I met with Professor Pawlak (Sept 1995)



E Menasalvas





Ernes first meeting with Rough Sets.

E Menasalvas

IPMU 2002, July 1-5, 2002 Annecy, France

2002 First meeting with rough sets = my first conference

BZW algebras for an abstract approach to roughness and fuzziness

Gianpiero Cattaneo, Davide Ciucci Dipartimento di Informatica, Sistemistica e Comunicazione Università di Milano – Bicocca

2003 Meeting with Z. Pawlak: International Workshop on Rough Sets in Knowledge Discovery and Soft Computing in Warsaw

2015 received from A. Skowron the whole collection of Pawlak's works

D Ciucci

First meeting with rough sets

RSKT 2010

Medina. Towards multi-adjoint property-oriented concept lattices. The Fifth International Conference on Rough Set and Knowledge Technology (RSKT 2010). Beijing (China). December 2010.

I met Yiyu Yao and Chris Cornelis.

BEIING HAOTON	50 7
School of Computer and Information Technology	Professor Jian Yu, Ph.D. School of Computer and Information Technology
No.3 Shang Tuan Cun, Hai Dian District, Deljing, 300044, China	Beijing, Jaostong University Beijing, 100044, P.R.China Tefi 86-10-51(682291 Emeil: janyu@bitu.ecku.cn
Dear Pr. Jesús Meda	Sep. 30, 2010
First of all, thenks for your support Knowing about your research addi and great supporting work in 18	ing RSKT 2010 exeminit in the area of rough out and knowledge technology RT2010, it is our honor to invite you to attend the Sti
International Conference on Boug Beijing, P.R.China, Cot. 15–17, 2013 Your professional involvement will	Sets and Knowledge Technology (KSKT 2010) will be held in grantly benefit the satcess of PSKT2010, and all participants
Not benefic enstmatch from your Feel free to contact me if there is a We are looking forward to seeing y	great work. my quantion for your whit to Beijing. ou in Beijing.
Yours Sincerely	
Jan Na, Ph.D. RSKT 2010 Program Chair	Jian Yu

J Medina

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Formal Concept Analysis

Rudolf Wille

Restructuring Lattice Theory: An Approach Based on Hierarchies of Concepts. Ordered Sets, pp. 445–470, 1982

- A set of oBjets.
- A set of Attributes.
- A relation R between A and B.



J. Medina, M. Ojeda-Aciego and J. Ruiz-Calviño On

multi-adjoint concept lattices: definition and representation theorem. *Lect. Notes in Computer Science*, 4390:197–209, 2007.

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

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 Wah Intelligence and Agent Systems



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RSDS Rough Set Dat	abase System						HOME CONTACT				US011301467B2
HOME SEARCH SEND	STATISTICS	OPINIONS	PEOPLE	SOFTWARE	МАР	HEI P	CONTACT	(12)	Unite Slezak	ed States Patent et al.	(10) Patent No.: US 11,301,467 B2 (45) Date of Patent: Apr. 12, 2022
USER MENU	Page 1 Page 2	Page 3 S FOR T	Page 4 Pag	Page 6 GH SET D	Page 7	SE SYS	TEM	(54)	SYSTEM INTELL TRANSE DATA SU Applicant	IS AND METHODS FOR GENT CAPTURE AND FAST ORMATIONS OF GRANULATED MMARIES IN DATABASE ENGINES : Security On-Demand, Inc., San Diego, CA (US) - bandiel's Steade. Wareney (PL):	 U.S. CL CPC
USER LOGIN Username:	The service has been Number of registere Number of authors (What kinds of	n visited 336304 d users: 405 . in the database): publications	8 times. : 42859. are included?	?				(12)		Richard Glick, Valley Center, CA (US): Pavel Bellinski, Warasw (PL): Fiort Synak, Winterthur (CH): Jakub Wroblewski, Lominski (PL): Agglezska Chadrynski-A rasowska, Sulejsova (PL): Jamusz Darkowski, Warsow (PL): Arkadhusz Wojna, Warsow (PL): Arkadhusz Wojna, Encimias, CA (US)	(56) References Cited U.S. PATENT DOCUMENTS 6,671,772 Bt 122003 Consist et al. 8,266,147 B2 92012 Sienzk et al. (Continued) FOREIGN PATENT DOCUMENTS WO 20080J4219 AI 3,2008
Password:		. North an of m						(73)	Assignce	Security On-Demand, Inc., San Diego, CA (US)	OTHER PUBLICATIONS
Log in	article inproceedings incollection	n Number of pu	udiications			21,552 15,324 1,232		(*) (21)	Notice: Appl. No	Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 463 days. : 16/459,274	International Preliminary Report on Patentability for International Patent Application No. PCTC:A200701627 dated Jan. 7, 2008. (Continued) Primary Examiner — Kris E Mackes (74) Attorney, Agent, or Firm — Smith, Gambrell & Russell LLP
 Request new password 	book techreport proceedings					176 144 60 26		(22)	Filed: US 2020/	Jul. 1, 2019 Prior Publication Data 0004749 A1 Jan. 2, 2020	(57) ABSTRACT Embodiments may provide methods and systems for intel- ligent capture and fast transformation of granulated data summaries. An engine may be used to transform input data unpravoice into result acts memorating and environment.
PATRONS OF SERVICE	phdthesis mastersthesis manual software					20 21 12 2 19		(60) (51)	Ro Provision 29, 2018. Int. Cl. <i>G06F 16</i>	Inted U.S. Application Data al application No. 62/691,751, filed on Jun. 2458 (2019,01) 3459 (2019,01)	summares into result sets representing query outcomes. In data summaries contain enough knowledge about the origi- nal data to accurately perform operations on the summaries without needing to access the original data. In an embodi- ment, the contents of data summaries are accessible via an SQL approximate engine which retrieves summaries stored on disk and utilizes them for its operations. Alternatively, the contents of data summaries are accessible via virtual tables
									G06F 16	2453 (2019.01) (Continued)	which give users direct access to the summary contents and (Continued)



Prior Publication Data

US 2020/0004749 A1 Jan. 2, 2020

 51) Int. Cl. G06F 16/2458

G06F 16/2453

Related U.S. Application Data

(60) Provisional application No. 62/691,751, filed on Jun.

