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BOOK OF ABSTRACTS

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May 12th – 15th, 2024 • Krakow, Poland

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Program of the

15^{th} European Symposium on Computational Intelligence and Mathematics including Workshop DigForASP

May 12^{th} - 15^{th}, 2024. Krakow, Poland

MONDAY 13th Location: Matejko Hotel	
8:30	Open Registration Desk
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	Independent subcontexts in fuzzy formal concept analysis Roberto G. Aragón, Jesús Medina and Eloísa Ramírez-Poussa
	Two sufficient conditions for having a maximal solution to fuzzy relational equations Vanja R. Stepanović
11:20–11:40	Coffee break
11:40–13:20	**Special Session: Rough Sets and Information Granulation** Chairperson: Jarosław Was
	Towards compatible subcontext by means of classical attribute reduction María José Benítez-Caballero, Jesús Medina
	Extension of The Time Dependent Travelling Salesman Problem Model with Interval-Valued Fuzzy Soft Sets with Arithmetic Mean Method AlMahasneh Ruba, László T. Kóczy
	Representation of distances between objects using weighted distance graph with rough set membership: application to cosmic rays dataset annotation Tomasz Hachaj, Marcin Piekarczyk, Jarosław Was
	Typology of Granular Sets based on Granular Spectrum of Covering Rough Sets Piotr Wasilewski, Dominik Ślęzak
	Ranking Bipolarity in Partial Approximation Spaces Zoltán Ernö Csajbók
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	Categories of L-fuzzy morphological operators on L-fuzzy groups and LR-fuzzy homomorphisms Ksenija Varfolomejeva, Alexander P. Šostak
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	Fuzzy Rule Systems design to model the decision method of a passenger profile David Muñoz Valero, Enrique Adrián Villarrubia Martín, Julio Alberto López-Gómez, Juan Moreno-García
	An interval-valued fuzzy soft sets based decision support model for route optimization Boldizsár Tüű-Szabó, Ruba AlMahasneh, László T. Kóczy
	Railway Capacity Allocation in Liberalized Markets: First Approach for an Artificial Intelligence-Based Computational Model David Muñoz Valero, Enrique Adrián Villarrubia Martín, Julio Alberto López-Gómez, Juan Moreno-García
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Workshop DigForASP

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	Semi-automatic knowledge representation and reasoning on vague crime concepts Manuele Dozzi, Talissa Dreossi, Luca Baron, Federico Costantini, Agostino Dovier, Andrea Formisano
	Empowering Emotional Behavior Trees with Neural Computation for Digital Forensic Stefania Costantini, Giovanni De Gasperis, Pierangelo Dell'Acqua, Andrea Rafanelli
	Legal and technical challenges of AI in the field of Criminal investigations Dévika Pérez-Medina, Nicolás Madrid, Piotr A. Kowalski
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	Stable Reasoning, ASP and the Interrogative Model of Inquiry David Pearce, Agustín Valverde
	Hypergraph logic program representation versus stratified programs David Lobo, Jesús Medina, José Ramón Portillo, José Antonio Torné-Zambrano
	A preliminary taxonomy of explanations in problem solving Pedro Cabalar, Esra Erdem, Muge Fidan, Brais Muñiz
	Efficiency of decision rule sets in classification problems Fernando Chacón-Gómez, María Eugenia Cornejo, Jesús Medina
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11:20–12:00	**Special Session: Decision and optimization model applied to logistics and transport**. Part 2 Chairperson: Julio Alberto López-Gómez
	Enhancement of Discrete Bacterial Memetic Evolutionary Algorithm for solving The Travelling repairman Problem Ali Jawad Ibada, Boldizsár Tüű-Szabó, László T. Kóczy
	Simulated Annealing and Bacterial Foraging for Probabilistic Neural Network parameters adjustment Szymon Kucharczyk, Piotr A. Kowalski
12:00–13:30	**Special Session: Recent trends in knowledge representation and modelling** Chairperson: Manuel Ojeda-Hernández
	Extreme Learning Machine as a New Learning Paradigm: Pros and Cons Irina Perfilieva, Nicolás Madrid, Manuel Ojeda-Aciego, Piotr Artiemjew, Agnieszka Niemczynowicz
	Inheritance of completeness between systems of strong and weak implications Francisco Pérez-Gámez, Pablo Cordero, Carlos Bejines-López, Manuel Ojeda-Hernández, Domingo López-Rodríguez
	Connections between attribute implications in heterogeneous formal contexts and GUHA association rules L'ubomír Antoni, Peter Eliaš, Ján Guniš, Dominika Kotlárová, Stanislav Krajči, Ondrej Krídlo, L'ubomír Šnajder
	Migrative properties for triangular conorms and fuzzy implications M. Eugenia Cornejo, Jesús Medina, Francisco José Ocaña
	Masonry strength assessment based on Fuzzy signature model András Kaszás, András Dormány, Vanda Pomezanski, Zoltán Orbán, László T. Kóczy
13:30–15:00	**Closing Session**

***Keynote speech*:**

An approach to Consensus and dissensus driven decision making under fuzziness

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[2] WIT – Warsaw School of Information Technology, Poland
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Abstract: We advocate a new way of decision making under fuzzy preferences and fuzzy majorities the essence of which is that the consensus driven paradigm, which is very often employed, is not followed as it can often prohibit reaching innovative decisions.

First, we briefly review main developments in the broadly perceived group decision making and indicate the main general approaches, namely via: 1) Unanimous decisions when all agents agree without reservations; 2) Consensus in which each agent agrees to give his/her consent to the decision reached, even if it would not be perfect, but acceptable, and is open to modify his or her testimonies; 3) Majority Rule when, e.g., more than a half, at least 2/3, etc, of the group votes in favor; 4) Expert in which a special agent, an expert, is chosen for running the decision making process; 5) Executive in which a special high lvel agent makes the decision with little or none involvement of other group members; 6) Default in which a decision is made as needed, without any analysis.

We analyze some new directions in social sciences, cognitive scence, psychoiogy, decision theory, etc. in which there is an explicit critique of consensus as a viable and effective and efficient way of making group decisions. Basically, the argument is that "consensus is the quickest way to kill innovation". This arguent is raised by many authors, and there are some attampts to use some more formal analyses.

We also use some results of the so called entrepreneurial action theory which also mentions that the most interesting forms of entrepreneurship involve ideas that contradict prevailing wisdom, and opinions. These behaviors may be irrational and seem impossible but may lead to innovative, even revolutionary outcomes.

We propose a new model of dissensus driven group decision making under fuzzy preferences and fuzzy majorities. We redefine the solution concepts along the line of the fuzzy cores and fuzzy consensus winners. We mention an examples.

A note on aggregation of T-fuzzy subgroups

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Abstract: This paper aims to provide an answer to the question of the preservation of fuzzy subgroup structure for some special classes of aggregation operators. Both binary and n-ary aggregation of fuzzy subgroups are considered. The main contribution of the approach proposed in this paper is the development of a new method for n-ary aggregation applicable to fuzzy subgroups regardless of the cardinality, based on n-ary aggregation operators generated by a family of binary aggregation operators.

Keywords: Fuzzy subgroups · Aggregation operator

Acknowledgement: This research was supported by the Science Fund of the Republic of Serbia, # Grant no 6565, Advanced Techniques of Mathematical Aggregation and Approximative Equations Solving in Digital Operational Research- AT-MATADOR.

References

1. Ardanza-Trevijano, S., Chasco, M.J., Elorza, J., de Natividade, M., Talavera, F.J., Aggregation of T-subgroups, Fuzzy Sets and Systems, **463**, 108390 (2023)
2. Bejines, C., Chasco, M.J., Elorza, J. Aggregation of fuzzy subgroups, Fuzzy Sets and Systems, **418**, 170-184 (2021)
3. Beliakov G., Pradera A., Calvo T. Aggregation Functions: A Guide for Practitioners. Berlin: Springer; 2007.
4. Cornejo, M.E., Medina, J., Štajner-Papuga, I., Tepavčević, A. (2024). Lattice Valued Aggregation Operators Applicable in Digital Forensics. Computational Intelligence and Mathematics for Tackling Complex Problems 5. Studies in Computational Intelligence. Vol 1127, pp. 101–108. Springer, Cham.
5. Grabisch, M., Marichal, J., Mesiar, R., Pap, E.: Aggregations Functions. Cambridge University Press (2009)
6. Karaçal, F., Mesiar, R., Aggregation functions on bounded lattices. International Journal of General Systems **46**:1, 37-51 (2017)
7. Talavera, F.J., Ardanza-Trevijano, S., Bragard, J., Elorza,J., Aggregation of T-subgroups of groups whose subgroup lattice is a chain, Fuzzy Sets and Systems, **473**, 108717 (2023).
8. Santos H., Dimuro G.P., Asmus T.C., et al.: General Grouping Functions. Information Processing and Management of Uncertainty in Knowledge-Based Systems **1238**, 481-495 (2020).

Independent subcontexts in fuzzy formal concept analysis

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Abstract: Independent subcontext is a fundamental notion for different purposes, such as in factorization of contexts in both the Boolean and fuzzy case. Although the notion can be intuitive, a mathematical definition is required. This paper formalizes this notion and provides some properties of the independent subcontexts of an L-fuzzy context.

Keywords: Formal concept analysis · factorization · independent subcontext.

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References

1. R. G. Aragón, J. Medina, and E. Ramírez-Poussa. Impact of local congruences in variable selection from datasets. *Journal of Computational and Applied Mathematics*, 404(113416), 2022.
2. R. G. Aragón, J. Medina, and E. Ramírez-Poussa. Study on the necessity operator to factorize formal contexts in a multi-adjoint framework. *Communications in Computer and Information Science*, 1601:107–117, 2022.
3. R. G. Aragón, J. Medina, and E. Ramírez-Poussa. Factorizing formal contexts from closures of necessity operators. *Computational and Applied Mathematics*, X:1–32, 2024. In press.
4. R. Bělohlávek. Fuzzy Galois connections. *Mathematical Logic Quarterly*, 45:497–504, 1999.
5. R. Bělohlávek and V. Vychodil. Discovery of optimal factors in binary data via a novel method of matrix decomposition. *Journal of Computer and System Sciences*, 76(1):3–20, 2010.
6. M. J. Benítez-Caballero, J. Medina, E. Ramírez-Poussa, and D. Ślęzak. Rough-set-driven approach for attribute reduction in fuzzy formal concept analysis. *Fuzzy Sets and Systems*, 391:117–138, 2020.
7. M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Attribute reduction in multi-adjoint concept lattices. *Information Sciences*, 294:41–56, 2015.
8. M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Attribute and size reduction mechanisms in multi-adjoint concept lattices. *Journal of Computational and Applied Mathematics*, 318:388–402, 2017.

9. M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Algebraic structure and characterization of adjoint triples. *Fuzzy Sets and Systems*, 425:117–139, 2021.
10. D. Dubois, J. Medina, H. Prade, and E. Ramírez-Poussa. Disjunctive attribute dependencies in formal concept analysis under the epistemic view of formal contexts. *Information Sciences*, 561:31–51, 2021.
11. D. Dubois and H. Prade. Possibility theory and formal concept analysis: Characterizing independent sub-contexts. *Fuzzy Sets and Systems*, 196:4–16, 2012.
12. S. Dutta and D. Ślęzak. Nature of decision valuations in elimination of redundant attributes. *International Journal of Approximate Reasoning*, 165:109091, 2024.
13. G. Georgescu and A. Popescu. Non-dual fuzzy connections. *Archive for Mathematical Logic*, 43(8):1009–1039, 2004.
14. J. Medina, M. Ojeda-Aciego, and J. Ruiz-Calviño. Formal concept analysis via multi-adjoint concept lattices. *Fuzzy Sets and Systems*, 160(2):130–144, 2009.
15. F. J. Valverde-Albacete, C. Peláez-Moreno, I. P. Cabrera, P. Cordero, and M. Ojeda-Aciego. Formal independence analysis. pages 596–608, 2018.

Two sufficient conditions for having a maximal solution to fuzzy relational equations

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Abstract: The existence of a maximal solution to some typical fuzzy relational equations is proved in the paper, in case when the codomain lattice is complete and meet-continuous, which means that the infimum commutes with the supremum of chains. These results extend the existing results, which are mostly limited to the existence of a maximal solution to some typical fuzzy set and fuzzy relatonal inequations. In order to prove that the same holds for the corresponding relational equations, it is proved that the property of meet-continuity in the codomain lattice implies another property in the lattice of fuzzy relations, namely that the composition of fuzzy relations, defined as usual, commutes with the supremum of chains. This condition can also be taken instead of the meet-continuity of the codomain lattice as another sufficient condition for the existence of a maximal solution to the equations considered here. Two examples are given, which prove that these conditions do not imply the existence of the greatest solution to some of the considered equations.

Keywords: Complete lattice · Meet-continuous lattice · Fuzzy relational equations · Maximal solution

Acknowledgement: This research was supported by the Science Fund of the Republic of Serbia, Grant no 6565, Advanced Techniques of Mathematical Aggregation and Approximative Equations Solving in Digital Operational Research - AT-MATADOR. It is also a result of the Agreement on the transfer of funds for the financing of scientific research work of teaching staff at accredited higher education institutions in Serbia in 2024, grant number 451-03-65/2024-03/200116.

References

1. Díaz-Moreno J.C., Medina J., Turunen E.: Minimal solutions of general fuzzy relation equations on linear carriers. An algebraic characterization. Fuzzy Sets Syst. **311**, 112–123 (2017)
2. Goguen, J.A.: L-Fuzzy Sets. Journal of Mathematical Analysis and Applications **18**, 145–174 (1967)
3. Ignjatović J., Ćirić M., Šešelja B., Tepavčević A.: Fuzzy relational inequalities and equalities, fuzzy quasi-orders, closures and openings of fuzzy sets. Fuzzy Sets and Systems **260**, 1–24 (2015)
4. Sanchez, E.: Resolution of composite fuzzy relation equations. Information and Control **30** (1), 38–48 (1976)
5. Stepanović, V.: Fuzzy set inequations and equations with a meet-continuous codomain lattice. Journal of Intelligent and Fuzzy Systems **34** (6), 4009–4021 (2018)
6. Zadeh, L.A.: Fuzzy sets. Information and Control **8**, 338–353 (1965)

Towards compatible subcontext by means of classical attribute reduction

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Abstract: Reducing a database is one of the main goals of the theories developed for the management of information in databases, such as Formal Concept Analysis (FCA) and Rough Set Theory (RST). On the other hand, this reduction should preserve some properties from the original database. In FCA, for example, it is recommendable to obtain compatible subcontexts. This paper introduces sufficient conditions to obtain compatible subcontexts from attribute reduction theory in FCA.

Keywords: Formal Concept Analysis · Attribute Reduction · Reduct · Compatible Subcontext

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References

1. R. G. Aragón, J. Medina, and E. Ramírez-Poussa. Impact of local congruences in variable selection from datasets. *Journal of Computational and Applied Mathematics*, page 113416, 2022. https://doi.org/10.1016/j.cam.2021.113416.
2. M. J. Benítez-Caballero, J. Medina, E. Ramírez-Poussa, and D. Ślęzak. Bireducts with tolerance relations. *Information Sciences*, 435:26 – 39, 2018.
3. M. J. Benítez-Caballero, J. Medina, E. Ramírez-Poussa, and D. Ślęzak. A computational procedure for variable selection preserving different initial conditions. *International Journal of Computer Mathematics*, 97(1-2):387–404, 2020.
4. M. J. Benítez-Caballero, J. Medina, E. Ramírez-Poussa, and D. Ślęzak. Rough-set-driven approach for attribute reduction in fuzzy formal concept analysis. *Fuzzy Sets and Systems*, 391:117–138, 2020.
5. X. Chu, B. Sun, X. Chu, J. Wu, K. Han, Y. Zhang, and Q. Huang. Multi-granularity dominance rough concept attribute reduction over hybrid information systems and its application in clinical decision-making. *Information Sciences*, 597:274–299, 2022.
6. M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Attribute reduction in multi-adjoint concept lattices. *Information Sciences*, 294:41 – 56, 2015.
7. M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. On the use of thresholds in multi-adjoint concept lattices. *International Journal of Computer Mathematics*, 92(9):1855–1873, 2015.
8. M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Attribute and size reduction mechanisms in multi-adjoint concept lattices. *Journal of Computational and Applied Mathematics*, 318:388 – 402, 2017.

9. 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.
10. B. Davey and H. Priestley. *Introduction to Lattices and Order*. Cambridge University Press, second edition, 2002.
11. K. Denecke, M. Erné, and S. L. Wismath, editors. *Galois Connections and Applications*. Kluwer Academic Publishers, Dordrecht. The Netherlands, 2004.
12. S. Dutta and D. Ślęzak. Nature of decision valuations in elimination of redundant attributes. *International Journal of Approximate Reasoning*, 165:109091, 2024.
13. B. Ganter and R. Wille. *Formal Concept Analysis: Mathematical Foundation*. Springer Verlag, 1999.
14. G. Liu, Y. Xie, and X. Gao. Three-way reduction for formal decision contexts. *Information Sciences*, 615:39–57, 2022.
15. J. Medina. Relating attribute reduction in formal, object-oriented and property-oriented concept lattices. *Computers & Mathematics with Applications*, 64(6):1992–2002, 2012.
16. Z. Pawlak. Rough sets. *International Journal of Computer and Information Science*, 11:341–356, 1982.
17. R. Wille. Restructuring lattice theory: an approach based on hierarchies of concepts. In I. Rival, editor, *Ordered Sets*, pages 445–470. Reidel, 1982.

Extension of The Time Dependent Travelling Salesman Problem Model with Interval-Valued Fuzzy Soft Sets with Arithmetic Mean Method

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Abstract: The Traveling Salesman Problem (TSP) is an extensively studied NP-hard graph search problem. Many researchers pursued the most efficient and practical solutions, by applying various techniques to find the optimum or semi optimum solution (the one with least cost). There are numerous practical extensions and modifications of the original problem, such as The Time Dependent Traveling Salesman Problem (TD TSP). Indeed. the TD TSP was towards more realistic assessment of the traffic conditions of the original TSP. The edges between nodes are assigned different costs (weights), whether they are traveled during the rush hour periods or if they crossed the traffic jam regions (such as city centers). In the classic TD TSP, the edges are assigned higher costs using concrete numbers, which might be looked at as a limitation; because those jam factors are non-deterministic and better be represented by fuzzy numbers. In this paper we introduce a more realistic novel fuzzy-based extension, the IVFSSTD TSP (Interval-Valued Fuzzy Soft Set for the Time Dependent Traveling Sales-man Problem). Our core concept employs interval-valued fuzzy soft sets on the costs between nodes to realistically quantify the traffic jam regions, and the rush hours periods effects on any tour, then we user the arithmetic mean operator to take in account all factors affecting an edge simultaneously, which lead to less information loss and more adequate representation for the jam factors. Since the interval-valued fuzzy soft sets are generalization of the original fuzzy sets, which has the ability to simulate uncertain road conditions more efficiently than concrete numbers, then our approach can be considered a useful extension and a practical alternative model of the original abstract problem.

Keywords: Rush hours · Jam regions · Interval-valued fuzzy soft sets · Time De-pendent Traveling Salesman Problem.

References

1. Short remark on fuzzy sets, interval type-2 fuzzy sets, general type-2 fuzzy sets and intuitionistic fuzzy sets. *IEEE Conf. on Intelligent Systems*, 1:183–190.