(Continued)

(2019.01)

(2019.01)

Embodiments may provide methods and systems for int

ligent capture and fast transformation of granulated data summaries. An engine may be used to transform input data summaries into result sets representing query outcomes. The data summaries contain enough knowledge about the origi

nal data to accurately perform operations on the summa

without needing to access the original data. In an embodi ment, the contents of data summaries are accessible via a SOL approximate engine which retrieves summaries store

on disk and utilizes them for its operations. Alternatively, the

contents of data summaries are accessible via virtual tables

which give users direct access to the summary contents a

(Continued

M Wnuk, S Stawicki, D Ślęzak: Reinventing Infobright's Concept of Rough Calculations on Granulated Tables for the Purpose of Accelerating Modern Data Processing Frameworks. IEEE BigData 2020: 5405-5412

D Ślęzak

THEORY AND DECISION LIBRARY

SERIES D: SYSTEM THEORY, KNOWLEDGE ENGINEERING AND PROBLEM SOLVING

ZDZISŁAW PAWLAK

ROUGH SETS

Theoretical Aspects of Reasoning about Data

What are the strongest points of rough sets?

- Tool for dealing with **imperfect knowledge**, vague concepts
- It does not need **any preliminary or additional information** about data
- It naturally can deal with:
 - finding hidden patterns in data,
 - data reduction
 - evaluation of the significance of data
 - generation of decision rules from data
 - easy-to-understand formulation
 - straightforward interpretation of obtained results
- Use to induce classifiers or clusters

E Menasalvas

What are the strongest points of rough sets?

- Wide applicability
 - Uncertainty is ubiquitous
 - Granularity is a natural way to deal with complex problems
 - Lower/upper bounds are easy and powerful concepts
- Natural use with other theories
 - Fuzzy sets, belief functions, formal concept analysis, ...

An example

Student	Mathematics (M)	Physics (Ph)	Literature (L)	Overall class
S1	good	medium	bad	bad
S2	medium 🗸	medium	bad	medium
S 3	medium	medium	medium	medium
S 4	medium	medium	medium	good
S5	good	medium	good	good
S6	good	good	good	good
S7	bad	bad	bad	bad
S 8	bad	bad	medium	bad

Rough Set Approach to multiple-criteria sorting

• Set of decision rules in terms of $\{M,Ph,L\}$ representing preferences:If $L \succeq good$, then student $\succeq good$ $\{S5,S6\}$ If $M \succeq$ medium & $L \succeq$ medium, then student \succeq medium $\{S3,S4,S5,S6\}$ If $M \succeq$ medium & $L \preceq$ bad, then student is bad or medium $\{S1,S2\}$ If $M \preceq$ bad, then student \preceq bad $\{S7,S8\}$ If $L \preceq$ bad, then student \preceq medium $\{S1,S2,S7\}$

Greco, S., Matarazzo, B., Słowiński, R.: Axiomatic characterization of a general utility function and its particular cases in terms of conjoint measurement and rough-set decision rules. *European J. of Operational Research*, 158 (2004) no. 2, 271-292

Good properties of Rough Set Approach

- Rough set approach has a lot of good properties:
 - Transparence
 - Possible use of qualitative evaluations
 - Explainability and interpretability
 - Traceability
- Users gives preference information by answering easy questions, and obtains transparent feedback ("glass box") in a learning oriented perspective

What are the strongest points of rough sets?

Lotfi Zadeh (Baku, 1921– Berkeley, 2017)



Zdzisław Pawlak (Łodz, 1926– Varsovia, 2006)

J Medina

Fuzzy Rough Sets

Multi-adjoint fuzzy rough sets

C. Cornelis, J. Medina, and N. Verbiest. Multi-adjoint fuzzy rough sets: Definition, properties and attribute selection. International Journal of Approximate Reasoning, 55:412- 426, 2014 (Q1).

- Generalization of Rough Set to a more flexible framework.
- Different implications can be applied to minimize the noise in the data.



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) Data Science and Machine Learning 1 Chairperson: Luciano Sanchez Room: 01/A

Andrzej Bedychaj, Przemysław Spurek, Aleksandra Nowak and Jacek Tabor Nonlinear Weighted Independent Component Analysis

Hannah Blocher, Georg Schollmeyer and Christoph Jansen Statistical Models for Partial Orders Based on Data Depth and Formal Concept Analysis

Marek Grzegorowski, Andrzej Janusz, Stanisław Łażewski, Maciej Świechowski and Monika Jankowska

Prescriptive Analytics for Optimization of FMCG Delivery Plans

[a] Daniel Kaluza, Andrzej Janusz and Dominik Ślęzak Uncertainty Measures for Active Learning over Imbalanced Data

Olga Grigorenko and Valerijs Mihailovs Aggregated fuzzy equivalence relations in clustering process

Ensembles of Rough-Set-Based Decision Reducts

D Ślęzak

Data Science and Machine Learning 2 Chairperson: Joao Paulo Carvalho Room: 01/A

Fanny Pagnier, Frédéric Pourraz, Didier Coquin, Hervé Verjus and Gilles Mauris A multilevel clustering method for risky areas in the context of avalanche danger management

Artur Simoes and Joao Paulo Carvalho Fast Text-based Classification of News Snippets for Telecom Assurance

Mohith Rajesh, Chinmay Kulkarni and Shylaja S S BEUD : Bifold-Encoder Uni-Decoder based Network for Anomaly Detection

[a] Andrzej Janusz, Andzelika Zalewska and Dominik Ślęzak Introducing Approximation-based Model Diagnostics into KnowledgePit -- A Platform for Organizing Data Mining Challenges



What is the future of such scientific areas as rough sets, approximate reasoning and uncertainty management?



- The world is imprecise, so these approaches are required
- Health sciences such as in patient diagnosis and disease classification

Applications of Rough Sets in Health Sciences and Disease Diagnosis

Dr. Aqil Burney Meritorious Professor CCSIS-IoBM / DCS-UoK, Pakistan

> Zain Abbas Lecturer DCS-UoK, Pakistan

WSEAS 15th International Conference on APPLIED COMPUTER SCIENCE (ACS '15) Konya, Turkey, May 20-22, 2015

Integrating rough sets, fuzzy logic and machine learning

- Granularity and graduality are basic concepts in human reasoning.
- They call for putting together rough set theory and fuzzy logic.
- Having the necessity to handle big data we need probability theory methods and statistical approaches.
- A statistic approach to gradual granular fuzzy-rough models is the basis of the next generation machine learning models.
- For a methodology in this perspective see:

Palangetić, M., Cornelis, C., Greco, S. and Słowiński, R., 2021. A Novel Machine Learning Approach to Data Inconsistency with respect to a Fuzzy Relation. arXiv preprint arXiv:2111.13447. What is the future of such scientific areas as rough sets, approximate reasoning and uncertainty management?

- Dynamical systems granular computing interaction
 - A. Campagner, D. Ciucci, V. Dorigatti, «Uncertainty representation in dynamical systems using rough set theory», Theor. Comput. Sci. 908: 28-42 (2022)
 - A. Skowron's keynote
- Rough Sets + other theories to cope with different forms of uncertainty... still a lot to do
- Rough Sets extensions
 - Covering, three-way decisions, partition with uncertainty (orthopartition), ...