2. R. Almahasneh, B. Tüű-Szabó, P. Földesi, and Kóczy. Interval-valued intuitionistic fuzzy model of jam regions and rush hours for te time.
3. R. Almahasneh, B. Tüű-Szabó, P. Földesi, and Kóczy. Intuitionistic fuzzy model of jam regions and rush hours for te time dependent traveling salesman problem. In *Proceedings of the IFSA World Congress and NAFIPS Annual Conference, in publication,2019.*
4. D. Applegate, R. Bixby, V. Chvátal, and W. Cook. *The Traveling Salesman Problem: A Computational Study.* Princeton University Press, Princeton.
5. R. Atanassov. Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, 20:87–96.
6. R. Biswas. On fuzzy sets and intuitionistic fuzzy sets. *Notes on Intuitionistic Fuzzy Sets*, 3:3–11.
7. N. Cagman and S. Enginoglu. *Soft matrices and its decision makings, Computers and Mathematics with Applications*, 59:3308 – 3314.
8. D. Chen, E. Tsang, D. Yeung, and X. Wang. The parameterization reduction of soft sets and its applications. *Computers and Mathematics with Applications*, 49:757 – 763.
9. N. F. Citak and S. Enginoglu. Fuzzy parameterized fuzzy soft set theory and its applications. *Turkish Journal of Fuzzy Systems*, 1:21 – 35.
10. E. Czogala. On distribution function description of probabilistic sets and its application in decision making. *Fuzzy Sets and Systems*, 10:21–29.
11. M. Gorzalczany. Approximate inference with interval-valued fuzzy sets- an outline. In *Proc. Polish Symp. on Interval and Fuzzy Mathematics*, pages 89–95, Poznafi, Poland.
12. K. Hirota. Concept of probabilistic sets. *Fuzzy Sets and Systems*, 5:31–46.
13. S. Karmakar, M. R. Seikh, and O. Castillo. Type-2 intuitionistic fuzzy matrix games based on a new distance measure: Application to biogas-plant implementation problem. Applied Soft Computing,Volume 106,2021.
14. L. Kóczy, P. Földesi, B. Tüű-Szabó, and R. Almahasneh. Modeling of fuzzy rulebase algorithm for the time dependent traveling salesman problem. In *Proceedings of the IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), in publication,2019.*
15. Z. Kong, L. Gao, and L. Wang. Comment on "a fuzzy soft set theoretic approach to de-cision making problems". *J. Comput. Appl. Math*, 223:540–542.
16. Z. Kong, L. Gao, L. Wang, and S. Li. The normal parameter reduction of soft sets and its algorithm. *Comput. Math. Appl*, 56:3029–3037.
17. P. Maji, R. Biswas, and A. Roy. Fuzzy soft sets. *Journal of Fuzzy Mathematics*, 9:589 – 602.
18. P. Maji, R. Biswas, and A. Roy. Soft set theory. *Computers and Mathematics with Applications*, 45:555 – 562.
19. P. Maji, A. Roy, and R. Biswas. An application of soft sets in a decision making problem. *Computers and Mathematics with Applications*, 44:1077 – 1083.
20. E. Mamdani. Application of fuzzy algorithms for control of simple dynamic plant. *IEEE Proc*, 121(12):1585–1588.
21. J. Mendel and R. John. Type-2 fuzzy sets made simple. *IEEE Transactions on Fuzzy Systems*, 10.
22. J. Mendel, R. John, and F. Liu. Interval type-2 fuzzy logic systems made simple. *IEEE Transactions on Fuzzy Systems*, 14(6).
23. K. Mittal, A. Jain, K. S. Vaisla, O. Castillo, and J. Kacprzyk. A comprehensive review on type 2 fuzzy logic applications: Past, present and future. In *Engineering Applications of Artificial Intelligence,Volume 95,2020.*

24. D. Molodtsov. The description of a dependence with the help of soft sets. *J. Comput. Sys. Sc. Int*, 40(6):977–984.
25. D. Molodtsov. Soft set theory - first results. *Computers and Mathematics with Applications*, 37:19 – 31.
26. D. Molodtsov. Soft set theory-first results. *Comput. Math. Appl*, 37:19–31.
27. D. Molodtsov. *The theory of soft sets (in Russian)*. URSS Publishers, Moscow.
28. D. Molodtsov, V. Leonov, and D. Kovkov. Soft sets sechnique and its appli-cation. *Nechetkie Sistemi I Myakie Vychisleniya*, 1(1):8–39.
29. A. Mukherjee and S. Chakraborty. On intuitionistic fuzzy soft relations. *Bull. Kerala Math. Assoc*, 5(1):35–42.
30. M. Mushrif, S. Sengupta, and A. Ray. Texture classification using a novel, soft-set theory based classification. *Algorithm. Lecture Notes In Computer Science*, 3851:246–254.
31. Z. Pawlak. Rough sets. *Int. J. Comput. Inform. Sci*, 11:341–356.
32. D. Pei and D. Miao. From soft sets to information systems. In X. Hu, Q. Liu, A. Skowron, T. Lin, R. Yager, and B. Zhang, editors, *Proceedings of Granular Computing, IEEE*, volume 2, pages 617–621.
33. A. Roy and P. Maji. A fuzzy soft set theoretic approach to decision making problems. *J. Comput. Appl. Math*, 203:412–418.
34. J. Schneider. The time-dependent traveling salesman problem. *PhysicaA*, 314:151–155.
35. T. Som. On the theory of soft sets, soft relation and fuzzy soft relation. In *Proc. of the Na-tional Conference on Uncertainty: A Mathematical Approach, UAMA-06*, pages 1–9, Burdwan.
36. Q. Sun, Z. Zhang, and J. Liu. Soft sets and soft modules. In G. Wang, T. Li, J. Grzymala-Busse, D. Miao, A. Skowron, and Y. Yao, editors, *Rough Sets and Knowledge Technology, RSKT-08, Proceedings*, pages 403–409. Springer.
37. Z. Xiao, L. Chen, B. Zhong, and S. Ye. Recognition for soft information based on the theory of soft sets. In J. Chen, editor, *Proceedings of ICSSSM-05*, volume 2, pages 1104–1106.
38. Z. Xiao, K. Gong, and Y. Zou. A combined forecasting approach based on fuzzy soft sets. *J. Comput. Appl. Math*, 228:326–333.
39. Z. Xiao, Y. Li, B. Zhong, and X. Yang. Research on synthetically evaluating method for business competitive capacity based on soft set. *Stat. Methods. Med. Res*, pages 52–54.
40. X. Yang, T. Lin, J. Yang, YLi, and D. Yu. Combination of interval-valued fuzzy set and soft set. *Computers and Mathematics with*, Application.58:521–527.
41. X. Yang, D. Yu, J. Yang, and C. Wu. Generalization of soft set theory: from crisp to fuzzy case. In *Bing-Yuan Cao,eds., Fuzzy Information and Engineering: Proceedings of ICFIE2007, Advances in Soft Computing 40*, pages 345–355. Springer.
42. L. Zadeh. Fuzzy sets. *Information and Control*, 8(3):338–353.
43. Y. Zou and Y. Chen. Research on soft set theory and parameters reduction based on re-lational algebra. In *Intelligent Information Technology Application, IITA*, volume 1, pages 152 – 156.
44. Y. Zou and Z. Xiao. Data analysis approaches of soft sets under incomplete information. *Knowl-Based Syst*, 21:941–945.

Representation of distances between objects using weighted distance graph with rough set membership: application to cosmic rays dataset annotation

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Abstract: In this work, we define a weighted distance graph with rough set membership [7,8,9] and its application to cosmic rays dataset annotation. The weighted distance graph we introduce is a weighted undirected graph whose vertices represent objects and the weights of the edges connecting the objects have weights that are a pair. The first element of the pair equals the distance between the objects that the edge connects. The second element of the pair is equal to the type of membership approximation in the sense of Rough set (lower or upper approximation). The objects can be, for example, m-dimensional vectors, between which it is possible to calculate the distance using, for example, the Euclidean metric. Formally, we define such a graph as a triple:

$$\mathbb{G}_k = (V, E, w) \tag{1}$$

where V is a set of l vertices (each vertex represents object defined by by m-dimensional vector), E is a set of undirected edges (due to the fact that distance function is symmetric) that links nodes, w is a function mapping edges to their values.

$$w : E \rightarrow (\mathbb{R}_+ \cup \{0\}, \{lower, upper\}) \tag{2}$$

Value $\mathbb{R}_+ \cup \{0\}$ is calculated using the f metric defined on $(N \times N)$, N is a set of all l objects.
The letter k in the notation $\mathbb{G}_k$ is directly related to the way this graph is generated. In order to check whether two vertices belonging to V are connected by an edge, for each vertex of the graph it is necessary to find the k nearest objects to it with respect to the f metric. Only these k closest objects will be connected by edges. For two vertices $v_1, v_2 \in V$ one of two situations may occur:

$$p^{v_1} = min_k f(\{v_1\} \times (V - \{v_1\})) \tag{3}$$

$$p^{v_2} = min_k f(\{v_2\} \times (V - \{v_2\})) \tag{4}$$

$$\begin{cases} f(v_1, v_2) \in p^{v_1} \cap f(v_1, v_2) \in p^{v_2} \rightarrow lower \\ f(v_1, v_2) \in p^{v_1} \cap f(v_1, v_2) \notin p^{v_2} \rightarrow upper \end{cases} \tag{5}$$

where $min_k f(\{v_1\} \times (N - \{v_1\}))$ is the set of k smallest distances between object v_1 and all other objects belonging to V. (5) should be interpreted as follows: if object v_1 is among k nearest objects to v_2 and object v_2 is among k nearest objects to v_1 then

both objects are in the lower approximation of rough set. If object v_1 is among k closest objects to v_2 and object v_2 is not among k closest objects to v_1 then both objects are in the upper approximation of rough set. The information whether the objects are in lower or upper approximation is added to the weight of the edge between these vertices. Graph $\mathbb{G}_k$ does not have self-loops.

If $k = l$, then graph $\mathbb{G}_k$ is a complete graph and all weights between vertices have lower approximation.

The $\mathbb{G}_k$ graph can be a useful tool, for example, for accelerating the semi-manual annotation of various datasets. In our case, we used it for annotation of cosmic rays dataset [2], which was collected by the Cosmic Ray Extremely Distributed Observatory (CREDO) project [6]. The dataset is composed of images with a resolution of 60×60 pixels [1] acquired with CMOS sensors [3]. Using principal component analysis (PCA), we performed dimensionality reduction leaving the 62 most significant dimensions. This corresponds to more than 95 percent of the variance in the dataset [5]. We then constructed a $\mathbb{G}_k$ graph for $k = 5$. We sorted the V vertices according to descending vertex degree. Each vertex was also given a status, whether it had already been visited or not. Then, starting from the vertex with the highest degree, we performed object annotation by assigning each object to one of four classes [4]. A class is an interpretation of the type of particle visible in the image based on the morphology of the trace left by it. After annotating a single particle v_i, we also annotated all particles v_j that were connected by an edge to v_i assigning them the same class as the particle v_i. If the edge had a weight denoting rough set lower approximation, we mark the vertex v_j as visited. From the list of edges connected to v_j, we removed all edges connecting v_j to vertices that already had a class assigned. We also removed all edges connecting v_i to other vertices. The above process was repeated until the degree of all V rows were equal to zero. The next step of the algorithm was an additional semi-manual validation of objects that had not been visited so far, and obtained automatic annotation by the fact of belonging to the k neighborhood of the closest objects. The use of rough sets approximation made it possible to eliminate objects that were close to each other from the process. This approach is very similar to density-based clustering except that it does not require a distance threshold. Currently there is no proposed method that indicates the optimal k for a given problem. The value of k is therefore estimated by an expert. In the case of the CREDO set, we know that the clusters in our embedding are not concentric. Therefore, in our application, we chose a small value of k relative to the size of the dataset. Thanks to the application of the discussed algorithm, we fully annotated the considered CREDO dataset. This achievement was very important, because we could use the set prepared in this way for further supervised classifier training.