RS AND COMPLEX PHENOMENA: WHAT NEXT? REASONING ABOUT CHANGES: ROUGH CALCULUS



$$\frac{ds}{dt} = G(t, s(t), e(t))$$

$$\frac{de}{dt} = H(t, s(t), e(t))$$

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).

A Skowron

RS AND COMPLEX PHENOMENA: WHAT NEXT? REASONING ABOUT CHANGES: ROUGH CALCULUS

ROUGH SETS IN INTELIGENT SYSTEMS DEALING WITH COMPLEX PHENOMENA:

DYNAMIC SPACE OF REASONING CONSTRUCTED OVER INTERACTIVE GRANULAR COMPUTATIONS (NOT PURELY MATHEMATICAL!) AS THE BASIS FOR APPROXIMATE REASONING, IN PARTICULAR FOR CONCEPT (CLASSIFICATION) APPROXIMATION IN INTELLIGENT SYSTEMS What is the future of such methodologies and scientific areas as rough sets, approximate reasoning and uncertainty management?





J Medina

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Different branches

Bireducts

Benítez-Caballero, Medina, Ramírez-Poussa, Ślęzak Bireducts with tolerance relations. *Information Sciences* 435, pp. 26–39, 2018.



Different branches

Attribute implications

Dubois, Medina, Prade, Ramírez-Poussa Disjunctive attribute dependencies in formal concept analysis under the epistemic view of formal contexts. *Information Sciences* 561, pp. 31–51, 2021.



From left to right: Luis Fariñas del Cerro, Jesús Medina, Henri Prade, Didier Dubois

J Medina

Different branches

Taking advantage of relevant notions

Chacón-Gómez, Cornejo, Medina, Ramírez-Poussa. Value reducts and bireducts: a comparative study. *Mathematical Methods in the Applied Sciences*. In press.

Applying in real problems

García-Aragón, Cornejo, Medina, Moreno-García, Ramírez-Poussa. Decision support system for photovoltaic fault detection avoiding meteorological conditions. *International Journal of Information Technology & Decision Making*. 21(03):911–932, 2022.



What is the future of such methodologies and scientific areas as rough sets, approximate reasoning and uncertainty management?



J Medina



FIRST APPLICATIONS OF RS CONTROL OF A ROTARY

CLINKER KILN IN A CEMENT PLANT

PP-RAI'2022

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

Moderator: Prof. Dominik Ślęzak

Panelists:

- Prof. Jan Komorowski (Sweden)
- Prof. Witold Pedrycz (Canada)
- Prof. Andrzej Skowron (Poland)
- Prof. Roman Słowiński (Poland)