Keywords: Weighted distance graph · Rough set · Data annotation · Cosmic rays dataset

References

1. Bibrzycki, Ł., Burakowski, D., Homola, P., Piekarczyk, M., Niedźwiecki, M., Rzecki, K., Stuglik, S., Tursunov, A., Hnatyk, B., Castillo, D.E.A., Smelcerz, K., Stasielak, J., Duffy, A.R., Chevalier, L., Ali, E., Lakerink, L., Poole, G.B., Wibig, T., Zamora-Saa, J.: Towards a global cosmic ray sensor network: Credo detector as the first

open-source mobile application enabling detection of penetrating radiation. Symmetry **12**(11) (2020). https://doi.org/10.3390/sym12111802, https://www.mdpi.com/2073-8994/12/11/1802

2. Hachaj, T., Bibrzycki, Ł., Piekarczyk, M.: Fast training data generation for machine learning analysis of cosmic ray showers. IEEE Access **11**, 7410–7419 (2023). https://doi.org/10.1109/ACCESS.2023.3237800
3. Hachaj, T., Piekarczyk, M.: The practice of detecting potential cosmic rays using cmos cameras: Hardware and algorithms. Sensors **23**(10) (2023). https://doi.org/10.3390/s23104858, https://www.mdpi.com/1424-8220/23/10/4858
4. Hachaj, T., Piekarczyk, M., Bibrzycki, Ł.: Deep neural network architecture for low-dimensional embedding and classification of cosmic ray images obtained from cmos cameras. In: Mantoro, T., Lee, M., Ayu, M.A., Wong, K.W., Hidayanto, A.N. (eds.) Neural Information Processing. pp. 307–316. Springer International Publishing, Cham (2021)
5. Hachaj, T., Piekarczyk, M., Wąs, J.: Searching of potentially anomalous signals in cosmic-ray particle tracks images using rough k-means clustering combined with eigendecomposition-derived embedding. In: International Joint Conference on Rough Sets. pp. 431–445. Springer (2023)
6. Homola, P., Beznosko, D., Bhatta, G., Bibrzycki, Ł., et al.: Cosmic-ray extremely distributed observatory. Symmetry **12**(11) (2020). https://doi.org/10.3390/sym12111835, https://www.mdpi.com/2073-8994/12/11/1835
7. Mathew, B., John, S.J., Garg, H.: Vertex rough graphs. Complex & Intelligent Systems **6**, 347–353 (2020)
8. Pawlak, Z.: Rough sets. International journal of computer & information sciences **11**, 341–356 (1982)
9. Skowron, A., Ślęzak, D.: Rough sets turn 40: From information systems to intelligent systems. In: 2022 17th Conference on Computer Science and Intelligence Systems (FedCSIS). pp. 23–34. IEEE (2022)

Typology of Granular Sets based on Granular Spectrum of Covering Rough Sets

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Abstract: In [8] we introduced granular spectrum of covering rough sets (see Fig. 1). In this paper we propose a typology of granular sets which is based on granular spectrum of covering rough sets. This typology is proposed by analogy to the typology of classical rough sets proposed by Z. Pawlak.

Rough sets were proposed [3], [4] (see also: [5]) to represent vague concepts and to deal with incomplete information [1], [2], [7]. Lower and upper approximations of any set $X \subseteq U$ for the approximation space (U, R) and R an equivalence relation of U:

$$R_*(X) := \bigcup\{Y \in U_{/R} : Y \subseteq X\} \quad R^*(X) := \bigcup\{Y \in U_{/R} : Y \cap X \neq \emptyset\},$$

were interpreted by Pawlak [4] as *conceptual measures* of a set X by analogy to *inner Jordan measure* and *outer Jordan measure* in space $\mathbb{R}^n$. On the basis of this interpretation Pawlak suggested a kind of typology of rough sets in which sets were catalogued whether their lower or upper approximations or their boundaries are empty sets, essential subsets of the space U or equal to the space U. For example, in such typology for the selector S of the family $U_{/R}$: $R_*(S) = \emptyset$ and $R^*(S) = U$. Actually, diagrams used in the rough set theory for representation of lower and upper approximations of sets are derived from the inner Jordan measure and the outer Jordan measure of the plane $\mathbb{R}^2$.

The granular spectrum of the object space U is based on arbitrary coverings of the object space in [8]. These approximation operators were introduced in [10]:

$$G_\forall(X) := \{a \in U : \forall A \in Gr(a) A \subseteq X\} \quad G^\exists(X) := \{a \in U : \exists A \in Gr(a) A \cap X \neq \emptyset\}.$$

$$G_\exists(X) := \{a \in U : \exists A \in Gr(a) A \subseteq X\} \quad G^\forall(X) := \{a \in U : \forall A \in Gr(a)\ A \cap X \neq \emptyset\}.$$

where $Gr(a) := \{A \in Gr(U) : a \in A\}$ and $Gr(U)$ is a family of granules covering the space U. Operators $G_\forall$ and $G^\exists(X)$ were investigated in [6] where the operator $G^\exists$ was defined in a new equivalent form using biting procedure. One can note that operators $G_\forall$ and $G^\exists(X)$ and operators $G_\exists$ and $G^\forall$ are dual, i.e. for example $G_\forall(X)^\complement = G^\exists(X^\complement)$.

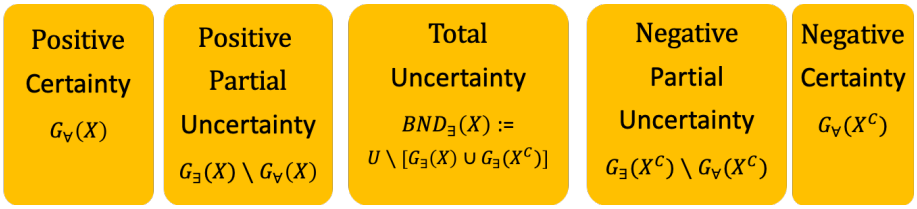

Fig. 1. Granular spectrum of space $(U, Gr(U))$ determined by subset $X \subseteq U$. [8]

Operators $G_\forall$, $G^\exists(X)$, $G_\exists$ and $G^\forall$ are related to each other in the following way:

$$G_\forall(X) \subseteq G_\exists(X) \subseteq X \subseteq G^\exists(X) \subseteq G^\forall(X).$$

when approximating any set $X \subseteq U$. All five regions presented in Fig. 1 are pairwise disjoint and their union covers the space U. However in general this granular spectrum does not have to be a partition of the space U since all five regions are not necessary non-empty. This gives the reason for introducing a typology of granular sets analogous to typology of rough sets proposed by Pawlak. One can note that not all possible cases $2^5 = 32$ are realized. For example, there are granular spaces $(U, Gr(U))$ and sets such that *positive certainty* and *negative certainty* regions are empty making *total uncertainty* region equal to the whole space U and so making the remaining two regions also empty.

Keywords: rough sets · granular sets · coverings · covering-based rough sets · granular spectrum of covering rough sets · vague concepts · incomplete information

References

1. Orłowska, E.: Semantics of vague concepts. applications of rough sets, Polish Academy of Sciences 469, in: G. Dorn, P. Weingartner (eds.), Foundations of Logic and Linguistics. Problems and Solutions, pp. 465–482. Plenum Press, (1985)
2. Orłowska, E.,Pawlak, Z.: Representation of nondeterministic information, Theoretical Computer Science **29** 27–39 (1984)
3. Pawlak, Z.: Rough sets. International Journal of Computing and Information Sciences. **18**, 341–356 (1982)
4. Pawlak, Z.: Rough sets. Theoretical Aspects of Reasoning About Data. Kluwer Academic Publishers, Dordrecht (1991)
5. Pawlak, Z., Skowron, A.: Rudiments of rough sets, Information Science **177** 3–27 (2007)
6. Ślęzak, D., Wasilewski, P.: Granular sets – foundations and case study of tolerance spaces. In: Lecture Notes in Artificial Intelligence 4482, 435–442. Springer, Heidelberg (2007)
7. Wasilewski, P., Ślęzak, D.: Foundations of rough sets from vagueness perspective, in: A. E. Hassanien, Z. Suraj, D. Ślęzak, P. Lingras (eds.) Rough Computing. Theories, Technologies and Applications, pp. 1–37. Information Science Refer. (2008)
8. Wasilewski, P., Ślęzak, D.: Granular Spectrum of Covering Rough Sets, In: Book of Abstracts, International Joint Conference on Rough Sets IJCRS 2023.

9. Yao, Y. Y.: Relational interpretations of neighborhood operators and rough set approximation operators. Information Sciences **111**, 239–259 (1998)
10. Yao, Y. Y.: On Generalizing Rough Set Theory In: Lecture Notes in Artificial Intelligence 2639, 44–51. Springer, Heidelberg (2003) In: Proceedings of the 9th International Conference (RSFDGrC 2003), LNAI 2639, pp. 44–51. Springer, Heidelberg (2003)
11. Yao, Y. Y., Yao, B.: Covering based rough set approximations. Information Sciences **200**, 91–107 (2012)

Ranking Bipolarity in Partial Approximation Spaces

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Abstract: Some phenomena have two distinct aspects, "positive" and "negative". Suppose that a dataset is available to describe these aspects. We propose a model to decide which one has the best evaluate value. First, based on the dataset, we offer a new partial approximation space, which serves a better set approximation than Pawlak's approximation space. Then, assigning two intervals to the two aspects, we evaluate them with the possibility degree formula, an effective tool for Multi-Attribute Decision Making (MADM) methods under uncertain environments. An example is used to illustrate how the theoretical construction works in practice. The proposed model can be applied to any two distinct entities and, even more, can be generalised to more than two separate entities.

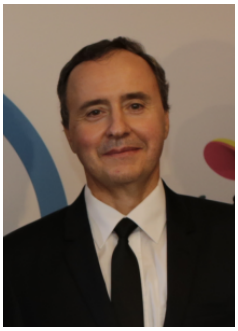
References

1. M. Banerjee and M. Chakraborty. Algebras from rough sets. In S. Pal, L. Polkowski, and A. Skowron, editors, *Rough-Neuro Computing: Techniques for Computing with Words*, pages 157–184. Springer (2004).
2. Z. Bonikowski, E. Bryniarski, and U. Wybraniec-Skardowska. Extensions and intentions in the rough set theory. *Information Sciences*, 107(1-4):149–167 (1998).
3. J. Cacioppo, W. Gardner, and G. Berntson. Beyond bipolar conceptualizations and measures: The case of attitudes and evaluative space. *Personality and Social Psychology Review*, 1(1):3–25 (1997).
4. D. Ciucci. Orthopairs: A simple and widely used way to model uncertainty. *Fundam. Inf*, 108(3-4):287–304 (2011).
5. D. Ciucci. Orthopairs in the 1960s: Historical remarks and new ideas. In *RSCTC 2014, Proceedings. LNCS*, volume 8536, pages 1–12 (2014).
6. Z. Csajbók and T. Mihálydeák. A general set theoretic approximation framework. In: Greco, S., et al. (eds.) *Proceedings of IPMU 2012, Part I. CCIS*, volume 297, pages 604–612. Springer (2012).
7. D. Dubois and H. Prade. Bipolar representations in reasoning, knowledge extraction and decision processes. In: Greco, S., et al. (eds.) *Proceedings of RSCTC 2006. LNCS*, volume 4259, pages 15–26. Springer (2006).
8. D. Dubois and H. Prade. An introduction to bipolar representations of information and preference. *International Journal of Intelligent Systems*, 23(8):866–877 (2008).
9. I. Düntsch and G. Gediga. Approximation operators in qualitative data analysis. In H. Swart, E. Orlowska, G. Schmidt, and M. Roubens, editors, *Theory and Applications of Relational Structures as Knowledge Instruments. LNCS*, volume 2929, pages 214–230. Springer (2003).

10. Z. Pawlak. Information systems theoretical foundations. *Information Systems*, 6(3):205–218 (1981).
11. Z. Pawlak. Rough sets. *International Journal of Computer and Information Sciences*, 11(5):341–356 (1982).
12. Z. Pawlak. *Rough Sets: Theoretical Aspects of Reasoning about Data*. Kluwer Academic Publishers, Dordrecht (1991).
13. Z. Pawlak and A. Skowron. Rudiments of rough sets. *Information Sciences*, 177(1):3–27 (2007).
14. L. Polkowski and A. Skowron. Rough mereological calculi of granules: A rough set approach to computation. *Computational Intelligence*, 17(3):472–492 (2001), `https://onlinelibrary.wiley.com/doi/abs/10.1111/0824-7935.00159`.
15. Y. Wang, J. Yang, and Xu. D.l.: A preference aggregation method through the estimation of utility intervals. *Comput. Oper. Res*, 32(8), 2027–2049 (Aug 2005).
16. Xu. Z.: Uncertain multi-attribute decision making. *Methods and Applications*. Springer (2015).
17. Z. Xu and J. Chen. Some models for deriving the priority weights from interval fuzzy preference relations. *European Journal of Operational Research*, 184(1):266–280 (2008).
18. Z. Xu and L. Da, Q. The uncertain owa operator 17, 569–575 (06 2002).
19. L. Zadeh. Fuzzy logic = computing with words. *IEEE Transactions on Fuzzy Systems*, 4(2):103–111 (1996).
20. L. A. Zadeh. Outline of a new approach to the analysis of complex systems and decision processes. *IEEE Transactions on Systems, Man, and Cybernetics SMC*, 3(1):28–44 (1973).

***Keynote speech*:**

Applications of metaheuristic algorithms to fuzzy control and model building, learning-based control, and mobile robot navigation



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Abstract: An optimization problem finds the best (i.e., optimal) solution among all feasible solutions. An optimization problem consists of two key components: the objective function and the constraints, which are optional. The objective function evaluates and compares solutions in the context of all feasible solutions by computing the desired quantity to be minimized or maximized. Constraints can be added to limit the possible values for the variables of the objective function and possibly to link these variables. The optimization algorithms find the solutions to the optimization problems (i.e., the optimal solutions) by trying variations of the initial solution and using the information gained to improve the solution. This solution finding can also be considered as learning, which is a popular topic nowadays. The complexity of classical algorithms is very high, which requires rather large amount of computation. Therefore, alternative algorithms with lower complexity are appreciated. Metaheuristic algorithms for finding optimal solutions have become very popular because they are much better in terms of efficiency and complexity than classical algorithms. This presentation highlights some of the results obtained by the Process Control Group of the Politehnica University of Timisoara, Romania. The presentation will focus on representative applications implemented in our labs, with real-time validation against experimental results. The results highlighted here include various laboratory equipment such as pendulum crane systems, multi-tank systems, servo systems, twin rotor aerodynamic systems, magnetic levitation systems, anti-lock braking systems, mobile robots, magnetic levitation systems, active mass damper systems, and shape memory alloy systems. The scope of development of these metaheuristic algorithms is to solve optimization problems involving tuning of low-cost fuzzy controllers, tuning of fuzzy models, reinforcement-based control in various schemes including adaptive ones, and solving optimization problems specific to mobile robot navigation.

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On aggregation operators and utility functions with truncation property

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Abstract: Aggregation operators form a vast class of mathematical tools that are highly applicable in modelling decision-making processes. Of special interest are aggregation operators with an annihilator, i.e., with an absorbing element, since they can be applicable in modelling situations involving participants with the power of veto. This paper presents an overview of results that consider the conditional distributivity of such operators, namely T-uninorms and nullnorms, over t-conorms and an analysis of the role of obtained distributive pairs in constructions of utility functions with a truncation property.

Keywords: Aggregation operators · annihilator · T-uninorms · nullnorms · conditional distributivity · utility function

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References

1. Aczel, J.: Lectures on functional Equations and their Applications. Academic Press (1966)
2. Dubois, D., Pap, E., Prade, H.: Hybrid probabilictic-possibilistic mixtures and utility functions. Preferences and Decisions under Incomplete Knowledge, Studies i Fuzziness and Soft Computing, vol. 51, Springer-Verlag 51–73 (2000)
3. Grabisch, M., Marichal, J., Mesiar, R., Pap, E.: Aggregation Functions. Cambridge Uviversity Press (2009)
4. Jočić, D., Štajner-Papuga, I.: Restricted distributivity for aggregation operators with absorbing element. Fuzzy Sets and Systems **224**, 23–35 (2013)
5. Jočić, D., Štajner-Papuga, I.: Some implications of the restricted distributivity of aggregation operators with absorbing elements for utility theory. Fuzzy Sets and Systems **291**, 54–65 (2016)
6. Jočić, D., Štajner-Papuga, I.: Distributivity and conditional distributivity for T-uninorms. Information Sciences **424**, 91–103 (2018)
7. Klement, E. P., Mesiar, R., Pap, E.: Triangular Norms. Kluwer Academic Publishers, Dordrecht (2000)
8. Mas, M., Mesiar, R., Monserat, M., Torrens, J.: Aggregation operations with annihilator. International Journal of General Systems **34**, 1–22 (2005)

Categories of L-fuzzy morphological operators on L-fuzzy groups and LR-fuzzy homomorphisms

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Abstract: Given a completely distributive lattice L, we introduce two categories whose objects are L-powersets L^X of additive groups $(X, +, 0)$ and the morphisms are respectively forward and backward operators $R^{\rightarrow} : L^X \to L^Y$ and $R^{\leftarrow} : L^Y \to L^X$ induced by L-relations $R : X \times Y \to L$ which preserve the algebraic structure of the underlying groups $(X, +_X, 0_X)$ and $(Y, +_Y, 0_Y)$. The objects of these categories serve as the field of action for operators of fuzzy erosion and dilation. We study some properties of these operators, in particular their behaviour under operators $R^{\rightarrow}$ and $R^{\leftarrow}$.

Keywords: Completely distributive lattices · L-relations · Categories of L-fuzzy groups · morphological operators on L-fuzzy groups

References

1. Birkhoff, G.: Lattice Theory, 3rd ed. AMS Providence, RI, 1995.
2. Bloch, I.: Duality vs. adjunction for fuzzy mathematical morphology, Fuzzy Sets Syst. 160, 1858–1867 (2009)
3. Bloch, I., Heijmans, H., Ronse, C.: Mathematical morphology, Chapter 14 in: M. Aiello, I. Pratt-Hartmann, J. Van Benthem (Eds.), Handbook of Spatial Logics, Springer, pp. 857–944 (2007)
4. Boucheli, A., Pastore, J.L., Billarin, V.L.: Segmentation of medical images using fuzzy mathematical morphology, J. Computer Sciences and Technology 7, 256–262 (2007)
5. Caponetti, L., Castelano, G., Bastillo, M.T., Corsini, V. Fuzzy mathematical morphology for biological images segmentation. Applied Intelligence 41, 117–127 (2014)
6. Davey, B.A., Priestley, H.A.: Introduction to Lattices and Order, Cambridge Univ. Press., pp.298 (2002)
7. De Baets, B., Kerre, E.E., Gupta, M.: The fundamentals of fuzzy mathematical morphology Part I: basic concepts, Int. J. Gen. Syst. 23, 155–171 (1995). Part II: idempotence, convexity and cecomposition, Int. J. Gen. Syst. 23, 307–322 (1995)
8. Gierz, G., Hofmann, K.H., Keimel, K., Lawson, J.D., Mislove, M.W., Scott, D.S.: Continuous Lattices and Domains, Cambridge University Press, Cambridge, (2003)
9. Han, S.-E., Šostak, A.: On the measure of M-rough approximation of L-fuzzy sets, Soft Comput. 22, 3843–3853 (2018)
10. Heijmans, H.J.A.M., Ronse, C., The algebraic basis of mathematical morphology I. Dilations and erosions, Computer Vision, Graphics and Image Processing, 50 (3), 245–295 (1990)