Chair: Prof. Piotr Jędrzejowicz

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	Conserts Fight Researcher at ScienceConstr	۲		ScienceDirect FUZZY	Conterns lists evaluable at ScienceOnect	
Knowledge-Based Systems	Information Sciences	Continions/Weights in a Discoursed Custom with Davidals	Structure-Activity Relationships of the Imidazolium	ELSEVIER Putty Sets and Systems 391 (2020) 117-138	Information Sciences	Application of Dominance-Based Rough Set
ELSEVIER journal homesage: www.aluevier.com/locate/knoeps	ELSEVIER Journal homepage: www.elsevier.com/tocate/ins	Conflict Model	Compounds as Antibacterials of Staphylococcus aureus and	www.cbevier.com/bcate/hit	ELSEVIER journal homepage: www.elsevier.com/locate/ina	Approach for Optimization of Pellets
			r-seudomonas aeraginosa	Pough sat driven approach for attribute reduction in furry formal		Tableting Process
Granular structure-based incremental updating for multi-label	A landscape and implementation framework for probabilistic ()	Małgorzata Przybyła-Kasperek	Lukasz Pałkowski ^{1,4} ⁽³⁾ , Maciej Kanolak ¹ ⁽³⁾ , Jerzy Blaszczyński ² , Jerzy Krysiński ¹ and Roman Słowiński ^{2,3}	concept analysis	Empirical risk minimization for dominance-based rough set	Maciej Karolak ^{1,4} 0, Lukasz Pałkowski ¹ 0, Bartlomiej Kubiak ² , Jerzy Blaszczyński ³ , Rafał Lunin ⁴ , Wiedaw Sawicki ⁵ , Roman Słowiński ^{3,6} 0 and Jercy Krysiński ¹
Yuanjian Zhang ¹² , Duoqian Miao ^{12,4} , Witold Pedrycz ^{12,4} , Tianna Zhao ¹³ , Jianfeng Xu ^{13,4} ,	rough sets using PROBLOG	Published online: 11 April 2020 © The Author(s) 2020	Department of Pharmaneutical Technology, Foculty of Pharmary, Necilian Coperation University Jorana 2, 95-196 Bydgesere, Poland, maciaj kandal-Bern unit pl (M.K.); prey keysindeBern unit pl (K.S.)	the serie and the basis of the series of the	approaches	¹ Department of Pharmacoutical Technology, Collegium Medicum, Nicolaus Copernicus University.
Ying Yu ¹ "Destroyer of Computer Science and Endnaings, Tongi University, Manguel, 20004, Chine	Patrick Doherty Adva.1, Andrzej Szałas ^{+2,2}		¹ Institute of Computing Petron, Vormal University of Technology, Network 2, 66:969 Technol, Polarul, Jersy Basecoprobables, put genus, pl GR3; researchiveloskolles, put promot, pl (RS3) ³ Systems Research Technology of Computing Sciences, Neurolida 6, 61:144, 86 (Marcan, Polarul)	M. José Benítez-Caballero ^{n,1} , Jesús Medina ^{n,1} , Eloísa Ramírez-Poussa ^{n,n,1} , Dominik Šlezak ³	Yoshifumi Kusunoki ^{a, *} , Jerzy Blaszczyński ^c , Masahiro Inuiguchi ^b , Roman Słowiński ^{cal}	85-009 Bydgosecc, Poland, lakaszpałkowski/fem umk.pl (E.P.), przyksystaki/fem umk.pl (K.) Adamied Pharma S.A., Perików, 05-152 Czosnów, Poland, and Stationiej kubiaki/fulamed.com.pl [] Institute of Computer Science. Research University of Technology (0.063 Research Related).
¹⁶ Exp Laboratory of Endoddel Tystem and Enriver Comparing, Ministry of Education, Tongi University, Standards, 201806, Obse ¹⁶ Department of University and Comparer Ingenering, Bioversity of Alteria, Education, Ad Canada Mill 2019 ¹⁶ Sperim Investment Anala, Academy of Sciences Warna, McAldel, Pannal.	"School of Intelligent Quereas and Engineering Joint Determing (Databati Centrana), Zhanka Chena "Department of Company and Information Science, Linkshiping University, IE-611 #3114884ping, Sourden "Institute of Informatics, University of Wespers, Bunarda 2, 22–297. Wannen, Publish	Abstract The article addresses the issues related to making decisions by an ensemble of clas-	 Consepondence: halase pullos vielben arit, pl. 56, +46 52-565-56-27 	* Recomment of Michaevice - Education of Cliffer, Spain	⁴ Gradiant School of Narianities and Eastainable System Sciences, Dasks Professor Meisenity, JL. Galarm-chin, Nalis-Ita, Salos, Oaito 590-8531, Japan ¹⁶ Gradiante School of Dighteeting Science, Daska Delormity, 1-2, Mathikaneyama, Tayonaka, Oaita 560-8533, Japan	 instance of computing Science, Forman Criterian et al. (1997) and the science of th
¹ Salport Colign, Harchang Delversky, Jangel 20047, One – ¹ Colign of Salport Englishing East Chine Jacomy Enteredy, Jangel 20073, Chine – ¹		sifiers. Classifiers are built based on local tables, the set of local tables is called a	Abstract: This paper presents the moults of structure-activity multicoship (SAR) studies of 140 $3_s N \cdot (\alpha_s \omega$ -diseasilian)Ne(1-sikylinsidaroilum) chlorides. In the SAR analysis, the dominance-based	^b Institute of Informatics, University of Warson, Poland	¹ Populit University of Polymology, Robinson of Computing Science, Pannovo 2, 80–985 Populit, Italiant ⁴ Spanner Research Justitute, Polish Academy of Sciences, 07:447 Warners, Poland	⁵ Department of Physical Chemistry, Medical University of Gdatok, 80-416 Gdatok, Poland: wirelaw anvicki@gumed.edu.pl
ARTICLE INFO ABSTRACT	ARTICLE INFO ABSTRACT	model to examine the relations between classifiers and to create coalitions of classi-	rough set approach (DRSA) was used. For analyzed compounds, minimum inhibitory concentration (MIC) against strains of Staphylociccus sames and Potskimmus arruptions was determined. In order to	Received 1.5 May 2019, received as revision term 9 visiterer 2019 Available online 19 November 2019		 Systems Research Institute, Polish Academy of Sciences, 01-447 Warsaw, Poland Cornespondence: maciej karolakitem.umk.pl; Tol.: +48-52-585-3927
ande koory becretering is an efficient comparisonal pandigm of acquiring approximate knowledge become knowledge because and an	Increased 18 April 2011 Encoded in ancied from 13 December 2021 Encoded in ancied from 13 December 2021	hers. Each coalition has access to some aggregated knowledge on the basis of which joint decisions are made. Various types of coalitions are formed—a strong coalitions	perform the SAR analysis, a tabular information system was formed, in which tested compounds were described by means of condition attributes, characterizing the structure (substructure parameters and		AND	Received: 25 September 2020; Accepted: 24 October 2020; Published: 26 October 2020
Bacarea a construction 20 September 2000 Accepted 22 September 2000 anamed in considering and september 2000 anamed a considerable comparison of the match and the considerable anamed a considerable comparison of the match and the considerable anamed anamed a	Accepted to December 2021 Available online 20 Docember 2021 More recently, the classical theory has been generalized to include probabilistic rough	consisting of a large number and significant classifiers, and a weak coalitions con- sisting of insignificant classifiers. The new contributions of the paper is a systemati-	 updates molecular description) and their surface properties, and a decision attribute, classifying compounds. Contex Tetravis, L.; Kavis, M.: with respect to values of MIC. DRSA allows to induce decision makes from data describing the 	Abstract	Received 5 May 2020 proposed in the literature: variable precision DRSA (VP-DRSA) and variable consistency Becaused in event from 13 Geneter 2020 DRSA (VC-DRSA). They were immediated to cope with classification data encountered in	Abstract: Multiple-unit pellet systems (MUPS) offer many advantages over conventional solid dosage
Anisane only is converging the challenge, we formulate a granular instance system (205) the proposed granular structure system in bottom up way provides a systematic were on label specific based classification. We	Environit: Set methods of which there are also a great variety of proposals. Pragmatic, easily accessi- finitabilitie rough set birth and any to use tools for specification and reasoning with this wide variety of methods.	cal investigation of the weights of coalitions that influence the final decision. Four	Manupule, 1. Ryuthit, 1: compounds in terms of condition and decision attributes, and to task condition attributes with respect Section 1. Ryuthit, 1: to relevance using a Bayesian confirmation measure. Decision rules present the most important	The reduction of the set of attributes is an important preliminary challenge in order to obtain information from knowledge systems. Two remarkable formal tools for extracting such information are Rough Set Theory (RST) and Formal Concept Analysis	Accepted to separaty AU1 Audiate celler 28 Peterary 2021 practice for which the original definition of lower approximations, which is consulted these extensions allow as augmentation of lower approximations, which is consulted	forms both for the manufacturers and patients. Coated pellets can be efficiently compressed into MUPS in classic tableting process and enable controlled release of active pharmaceutical ingredient
Must Judet clearity labor must - Judet Classification, is compatible with CSS in granularism. An incremental inectanism of CSS is Canadae involves spream introduced for both Judet-specific feature generation and optimization, and an incremental three-way	Problem Proble	of these methods consider another aspect of the structure of the coalitions. Gener-	Assessed of the compounds on one hand, and their Compounds as forthermain of antibacturial activity on the other hand. They also indicate directions of synthesizing more efficient forther ones and Pandeman	(FCA), as well as their fazzy generalizations. This work introduces a new method to reduce attributes in Fuzzy FCA considering the induction philosophy given in RST and studies its main properties. This method allows us to carry out a deeper study of the relation.	Report to the parameterization of other end ways. We goe statistical interpretations for two locks and VC- DBA from the perspective of empirical risk minimization typical for machine learning. Crane function of characterization reports and sensitive and complex characterization typical for machine activity.	(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