11. Klawon, F.: Fuzzy points, fuzzy relations and fuzzy functions, in: V. Novak, I. Perfilieva (Eds.), Discovering the world with fuzzy logic (Studies in Mathematics and Soft Computing), Cambridge University Press, (2000)
12. Madrid, N., Ojeda-Aciego, M., Medina, J., Perfilieva, I.: L-fuzzy relational mathematical morphology based on adjoint triples, Inf. Sci., 474, 75–89 (2019)
13. Matheron, G.: Random sets and Integral Geometry, Willy, (1975)
14. Morgan, W., Dilworth, R.P.: Residuated lattices, Trans. Amer. Math. Soc. 45, 335—354 (1939)
15. Nachtegael, M., Kerre, E.E.: Classic and fuzzy approaches to mathematical morphology, Chapter 1 in: Kerre E.E. et al. (Eds.), Fuzzy Technique in Image Processing, Springer Verlag Berlin, Heilderberg, (2000)
16. Nakatsuyama, M.: Fuzzy mathematical morphology for image procesing, In ANZIS-93, Perth, Western Australia, pp.75-79 (1993)
17. Perfilieva, I., Šostak, A.: From Lattice Valued Theories to Lattice-valued analysis, Chapter 9 in: R. Seising et al. (Eds.), Towards the future of Fuzzy Logic, Studies in Fuzziness and Soft Computing 325, Springer Intern. Publ., pp.167-182 (2015)
18. Rodabaugh, S.E.: Powerset operator based foundations for poslat fuzzy set theories and topologies, Quaest. Math. 20, 463–530 (1997)
19. Serra, J.: Image analysis and mathematical morphology, Academic Press, London, New York, Paris, San Diego, San Paolo, Sydney, Tokyo, Toronto, (1982)
20. Soille, P.: Morphological Image Analysis: Principles and Applications (2nd edition), Springer Verlag (2003)
21. Šostak, A., Uljane, I.: Manithestation of fuzzy topology in other fuzzy mathematical structures, TWMS Journal of Pure and Appl. Mathematics, Special Issue on Fuzzy Sets in Dealing with Imprecision and Uncertainty: Past and Future. Dedicated to the Memory of Lotfi A. Zadeh, 12, 142–172 (2021)
22. Šostak, A., Uljane, I.: On two categories of many-valued morphological spaces, Studies in Computational Intelligence 955, 207-217 (2018)
23. Šostak, A., Uljane, I., Powerset operators induced by fuzzy relations as a basis for fuzzification of various mathematical structures, International Journal of Approximate Reasoning, 155, 17-39 (2023)
24. Šostak, A., Uljane, I., Eklund, P.: Fuzzy relational mathematical morphology, Communications in Computer and Information Science 1239 CCIS 712–725 (2020)
25. Zadeh, L.A.: Similarity relations and fuzzy orderings, Inf. Sci. 3, 177–200 (1971)

Message Passing Graph Neural Network for Seeds Classification

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Abstract: Within the field of High Energy Physics various machine learning techniques are being constantly researched. Due to upcoming HL-LHC (High Luminosity Large Hadron Collider) upgrade, which aims to increase probability of occurrence of rare physical phenomenas by significant increase of number of collisions occuring each second, currently used algorithms in the area of charged particle reconstructions are not going to scale well enough. The data from tracking detectors if the LHC experiments can be represented in the form of a graph, where detected signals are represented as nodes and hypothetical connections between them are represented by edges. In particular the initial stage of track finding, the formation of seeds can be represented in that way. Within this paper we propose solution based on Graph Neural Network used to dramatically decrease number of seeds and therefore significantly reduce amount of calcuations needed by downstream algorithms in order to reconstruct tracks. The numerical experiments were carried out with use a data set obtained from Monte Carlo simulation of the Open Data Detector. The initial results showed, that proposed solution based on Graph Neural Network has application potential.

Keywords: Graph Neural Networks · Clasification task· Reconstruction · Tracking · Large Hadron Collider · ATLAS · High Energy Physics

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References

1. Evans, L., Bryatn, P.: LHC Machine. JINST **3**(S08001) (2008)
2. ATLAS Collaboration: The ATLAS Experiment at the CERN Large Hadron Collider. JINST **3**(S08003) (2008)
3. CMS Collaboration: The CMS Experiment at the CERN LHC. EPJC **3**(S08004) (2008)
4. ATLAS Collaboration: Performance of the ATLAS track reconstruction algorithms in dense environments in LHC Run 2. JINST **77**(673) (2017)
5. Frühwirth, R.: Application of Kalman filtering to track and vertex fitting. Nucl. Instrum. Methods A **262**(444) (1987)

6. Zlokapa, A., Abhishek, A., Vlimant, JR., Duarte, J.M., Job J., Lidar D., Spiropulu M.: Charged particle tracking with quantum annealing optimization. Quantum Mach. Intell. **3**(27) (2021)
7. DeZoort, G., Thais, S., Duarte, J. et al. Charged Particle Tracking via Edge-Classifying Interaction Networks. Comput Softw Big Sci. **5**(26) (2021)
8. Cerati, G. et al: Parallelized Kalman-Filter-Based Reconstruction of Particle Tracks on Many-Core Architectures. J. Phys. Conf. Ser. **1085**(042016) (2018)
9. Z. Wu, S. Pan, F. Chen, G. Long, C. Zhang and P. S. Yu: A Comprehensive Survey on Graph Neural Networks. IEEE Transactions on Neural Networks and Learning Systems **32**(1) (2021)
10. W. Cao, Z. Yan, Z. He and Z. He: A Comprehensive Survey on Geometric Deep Learning. IEEE Access **8**(35929-35949) (2020)
11. Xu K., Hu W., Leskovec J., Jegelka S.: How Powerful are Graph Neural Networks? ICLR (2019) arXiv 1810.00826 (2019)
12. Hamilton W., Ying Z., Leskovec J.: Inductive representation learning on large graphs. Advances in neural information processing systems. **30** (2017)
13. Zhang X.M., Liang L., Liu L., Tang M.J.: Graph Neural Networks and Their Current Applications in Bioinformatics. Sec. Computational Genomics. **12** (2021)
14. Allaire C., Gessinger P., Hdrinka J., Kiehn M., Kimpel F., Niermann J., Salzburger A., Sevova S.: OpenDataDetector. (2022)
15. Sjöstrand T., Ask S., Christiansen J.R., Corke R., Desai N., Ilten P., Mrenna S., Prestel S., Rasmussen C.O., Skands P.Z.: An introduction to PYTHIA 8.2. Computer Physics Communications **191**(159-177) (2015)
16. Mechnich J.: FATRAS - the ATLAS Fast Track Simulation project. Journal of Physics: Conference Series **331**(3) (2011)
17. Ai, X., Allaire, C., Calace, N. et al.: A Common Tracking Software Project. Comput Softw Big Sci **6**(8) (2022)
18. Hamilton W.L., Ying R., Leskovec J.: Inductive Representation Learning on Large Graphs. arXiv 1706.02216 (2018)

Fuzzy Rule Systems design to model the decision method of a passenger profile

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Abstract: The method by which a passenger purchases a train ticket is crucial for railway companies to provide appropriate offers, both to the passenger and to the infrastructure operator. In this paper we study how Fuzzy Rule Systems can be used to model the decision-making process of a train passenger when purchasing a ticket. In addition, two examples are presented that have allowed us to extract the first ideas for the design of an automatic method for the generation of fuzzy rule systems to support in the decision-making process of train passengers.

Keywords: Decision model · Fuzzy Rules Systems · Fuzzy Sets

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References

1. EC. 1991. Council Directive 91/440/EEC of 29 July 1991 on the Development of the Community'srailways, European Commission.
2. ADIF AV. Adif y Adif AV aprueban el Horario de Servicio 2021-2022, que arrancará el próximo 12 de diciembre. ADIF AV Press Releases. 1st October (2021) `https://www.adifaltavelocidad.es/w/adif-y-adif-av-aprueban-el-horario-de-servicio-2021-2022-que-arrancar%C3%A1-el-pr%C3%B3ximo-12-de-diciembre` (Last visited 10 Jan. 2024)
3. Ait Ali, A.: Methods for Capacity Allocation in Deregulated Railway Markets Doctoral thesis,comprehensive summary, Linköping University Electronic Press (2020)
4. Castillo-Herrera E., García-Ródenas R., Jimenez-Linares L., López-García M.L, López-Gómez J.A., Martín-Baos J.A. , Moreno-Garcia J., Munoz-Valero D., Rodriguez-Benitez L., Villarrubia-Martin E.A. ROBIN: Rail mOBIlity simulatioN, Transportation Research Procedia, 2023.
5. Zadeh L.A.. Fuzzy sets, Information and Control, volume 8, Issue 3. 1965. Pages 338-353.

6. Zadeh L.A.. The concept of a linguistic variable and its application to approximate reasoning—I, Information Sciences, volume 8, Issue 3, 1975, 199-249.
7. Takagi T., Sugeno M.. Fuzzy identification of systems and its applications to modeling and control,IEEE Transactions on Systems, Man, and Cybernetics, vol. SMC-15, no. 1, pp. 116-132, Jan.-Feb. 1985.
8. Chen T., Shang C., Su P., Shen Q., Induction of accurate and interpretable fuzzy rules from preliminary crisp representation, Knowledge-Based Systems, volume 146, pp.152-166, 2018.
9. Salimi-Badr A., Mehdi Ebadzadeh M., A novel learning algorithm based on computing the rules'desired outputs of a TSK fuzzy neural network with non-separable fuzzy rules, Neurocomputing, volume 470, pp.139-153, 2022.

An interval-valued fuzzy soft sets based decision support model for route optimization

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Abstract: Route optimization is an extensively studied NP-hard graph search problem. Many researchers applied numerous techniques to find the optimum or semi optimum solution (the one with least cost). There are many practical extensions and modifications of this problem applied using deterministic methods. However, traveling between nodes (locations) might encounter additional fuzzy cost (time) on the overall trip, whether they are traveled during the rush hour periods or if they crossed traffic regions (the city centers). Since, those factors are non-deterministic; it would be closer to reality to represent them using fuzzy numbers. In this paper, we propose a novel route optimization under road uncertainties using Interval-Valued Fuzzy Soft Sets. We use scoring technique to help determining the optimum route amongst all alternatives. Our novel approach can be looked at as a practical and closer to reality estimation for non-deterministic factors of the original abstract route optimization problem.

Keywords: routing optimization problem · interval-valued fuzzy soft sets · vehicle routing problem.

References

1. R. Ballou. *Business Logistics/Supply Chain Management: Planning, Organizing and Controlling the Supply chain.* Prentice Hall Inc, New Jersey.
2. D. Chen, E. Tsang, D. Yeung, and X. Wang. The parameterization reduction of soft sets and its applications. *Computers and Mathematics with Applications*, 49:757 – 763.
3. P. Maji, R. Biswas, and A. Roy. Fuzzy soft sets. *Journal of Fuzzy Mathematics*, 9:589 – 602.
4. P. Maji, R. Biswas, and A. Roy. Soft set theory. *Computers and Mathematics with Applications*, 45:555 – 562.
5. P. Maji, A. Roy, and R. Biswas. An application of soft sets in a decision making prob-lem. *Computers and Mathematics with Applications*, 44:1077 – 1083.
6. D. Molodtsov. Soft set theory - first results. *Computers and Mathematics with Applications*, 37:19 – 31.
7. X. Yang, T. Lin, J. Yang, Y. Li, and D. Yu. Combination of interval-valued fuzzy set and soft set. *Computers & Mathematics with Applications*, 58(3):521–527.
8. X. Yang, D. Yu, J. Yang, and C. Wu. Generalization of soft set theory: From crisp to fuzzy case. In B. Cao, editor, *Proceeding of the second international conference on fuzzy information and engineering, May, 23-16*, volume 40, pages 345–354, Guangzhou. Springer-Verlag.
9. L. Zadeh. Fuzzy sets. *Information and Control*, 8(3):338–353.