sectory encode approximation of many period of the proposed approximation (MMUSAV) is presented, toperatively, complete on six datasets show that the proposed approximation considerable classification performance while configuration contentiation the forested for COL and the	Itale-based tangaages 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	ally, it has been experimentally confirmed that, for a method that correctly identi- fies the relations between base classifiers, the use of coalitions weights improves the	arrights, bt. J. Md. Sc. 200, 22, 7967, https://doi.org/302306/ 2007. https://doi.org/302306/	between these two theories. Moreover, the proposed methodology has been compared with other existing reduction mechanisms. © 2019 Elsevier B.V. All rights reserved.	Engineering in interestation Variable commonly dominance-based registry agenesis registry up of the second seco	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
© 2019 Ebovier RV. All rights reserved.	about any of these methods using rooms, a popular and widely used probabilistic logic programming language based on www. The paper also considers new techniques in this content such as the size of emphablishic larger sets when division much solution and the size.	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	guo2117867 Kayreendic gemini-inidiacelium chloridas; antimicrobial activity; molecular descriptors; SAR; doubrance-based much at represel; (DDIA).	Kennedy Farry sets Attilute industries: Roket Evend concert and/sis: Reach of theory	Variable precision determines based reaght an approach of associated empirical risk minimization problems. As a consequence, a connection between parameters DBCA and statistical learning is established. Moreover, new character- issistent of the second statistical learning is established. Moreover, new character- issistent of the second statistical learning is established.	similarity factor (2) of MUPS containing pellets with verapamil hydrochloride as APL by applying a dominance-based rough wt approach (DRSA) mathematical data mining technique. DRSA generated
1. Introduction	of partially specified base relations that are also prohabilistic. Additionally, prohabilistic approaches using toferance spaces are proposed. The paper includes a rich set of examples	coalitions and the method based on the unambiguous of the decisions.	Anderen Editar Supradory antimania (Anthe Registar approach (Anthe)	Automatic Party Act, January Partonet, Robert, Comme Concept Bactyre, Honge Actionary	Lattier of the augmented some approximation atom is to ename dimension and simi- lattier between VP-DRSA and VC-DRSA. 0.2021 Elsevier Inc. All rights reserved.	decision rules representing cause-effect relationships between condition attributes and decision attribute. Similar API selease profiles from pellets before and after tableting can be ensued by proper
Granular Computing [1] is an effective structured problem shie solution is to assess the reliability of learnt knowledge	and provides a finanework based on a library of generic musco, relations that make speci- fication of any of these methods, straightfoeward, efficient and compact. Complete, ready to	Keywords Conflict analysis - Dispersed knowledge - Multiple classifiers - Coalitions	Restored 21 June 2021 Accessed 14 June 2023 B. Introduction	1. Introduction		polymer coating (Eudragit [®] NE, absence of ethyl cellulose), compression force higher than 6 kN, microsenstalling cellulose (Active [®] 107) as exclusion and tablet backness >42.4 NLDRSA can be useful
solving methodology. It simulates human-centric operations re- alized in the presence of multifaceted data, and embraces a accommodate information variations. For single-label learning,	 cone in inclusion in the appretation of a stampler considered. 2021 The Author(s) Published by Elsevier Inc. This is an open access article under the GC. BY Society (Introduction of the access article under the GC. 		Paintest 27 (vir) 2021 Cationic surfactures, including bis-imidatolium chiorides (also colled gemini-compounds), are able to lower the surface levalor while keeping good antimizebial activity. This activity is a	The study of the knowledge stored in databases is one of the most important goals in several research fields, which		for analysis of complex technological data. Decision rules with high values of confirmation measures can bein technological formulation development
pretroira or reconsigents which minimizer uncertainty, the generic there are many isoparing works. Thereefully, knowledge upda- component, information granule, is rich in semantics and reflects a cretain level of abstraction for a conservative multi-m		1 Introduction	Publisher's Note: MTM important of the interaction of the cationic surfactant with the cell membrane of the interaction of membrane structure, the degradation of proteins and	has produced the necessity of developing mathematical tools to manage the collected information. In addition, to deal with imprecise or incomplete information is crucial in many knowledge systems. Formal Concept Analysis (FCA) [50]	1. Introduction	Can help declinibulger an optimize remainant de viropanen.
set theory (RST), established by Pawlak [2] in 1982, in capable of drailing with ambiguous concept. Rough Sets have been extern- immigrations. 'Yu and Xu [3] proposed an incremental updating	1. Introduction	An important problem in today's world is the dispersion of knowledge. Many units,	pathologies and waterateral atta- internal automatical and cell death. The type of interactions and the mechanism of antimicrobial effect depend largely on the surfactant concentration, pH, temperature, type of microorganism, or	and Rough Set Theory (RST) [47] are two widely studied mathematical theories, devoted to obtain information from relational displayers that contain uncertainty.	In data analysis, we other 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 data set given in the form of a decision table when submit composition to chiert of clinears and composition of a stribute describing the decision.	krowledge discovery; machine learning
strategy for interval-salaed ordered information system given (e.g. [3]), social openeous (e.g. [4]) and vitro analysis (e.g. [5]). Bunches and the memory interval salaed ordered information system given	1.1. Presentative rough yes	to which they have access. This knowledge can be the result of various factors-	concentration of other ions. Quaternary armonium salls (containing quaternary nitrogen in its molecule) are particularly active against Gram-positive bacteria. In contrast, Gram-negative	Although it is easy to notice that both theories have several common aspects, the philosophy that underlies the	attributes are divided into condition attributes and a decision attribute. The decision attribute specifies a target classification of abacts he may relate the anticipation of the second starget classification of a second starget classification attributes and a decision attribute. The decision attribute specifies a target classification of a second starget classification attribute second starget starget classification attribute second starget starget classification attribute second starget	
with all information is known in advance. However, the emergi- ning features occur unexpectedly in a dynamic environment. In	cepts intended to be modeled such as vagueness, imprecision and incompleteness. Rough set theory [2,7,19,25,38,47,48]	experience, history, analyzed cases, sensors. Very popular form of saving knowledge is a decision table. However, if the knowledge contained in local decision tables is	Copyright © 2023 by the indices. Building the indices and the property of acquire resistance to this group of compounds. The high affinity of the quadernary sales to the biological membranes also	the knowledge in small pieces, called concepts, which contain a subset of objects, as well as, the subset of shared	sion classes in terms of condition attributes, and to make it possible to infer decision classes of objects based on their descriptions. This setting is called supervised learning, and is a part of the field of machine learning.	1. Introduction
name a few examples, services continuously monitor the status	* Corresponding author at Department of Computer and Information Science Linklying University, 52-561 K1 Linklying, Soweles,	the result of different stimuli or analysis, the form of the tables can be very different,	The article are spin areas while the article are spin areas while He-ATTase [1-3]. He-ATTase [1-3].	attributes by that objects. All these information pieces can be ordered, obtaining the algebraic structure of a concept	Because available condition attributes are limited both in number and in their value sets, some objects may be indis- cernible, that is, they have identical values of all considered condition attributes. This idea is a mathematical basis of rough	Pellets, microcapsules, as well as other solid particles can form multiple-unit dosage forms. By a proper modification, such forms allow a modified or constant wlease rate, whereby the concentration
¹⁰ No author associated with this paper has deduced any potential or portions which may be percented to have repending million with manufacture deduced any potential or duction updating with sample arriving based on fuzzy rough set.	E-end addresses particular/employee. P. Deterty: antreparticular (A. States). ¹ This work has been supported by the ELLET Network Organization for Information and Communication Technology, Sweder; the Swedick Insulation for Tractical Ensuring VP Cloud Systems Terror (1973). 0073-2 algorith and your main them there say and an Utwares Terror (2020).11 (2020).11 (2020).11	IFO Małgorzata Przybyła-Kasperek	indition of the Castin Conners Anthesise (CC IV) lister of the Castin Conners with different susceptibility to antibiotics, disinfectants, and antiseptics. This is due to the different construction of the call healt lines of the call activity	* Corresponding author: E- and addresses requires begins there are (M.I. Bashes Caladhers), here reached been of Median chine particulation of	set theory. We suppose that indiscernible objects should be classified into the same decision class. Otherwise, the classifi-	of the drug is maintained within therapeutic limits for a longer period of time. An appropriate release profile allows controlled absorption of active pharmaceutical ingredients (APIs) in the specific part of