Railway Capacity Allocation in Liberalized Markets: First Approach for an Artificial Intelligence-Based Computational Model

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Abstract: In response to the European Union's push towards liberalized railway markets, this study examines the complexities of capacity allocation among various Railway Undertakings. The evolution of market structures is explored, from monopolistic to shared market structures, emphasizing Spain's railway market transition. Optimizing infrastructure utilization and resolving the challenges of slot distribution in a liberalized market are the main focus of the research. Building on previous works, limitations in existing capacity allocation models has been detected, and advanced solutions based on Artificial Intelligence are proposed. By integrating neural networks and metaheuristic algorithms, more complex and large-scale railway systems could be managed more effectively. This methodology explores alternative capacity allocation mechanisms for efficient train scheduling. The future scope of this research includes further development and comparative analysis to enhance railway network efficiency and sustainability.

Keywords: Capacity Allocation · Train Timetabling Problem · Liberalization · Metaheuristics · Artificial Neural Networks

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References

1. Ait Ali, A., Eliasson, J.: European railway deregulation: an overview of market organization and capacity allocation. Transportmetrica A: Transport Science, 18(3), 594-618 (2022) https://doi.org/10.1080/ 23249935.2021.1885521
2. EC. 1991. Council Directive 91/440/EEC of 29 July 1991 on the Development of the Community'srailways, European Commission.

3. ADIF AV. Adif y Adif AV aprueban el Horario de Servicio 2021-2022, que arrancará el próximo 12 de diciembre. ADIF AV Press Releases. 1st October (2021) https://www.adifaltavelocidad.es/w/adif-y-adif-av-aprueban-el-horario-de-servicio-2021-2022-que-arrancar%C3%A1-el-pr%C3%B3ximo-12-de-diciembre (Last visited 10 Jan. 2024)
4. Ait Ali, A.: Methods for Capacity Allocation in Deregulated Railway Markets Doctoral thesis,comprehensive summary, Linköping University Electronic Press (2020)
5. EC. 2001. Directive 2001/14/EC on the Allocation Of Railway Infrastructure Capacity and the Levyingof Charges for the Use of Railway Infrastructure And Safety Certification, EU Parliament.
6. EC. 2012. Directive 2012/34/EU on Establishing a Single European railway area, EU Parliament.
7. EC. 2016a. Commission Implementing Regulation (EU) 2016/545 of 7 April 2016 on Procedures andCriteria Concerning Framework Agreements for the Allocation of Rail Infrastructure Capacity,European Commission.
8. EC. 2016b. Fourth Railway Package of 2016, European Commission.
9. Peña-Alcaraz, M.: Analysis of capacity pricing and allocation mechanisms in shared railway systems. PhD, MIT - Massachusetts Institute of Technology.
10. International Union of Railways. UIC Code 406 - Capacity. Paris (2004)
11. Castillo-Herrera E., García-Ródenas R., Jimenez-Linares L., López-García M.L, López-Gómez J.A., Martín-Baos J.A., Moreno-Garcia J., Muñoz-Valero D., Rodriguez-Benitez L., Villarrubia-Martin E.A. Robin: Rail mobility simulation. Sent to: Transportation Research Procedia. September 2023.
12. Aarts, E., Korst, J., Michiels, W.: Simulated annealing. In: Search Methodologies, pp. 187–210. Springer, Heidelberg (2005)

***Keynote speech*:**

Logic Programming and Legal Reasoning: the Past and the Future

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Abstract: Logic Programming is an extremely powerful tool for legal reasoning due to its declarative, rule-based nature, suitable for modelling in a natural and understandable way legal rules and constraints. In this talk, I will discuss the advantages and disadvantages of exploiting Logic Programming in the legal domain, and I will provide examples of use in different Logic Programming languages.

Semi-automatic knowledge representation and reasoning on vague crime concepts

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Abstract: In this paper we address the formal representation of vagueness in the legal domain, focusing on a "use case" in the Italian criminal law, namely the distinction of two crimes, "snatching" and "robbery". After a few epistemological clarifications on the concept of vagueness and a short premise on the legal background, we tackle the problem by adopting Answer Set Programming as modelling language. First, we encode the "static" law parts and then we enhance the encoding by learning from sentences. This is a first step for a legal reasoning system capable of evolving by doing a fully automatic learning from sentences.

Keywords: Legal Reasoning · Automated Reasoning · ASP · Criminal Law · Vagueness.

Acknowledgement: Research partially supported by Action COST CA17124 *DigForASP*, by Inter-departmental projects on Artificial Intelligence and on Cross Border Digital Forensics (*Strategic Plan UniUD–22-25*), and by INdAM-GNCS project CUP E53C22001930001. Although the contribution is the result of a joint discussion among coauthors, Sections can be attributed as follows: 2 and 3 Manuele Dozzi, Federico Costantini and Luca Baron, 4 and 5 Talissa Dreossi, Agostino Dovier and Andrea Formisano.

References

1. Baral, C.: Knowledge Representation, Reasoning and Declarative Problem Solving. Cambridge University Press (2010)
2. Beccaria, C.: Dei delitti e delle pene. Andrea Bonducci, Firenze (1764)
3. Boolos, G.: Zooming down the slippery slope. Noûs **25**(5), 695–706 (1991)
4. Dovier, A., Formisano, A., Pontelli, E.: Parallel answer set programming. In: Hamadi, Y., Sais, L. (eds.) Handbook of Parallel Constraint Reasoning, pp. 237–282. Springer (2018), DOI:10.1007/978-3-319-63516-3_7
5. Dovier, A., Formisano, A., Pontelli, E., Vella, F.: A GPU implementation of the ASP computation. In: Gavanelli, M., Reppy, J.H. (eds.) Proc. of PADL 2016. LNCS, vol. 9585, pp. 30–47. Springer (2016), DOI:10.1007/978-3-319-28228-2_3
6. Dovier, A., Formisano, A., Vella, F.: GPU-based parallelism for ASP-solving. In: Hofstedt, P., Abreu, S., John, U., Kuchen, H., Seipel, D. (eds.) Declarative Programming and Knowledge Management - DECLARE 2019, Revised Selected Papers. LNCS, vol. 12057, pp. 3–23. Springer (2019), DOI:10.1007/978-3-030-46714-2_1

7. Dreossi, T.: Exploring ILASP through logic puzzles modelling. In: Dovier, A., Formisano, A. (eds.) Proc. of CILC-23. CEUR Workshop Proceedings, vol. 3428. CEUR-WS.org (2023)
8. Dummett, M.: Is time a continuum of instants. Philosophy **75**(4), 497–515 (2000)
9. Endicott, T.A.O.: Vagueness in Law. Oxford University Press, New York (2000)
10. Erdem, E., Gelfond, M., Leone, N.: Applications of answer set programming. AI Mag. **37**(3), 53–68 (2016)
11. Evans, G.: Can there be vague objects? Analysis **38**(4), 208–208 (1978)
12. Feuerbach, P.J.A.: Lehrbuch des gemeinen in Deutschland geltenden peinlichen Rechts. Heyer, Giessen (1801)
13. Fiandaca, G., Musco, E., Cupelli, C., Masullo, M.N. (eds.): Diritto penale. Parte speciale. 2.2, I delitti contro il patrimonio. Zanichelli, Bologna, 8 edn. (2023), oCLC: 1381804647
14. Gelfond, M., Lifschitz, V.: The stable model semantics for logic programming. In: Kowalski, R.A., Bowen, K.A. (eds.) Proc. of ICLP/SLP. pp. 1070–1080. MIT Press (1988)
15. Hyde, D.: Vagueness, Logic and Ontology. Routledge (2008)
16. Law, M.: Inductive learning of answer set programs. Ph.D. thesis, Imperial College London (2018)
17. Ludovica, D.: Manuale di diritto penale: parte speciale II. Giuffrè Francis Lefebvre (2022)
18. Parsons, T.: Indeterminate Identity: Metaphysics and Semantics. Clarendon Press (2000)
19. Raffman, D.: Unruly Words: A Study of Vague Language. Oxford University Press, Oxford, England (2013)
20. Sorensen, R.: The sorites and the generic overgeneralization effect. Analysis **72**(3), 444–449 (2012)
21. van Inwagen, P.: How to reason about vague objects. Philosophical Topics **16**(1), 255–284 (1988)
22. Waldron, J.: Vagueness in law and language: Some philosophical issues. California Law Review **82**(1), 509 (1994)
23. Williamson, T.: Vagueness. Routledge, New York (1994)

Empowering Emotional Behavior Trees with Neural Computation for Digital Forensic

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Abstract: Empowering interactive agents with empathetic capabilities leads, on the human side, to more trust and increased engagement. This article focuses on modeling the empathetic behavior of virtual agents interacting with humans employing behavior trees which we further enhance with neuro-symbolic capabilities. This allows the specification of various kinds of empathy for the agents to be deployed for user support in critical fields such as digital forensics. This paper is a follow-up to our work in the COST Action DigForASP.