2014 (ECGG) Lang et al. [13] presented a matrix-based approach for updating to corresponding autor. Lang et al. [13] presented a matrix-based approach for updating reduct of type-1 and type-2 characteristic matrices. Jung et al. [14]	Invest the Gaugeforg Department of Inforce and Technology, China, ¹ This work has been supported by gaint 2017/2718/570/2018 of the National Science Center Poland.	malgorzata przy była-kasperek (fius, edu pl	instruction of chemical compounds on these microbes are different.	(I. Ravine-Possa), should intervente pl (D. Speak). ¹ Darially supervised by the Stars Research Associ (ALI) and the European Research Development Fund (PEDER) research TDX205-56651-P.	* Corresponding author, Long objects workford increasibles called as a 10 V Respective and Assessment of a Respective Vision and a second	the gastrointestinal tract, providing a desirable therapeutic effect and reduces side effects. A special type of multiparticulate drug delivery systems is a multiple unit pellet system (MUPS) in which
the about of a line o	https://doi.org/10.1018/j.htt.2023.12.062 0800.0255/st 2023. The Austracia, Published by Diseler Inc.	Institute of Computer Science, University of Silesia, Bedridska 39, 41-200 Sonnowiec, Poland		Magac Adul, ang 200, 101653, iliu 2019, 11,009	ac jp (M. bargachi), temanikwishiket pat jeo nav pi (K. Slowilski)	microparticles or pellets are compressed to obtain a tablet. Tableted pellets demonstrate faster passage
055-361(0 2019 Davier BV: All rights coursed.	This is an operaction article lander the CC BV license (http://creativermention.org/icenses/by)4.015	Springer	htt.]. MA. Sil. 2023, 72, 7947. https://doi.org/10.3940/gas22152907 https://www.indpi.com/journal/igas	0103-01147E 2019 Elsevar B.V. All rights reserved.	https://doi.org/10.1016/j.ps/2021.02.001 0020-025/v-2021 Elsevier Iac. AB rights reserved.	Pharmaceutics 2020, 12, 1024, doi:10.33902pharmaceutics12111024 server.mdpi.com/psamal/pharmaceutics
Topics1 Spitiense with Applications 16() (2021) 117748	International Journal of Approximate Resoluting 110 (2020) 40-37	telemational Journal of Approximate Reasoning 125 (2020) 187-200		iii sensors	Jas Jaam of Uncommunical Companies, Vol. 15, pp. 287–299 0.0020 Old Cay Publishing, Inc.	<u> </u>
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Expert Systems with Applications	International Journal of Approximate Reasoning	International Journal of Approximate Reasoning		Antike		incomplete data using characteristic sets
ELSEVIER journal homepage: www.elsevier.com/locato/eswa	ELSEVIER www.elsevier.com/locate/jar	ELSEVIER www.alsovier.com/locate/jar		in Fall Detection System		and generalized maximal consistent blocks
				Barbara Pekala 12+0, Teresa Mroczek 20, Dorota Gil 20 and Michal Kepski 10		PATRICK G. CLARK* Department of Electrical Envineering and Commuter
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 Connector Science Discoulty of Encoder 35 Will Encode Poland interdallibrate of	Pough Sat Pased Description of	Science, University of Kansas, Lawrence, KS 66045, USA.
versus machine learning methods	information systems*	It fadered it B. Zielede 2		Department of Artificial Intelligence, University of Information Technology and Management, 38-228 Researce, Poland, transcardellweiz edu pt (EM.), digit@wviz.edu.pt (D.C.)	Plasmodium Propagation	CHENG GAO**. Department of Electrical Engineering and Computer Science.
Jerzy Błaszczyński *, Adiel T. de Almeida Filho ⁵ , Anna Matuszyk ^{c.d} , Marcin Szeląg **, Roman Słowiński *#	Marcin Wolski 2.*, Anna Gomolińska b.*	 Statiliczyk *** , B. Z. PEROBIO * * Department of Graphics, Computer Vision and Digital Systems, Bacalty of Automatic Control. Discourses and Computer Science. Silvian 		 Consepondence hypekala@sexedu.pt 	Thismodium Tropagation	University of Kansas, Lawrence, KS 66045, USA.
*Pacificker of Comparing Science: Neural Generation of Environing: Neural Neural *Conce de Universitate, Deventual Industrie de Internationes Recipt, Bald Materiale Chemistrie, Galdwarder, Galdward of Materianem and Thomas National Paland	⁴ Murits Carlo-Sakadawska University, Department of Lagic and Capitities Science /H. Mark Carlo-Sakadawski(e) 4, 20-001 Lables, Poland ⁸ Datawarky of Debatek, Excilator of Evidencias, and Economicous Californiations (ML 15-243 Balancek, Poland)	Desiensity' of Testinarioge, Alasdenskisa 16, 46-800 Gibeicz, Polonił ¹⁰ homiace of Computer Science. University of Silesia in Sciencesce. Epitrybala 38, 41-200 Semenvier, Poland	ι οητόςτ	Abstract: Considering that the population is aging mpidly, the domaind for fochrology for aging ab- hiores, which can provide whishle, unobtrastive monitoring of human activity, is expected to expand.	KRZYSZTOF PANCERZ*	JERZY W. GRZYMALA-BUSSE [†] , Department of Electrical Engineering and
⁴ Alex Took Conversity, TERM Audient School, Took Took, TERA ⁵ Systemic Research Incenter, Adult Academy of Sciences, Manual, Haland		ARTICLE INFO ABSTRACT		This means h because on improving the solution of the posture detection problem, which is a part of fail detection system. Fail detection, using depth maps obtained by the Microsoft Kinect sensor, is a	Collare of Natural Sciences. University of Research. Poland	Computer Science, University of Kansas, Lawrence, KS 66045, USA and
ARTICLE INFO ABSTRACT	ARTICLE INFO ARSTRACT	Article lineary: The paper presents the proposed research methodology, dedicated to the application of		two-stage method. We concentrate on the first stage of the system, that is, pose recognition from a depth map. For lying pose detection, a new hybrid HiStystem is proposed. In the system, two rule	Received January 6, 2019, Accepted May 2, 2020.	Information Technology and Management, 35-225 Rzeszow, Poland.
Adds blaces Financial frand is escalating as franteal services and operations graw. Despite preventee actions and Adds frances 2010	Incriming 28 Jans 2011 USL GBIS provide the stational means in proceedings of an anting point for the task Reviewed in mixed from 30 December 2019 of interest, They also form a starting point for the task of information provide the stational form the data of information to assist of information proceedings of assistant form task data form the data of information to assist of information proceedings of assistant form task data form the data of information to assist of information proceedings of assistant form task data form the data of information to assist of information proceedings of assistant form task data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assist of information proceedings of assistant form the data of information to assistant form the d	Becomed in point 2019 Becomed in resided (corn 1) Retrainy 2028 Annueld 1 July 2020 Recomeding, represented in the form of generating decision rules, was employed to support		whe are investigated, the tirre one created based on a domain survivolge and the second induced based on the mugh set theory. Additionally, two inference aggregation approaches are considered	In plasmodium propagation, some ambiguous behaviour can be	TERESA MIDOCZER ¹¹ Decomposed of Presed Decime and Antibul Intelligence
Invest 30 Jan 2020 to get around hand prevention systems, thereby, challenging quantitative techniques and predictive reades. Thus, new techniques must be explored and tested to the insights obtained from the analysis	Accepted 1 January 2003 Available unlike II January 2000 Available unlike II January 2000 metrolog of data: What do entries in the data table actually tell us about objects? It	Available colore 4 August 2020 set: approach. Observations: were executed over topic data sets discretioned by several netbods, Experimental results show that elimination of less relevant attributes through		knowledge measures, which we propose has a positive impact on the effectiveness of inference and the set is built of the set of the	observed. To describe it, a rough set approach based on neighbour- hood systems is proposed. The rough set approach enables us to con-	University of Information Technology and Management, 35-225 Rzeszow, Poland.
transition of the development of fload provides may be used to support men accurate fload prediction and the development of fload prevention systems which have addressed checks to ensight support ments, data lises is a significant financial prediction constrained in the lister and solution of medic contrained for the constrained in the lister and the development of fload prevention	Exystemic entails another question: How should the maxing be further processed? The primary Data maxing arm of the article is an attempt to answer these two questions. To this end we are	Bough sets the proposed methodology led to inferring rule secs with reduced castinalities, while Greatly beamsion enabling rule quality necessary for satisfactory classification.	tar Daugh	Kewands movidence indicates knowledge maaare force inference rule induction radius	sider plasmodium propagation in terms of three situations: behaviour is certain, behaviour is possible, behaviour is impossible. The presented	PAEAL NIEMIEC ¹ Department of Expert Systems and Artificial Intelligence
Noted directions Anni low Domannee Haard Margh Ser Balanced Bala applications using a technique not yet explored for financial fault prediction, namely the Dominance-	Registration system Reads are theory of data processing introduced by Radel Wille, and apply them to data tables so as to obtain mailwaterd allocation systems, which were introduced and developed within	because name 0 2000 The Author(s). Published by Exerver IIIs, to an open access allose under the Possure selection CC BV-NC-ND license (http://cmadiwecommoni.org/licenses/by-to-nd/4.0/). Discretization		detection: aggregation function	approach is focused on ambiguities of connections, made by protoplas- mic veins, between distinguished regions.	University of Information Technology and Management, 35-225 Rzeszow, Poland.
Isoanble band Rough Set Balance Rale Essensible (DECA 4002) and after comparing is with other sechstapan to- taxious rales distantily used for predicting financial fixed, finds that the proposed approach has several advantages each memory cover the Coldification cover.	tumat coorept analysis the conceptual transpoork of rough set theory by Zitzislaw Pantak and Das Orlowska. Our main idea is to regard multivalued information systems as the remarks or incoming	Sylverity		Chalses Pylotic B. Miccolt, T. Cli.	Knywords: Plasmodium propagation, rough sets, approximation, ambiguity,	
9/bit © 2020 Elamier Izzl. All rights merved.	of the original cames this sea allows is to describe and combine casolical rough set theory, dominance-based rough set approach, and format concept analysis within the single formation of studied information protons which is not with a	1. Introduction	U	Dynamic St. Application invary and Encode Logic in Distance Exactly Light in Distance Function Funct Function Function Funct Function Function	neighbourhood system	Abstract
	number of sensareical numces that may occur during the process of data analysis. © 2020 Published by Rowier inc.	1. Interviewe		issues BB2 22 test, separ// of data and knowledge. The former allows classification of objects as belonging to a story (10000-22000) given degree to a set or relation. The latter provides approximations in cases where the		In this paper, maning attribute values in mempore data sets have three possible interpretations, not values, attribute-concept values and 'do not care' conditions. For rule induction, we use characteristic sets and generalized maximal consistent blocks. Therefore, and the set of the se
 Introduction impact of this problem, given the high increase in the figures, which wared to about \$2-4 hillion in 2015. 		in rough set perspective [1,2] the universe is seen as granular, with data points grouped in space into equivalence classes, imposed by indiscernitivity relation. When two objects have the same values of considered features, they cannot be		Andemic later Connegitions information is incomplete. In this paper, we demonstrate how the mentioned theories can be merged into a hybrid system to improve the solution of the postare detection problem,	1 INTRODUCTION	error rate evaluated by tm-fold cross validation as the main criterion of quality, no approach is universally the best. Thus, we decided to commerce our six approaches using correlativity of rule sets induced from incomplia data sets. We show that the
therey year manufacter manufactions cause insense of binings of dollars in the financial sector and consequently, mitgating these human neurone constant of the and the and the sector of the manufaction of the sector of the sector of the sector of the manufaction of the sector of the sector of the sector of the manufaction of the sector of the sector of the sector of the sector of the sector of the sector of the sector of the sector of the sector of the sector		discribing benefition or patients in granues seals to intering decision rules. Ease on continuous of articulate in the premises, the rules assign class labels to examples. A length of a rule, corresponding to the number of its conditions, is	NOT VONORC	Reason: 4 January 2022 whitch is a part of a fall delection system. Anaport 16 Femary 2022 Considering that the population is aging rapidly, the demand for assistive technology	A Plasarum machine is a programmable amorphous biological computing	smallest rule sets are induced from incomplete data sets with attribute-concept values, while the most complicated rule sets are induced from data sets with lost values. The choice between interpretations of missing attribute values is more important
Annuale, Meganore, B. Otterstein, 2010; Bantacharypa, Jhe, Thurshurenel, & Weitland, 2011; Chan, Far, Prodremsda, & Stolly, heathcare interance, telecommunication, online transaction and	1. Introduction	one of important macators of rate dataty 13,45 whong other dataty measures there is also used support, which gives the		Patience Non-MNT into a provide relative undersearch undersearch in the aging at home which can provide relative, undersearch monitoring of human activity is repected to expand. One important aim of assistive technology is to provide prolonged independent likense.	device, experimentally implemented in the plasmodium of Physarum poly-	than the choice between characteristic sets and generalized maximal consistent blocks.
1999; Chen, Shu-Ting, & Shiae Shiae, 306; Bal Pozzilis, Carlen, Ja Bergne, Waterschott, & Bostempi, 2014; Eshaar & Sadaosi, (ACPE, 2019) the sectors that are mostly exposed to fault events		the interesting samples that makes the rule, tergin and support are incidently sales under consideration in a search		THE PARTY AND A REPAIR AND A RE		
and the state of the second se	Data tables provide a simple, yet effective means of representation of qualitative or quantitative pieces of data / informa- tion about objects. Therefore they are used as standard input of data analysis tools and theories, output of which is usually	haitorer or sensing tubs: for interesting tubs: peptiding on the selected focus, there are many rule induction algorithms: booksan reasoning [5/6], dynamic pro- perioding on the selected focus, there are many rule induction algorithms: booksan reasoning [5/6], dynamic pro- gramming [7/9], separate-an-conquer approximation [10-12], dynamic tubber of decision tree construction [13,14], generic		patheot separations and Falls are a severe problem within the growing aging population. Many efforts have been undertaken to develop reliable methods of fall detection. The increasing number of	gle cell organism in whose propagation we can notice some behaviour influ-	Acywordy: incompete data, characteristic sets, maximal consistent bioccs, MLEM2 rule induction algorithm, provabilistic approximations.
International procession of the second secon	Data Lables provide a simple, yet effective means of representation of qualitative or quantitative pieces of data), informa- tion about operators. Therefore they are used as standard input of data analysis tools and thereises, napper of which is usually referred to as knowingle. Needless to say, all these terms such as knowingle, following, and dere are ambiguous and have many differenze, and others incompatible interpretations. As Zdonkar Penado tobereol [17]:	minime to intriming sampler that makes the true chrgas and support or interpretary starts using concernations in a second for interesting on the solected focus, there are many nate induction algorithm: Boolean reasoning [5,6], dynamic pro- gramming [1–9], logitate-indicompariparised [10–11], algorithms based on discussion tree constrained [15,6], dynamic pro- gramming [1–9], parate-indi-compariparised approximal [10–12], algorithms based on discussion tree constrained (13,64], genera- algorithms [15,6], different study of greedy algorithms [15,17], and various others. Each of these methods has different frems, which ensume not sets with varying constrainties and characteristics. In discustories can discustoristics of materials on manyles are		rented upperturbation of the service problem within the growing aging population. Many efforts have been undertaken to develop within the growing aging population. Many efforts have studies in this area have allowed us to identify the major childenges and issues for fall one of the service problem service in technologies especially: profermance, assolities, and acceptance by the elderby.	community, and called the same include [1] Projection project/number is a single cell organism in whose propagation we can notice some behaviour influencing unambiguity of connections, made by protoplasmic veins, between distinguished regions. To model ambiguities of connections in <i>Physarum</i>	Acjussity: incomprese data, characteristic sets, maximal consistent nocco, MLEM2 rate induction agerratin, proceedings approximations.
Version, Aniz, Vol. 20, et al. (2019) there is a stretch the mode linear assiss first match lases will be avoid 54-6 billion (2017) (Investively in a stretch stretch and modifying documents, is and found that the insert and and modifying documents, is and found that the insert and and modifying documents, is and found that the insert and the stretch stretch stretch stretch stretch stretch stretch stretch and modifying documents, is and found that the insert and the stretch stret	Data takes provide a single, pet effective means of representation of qualitative or quantitative pieces of data.) Informa- tion about enjoys. Therefore they are used as standard opport of data analysis toom and thereises, enjoye of which is unauly referred to as knowingle. Needesis to say, all these terms such as knowingle, hybrinicitor, and data are ambiguous and have same gridferent, and offen incompatible interpretedims. All Sales Postade Posted 1971 Ashrough there have been stury publications on there mplex [] the quantitative comming havehading on the have do its representa-	Increasing and the intervent of the second s		rentering an antimistration of the second se	reprinting and cancer they make a more inside [1]. Programm porceptional is a sim- gle cell organism in whose propagation we can notice some behaviour influ- encing unambiguity of connections, made by protoplasmic veins, between distinguished regions. To model ambiguities of connections in <i>Physicarum</i> machines, we propose to use rough set theory. Rough set theory has been	Acywory: moorpere and, characteristic sets, maximal consistent modes, MLEM2 rule materian agerrant, provisionic appendimition.
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PP-RAI'2022 Polish Conference on Artificial Intelligence, 25-27 April 2022, Gdynia, Poland

Certificate of appreciation

awarded to

María José Benítez-Caballero, Jesús Medina, Eloísa Ramírez-Poussa and Dominik Ślęzak

for winning the First Prize for publication titled

Rough-set-driven approach for attribute reduction in fuzzy formal concept analysis. Fuzzy Sets and Systems 391: 117-138 (2020)

in the PP-RAI contest for the most influential article on Rough Sets co-authored by Polish researchers in 2020-2021



Prof. Andrzej Skowron Representing the Organizers

Prof. Piotr Jędrzejowicz Representing the Organizers

3-DNIOWY BALTYCKI REJS ŻAGLOWCEM S/V DAR MŁODZIEŻY

NAGRODA W KONKURSIE NA NAJBARDZIEJ WPŁYWOWY POLSKI ARTYKUŁ NAUKOWY ZWIĄZANY Z TEORIĄ ZBIORÓW PRZYBLIŻONYCH OPUBLIKOWANY W LATACH 2020 - 2021

PP-RAI'2022 3rd Polish Conference on Artificial Intelligence April 25-27, 2022, Gdynia, Poland

Rektor Uniwersytetu Morskigo w Gdyni . prof. dr hab. inż. kpt. ż.w. Adam Weintrit

Thank you!!!

- The 2022 International Joint Conference on Rough Sets (<u>IJCRS'22</u>)
- The 17th International Conference on Computer Science and Intelligence Systems (<u>FedCSIS'22</u>)
 - The Anniversary Rough Set Lecture
 - The 4th International Symposium on Rough Sets: Theory and Applications (<u>RSTA'22</u>)
- The 2022 IEEE International Conference on Big Data (<u>IEEE BigData'22</u>)
 - Special Session: 40 Years of Rough Sets from Big Data Perspective
 - The 8th Special Session: Information Granulation in Data Science and Scalable Computing