Keywords: Affective Computing · Human-Agent teaming · Neuro-Symbolic · Behavior Trees · Digital Forensic

References

1. Bagheri, E., Esteban, P.G., Cao, H., Beir, A.D., Lefeber, D., Vanderborght, B.: An autonomous cognitive empathy model responsive to users' facial emotion expressions. ACM Trans. Interact. Intell. Syst. **10**(3), 20:1–20:23 (2020). https://doi.org/10.1145/3341198
2. Barange, M., Rasendrasoa, S., Bouabdelli, M., Saunier, J., Pauchet, A.: Impact of adaptive multimodal empathic behavior on the user interaction. In: Proceedings of the 22nd ACM International Conference on Intelligent Virtual Agents. IVA '22, Association for Computing Machinery, New York, NY, USA (2022). https://doi.org/10.1145/3514197.3549675
3. van Bekkum, M., de Boer, M., van Harmelen, F., Meyer-Vitali, A., ten Teije, A.: Modular design patterns for hybrid learning and reasoning systems. Appl. Intell. **51**(9), 6528–6546 (2021). https://doi.org/10.1007/s10489-021-02394-3
4. Brave, S., Nass, C., Hutchinson, K.: Computers that care: Investigating the effects of orientation of emotion exhibited by an embodied computer agent. International Journal of Human-Computer Studies **62**, 161–178 (Feb 2005). https://doi.org/10.1016/j.ijhcs.2004.11.002
5. Charrier, L., Rieger, A., Galdeano, A., Cordier, A., Lefort, M., Hassas, S.: The rope scale: a measure of how empathic a robot is perceived. In: 14th ACM/IEEE

International Conference on Human-Robot Interaction, HRI 2019, Daegu, South Korea, March 11-14, 2019. pp. 656–657. IEEE (2019). https://doi.org/10.1109/HRI.2019.8673082
6. Colledanchise, M., Ögren, P.: Behavior trees in robotics and AI: An introduction. CRC Press (2018)
7. Costantini, S., De Gasperis, G., Olivieri, R.: Digital forensics and investigations meet artificial intelligence. Ann. Math. Artif. Intell. **86**(1-3), 193–229 (2019). https://doi.org/10.1007/S10472-019-09632-Y
8. Cuff, B.M., Brown, S.J., Taylor, L., Howat, D.J.: Empathy: A review of the concept. Emotion Review **8**(2), 144–153 (2016). https://doi.org/10.1177/1754073914558466
9. Dell'Acqua, P., Costantini, S.: Empathetic human-agent interaction via emotional behavior trees. Intelligenza Artificiale **17**(1), 89–100 (2023).https://doi.org/10.3233/IA-230014
10. Dell'Acqua, P., Costantini, S., Dyoub, A., De Gasperis, G., Monaldini, A., Rafanelli, A.: Empathy-aware behavior trees for social care decision systems. In: Lessons Learned from a Multi-National Project on Developing a Platform for the Silver Economy. In Procceding of Projman 2023 - International Conference on Project MANagement, CENTERIS/ProjMAN/HCist 2023. Procedia in Computer Sience, Elsevier (2023)
11. d'Avila Garcez, A.S., Lamb, L.C.: Neurosymbolic AI: the 3rd wave. CoRR **abs/2012.05876** (2020), https://arxiv.org/abs/2012.05876
12. Iovino, M., Scukins, E., Styrud, J., Ögren, P., Smith, C.: A survey of behavior trees in robotics and AI. Robotics and Autonomous Systems **154** (2022), https://doi.org/10.1016/j.robot.2022.104096
13. Johansson, A., Dell'Acqua, P.: Emotional behavior trees. In: 2012 IEEE Conference on Computational Intelligence and Games (CIG). pp. 355–362 (2012). https://doi.org/10.1109/CIG.2012.6374177
14. Kautz, H.A.: The third AI summer: AAAI robert s. engelmore memorial lecture. AI Mag. **43**(1), 93–104 (2022). https://doi.org/10.1609/aimag.v43i1.19122
15. Knafla, B., Champandard, A.J.: Behavior trees: introduction and memory-compact implementation. In: Algorithmic and Architectural Gaming Design: Implementation and Development, pp. 40–66. IGI Global (2012)
16. Leite, I., Castellano, G., Pereira, A., Martinho, C., Paiva, A.: Empathic robots for long-term interaction. International Journal of Social Robotics **6**, 329–341 (July 2014). https://doi.org/10.1007/s12369-014-0227-1
17. Leite, I., Pereira, A., Castellano, G., Mascarenhas, S., Martinho, C., Paiva, A.: Modelling empathy in social robotic companions. In: Ardissono, L., Kuflik, T. (eds.) Advances in User Modeling - UMAP 2011 Workshops, Girona, Spain, July 11-15, 2011, Revised Selected Papers. Lecture Notes in Computer Science, vol. 7138, pp. 135–147. Springer (2011). https://doi.org/10.1007/978-3-642-28509-7_14
18. McQuiggan, S.W., Lester, J.C.: Learning empathy: a data-driven framework for modeling empathetic companion agents. In: Nakashima, H., Wellman, M.P., Weiss, G., Stone, P. (eds.) 5th International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2006), Hakodate, Japan, May 8-12, 2006. pp. 961–968. ACM (2006). https://doi.org/10.1145/1160633.1160806
19. Montiel-Vázquez, E.C., Ramírez Uresti, J.A., Loyola-González, O.: An explainable artificial intelligence approach for detecting empathy in textual communication. Applied Sciences **12**(19) (2022). https://www.mdpi.com/2076-3417/12/19/9407
20. Paiva, A.: Empathy in social agents. International Journal of Virtual Reality **10** (11 2015). https://doi.org/10.20870/IJVR.2011.10.1.2794

21. Park, S., Whang, M.: Empathy in human-robot interaction: Designing for social robots. International Journal of Environmental Research and Public Health **19**, 1889 (Feb 2022). https://doi.org/10.3390/ijerph19031889
22. Plutchik, R.: Emotions and life: Perspectives from psychology, biology, and evolution. American Psychological Association (2003)
23. Stock-Homburg, R.: Survey of emotions in human–robot interactions: Perspectives from robotic psychology on 20 years of research. International Journal of Social Robotics **14**(2), 389–411 (2022)
24. Takahashi, Y., Kawamata, T., Asada, M., Negrello, M.: Emulation and behavior understanding through shared values. In: 2007 IEEE/RSJ International Conference on Intelligent Robots and Systems, October 29 - November 2, 2007, Sheraton Hotel and Marina, San Diego, California, USA. pp. 3950–3955. IEEE (2007). https://doi.org/10.1109/IROS.2007.4399385
25. Tavabi, L., Stefanov, K., Gilani, S.N., Traum, D.R., Soleymani, M.: Multimodal learning for identifying opportunities for empathetic responses. In: Gao, W., Meng, H.M., Turk, M.A., Fussell, S.R., Schuller, B.W., Song, Y., Yu, K. (eds.) International Conference on Multimodal Interaction, ICMI 2019, Suzhou, China, October 14-18, 2019. pp. 95–104. ACM (2019). https://doi.org/10.1145/3340555.3353750
26. Wang, Y., Song, W., Tao, W., Liotta, A., Yang, D., Li, X., Gao, S., Sun, Y., Ge, W., Zhang, W., Zhang, W.: A systematic review on affective computing: emotion models, databases, and recent advances. Inf. Fusion **83-84**, 19–52 (2022). https://doi.org/10.1016/j.inffus.2022.03.009
27. Yalçın, Ö.N.: Evaluating empathy in artificial agents. In: 8th International Conference on Affective Computing and Intelligent Interaction (ACII). pp. 1–7. IEEE (2019)

Legal and technical challenges of AI in the field of Criminal investigations

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Abstract: This article addresses critical challenges in the intersection of artificial intelligence, crime investigation and digital forensics, particularly in light of the proposed Regulation on Artificial Intelligence in the European Union. The focus is on mitigating biases caused by databases and algorithms, with real-world examples highlighting discriminatory biases in criminal proceedings. The article emphasises the necessity of addressing biases in both data and algorithmic decision-making to ensure fair outcomes. Another key concern explored is the lack of traceability in AI-based decisions, posing challenges to accountability and transparency, especially in the context of criminal investigations. Additionally, the article delves into the protection of private and family data in the vast datasets analysed by AI systems, referencing a legal case that underscores the potential violation of the right to a fair trial. To address this, the article proposes the development of anonymisation systems to safeguard individuals' privacy rights. The overarching theme is the need for ethical considerations and legal frameworks to guide the responsible development and deployment of AI tools in digital forensics.

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References

1. K. Alikhademi, E. Drobina, D. Prioleau, B. Richardson, D. Purves, and J. Gilbert. A review of predictive policing from the perspective of fairness. *Artificial Intelligence and Law*, 30:1–17, 03 2022.
2. J. Angwin, J. Larson, M. S., and K. L. Machine bias: There's software used across the country to predict future criminals. and it's biased against blacks. *ProPublica*, 2016.
3. F. J. Bariffi. Artificial intelligence, human rights and disability. *Pensar-Revista de Ciências Jurídicas*, 26(2), 2021.

4. S. Barocas and A. D. Selbst. Big data's disparate impact. *California Law Review*, 104(3):671–732, 2016.
5. T. Brennan and W. Dieterich. *Correctional Offender Management Profiles for Alternative Sanctions (COMPAS)*, pages 49–75. 11 2017.
6. J. Buolamwini and T. Gebru. Gender shades: Intersectional accuracy disparities in commercial gender classification. In S. A. Friedler and C. Wilson, editors, *Proceedings of the 1st Conference on Fairness, Accountability and Transparency*, volume 81 of *Proceedings of Machine Learning Research*, pages 77–91. PMLR, 23–24 Feb 2018.
7. A. Chapman, P. Grylls, P. Ugwudike, D. Gammack, and J. Ayling. A data-driven analysis of the interplay between criminological theory and predictive policing algorithms. In *Proceedings of the 2022 ACM Conference on Fairness, Accountability, and Transparency*, FAccT '22, page 36–45, New York, NY, USA, 2022. Association for Computing Machinery.
8. European Commission. Proposal for a regulation of the european parliament and of the council laying down harmonised rules on artificial intelligence and amending certain union legislative acts.
9. European Parliament. Resolution on artificial intelligence in criminal law and its use by the police and judicial authorities in criminal matters. 06.10.2021.
10. European Parliament and the Council of European Union. Directive (EU) 2023/1544 of the European Parliament and of the Council of 12 July 2023 laying down harmonised rules on the designation of designated establishments and the appointment of legal representatives for the purpose of gathering electronic evidence in criminal proceedings.
11. European Parliament and the Council of European Union. Regulation (EU) 2016/679 of the European Parliament and of the Council (General Protect Data Regulation).
12. M. M. Kasar, D. Bhattacharyya, and T. Kim. Face recognition using neural network: a review. *International Journal of Security and Its Applications*, 10(3):81–100, 2016.
13. N. Li, T. Li, and S. Venkatasubramanian. t-closeness: Privacy beyond k-anonymity and l-diversity. In *2007 IEEE 23rd International Conference on Data Engineering*, pages 106–115, 2007.
14. S. Liu and L. Vicente. Accuracy and fairness trade-offs in machine learning: A stochastic multi-objective approach, 08 2020.
15. I. Mirzazadeh. Artificial intelligence (ai) and violation of human rights. *Available at SSRN 4310188*, 2022.
16. G. Mohler, M. Short, S. Malinowski, M. Johnson, G. Tita, A. Bertozzi, and P. Brantingham. Randomized controlled field trials of predictive policing. *Journal of the American Statistical Association*, 110:00–00, 10 2015.
17. J. Pearl. *Causality: Models, Reasoning and Inference*. Cambridge University Press, USA, 2nd edition, 2009.
18. Z. Tu, K. Zhao, F. Xu, Y. Li, L. Su, and D. Jin. Protecting trajectory from semantic attack considering k -anonymity, l -diversity, and t -closeness. *IEEE Transactions on Network and Service Management*, 16(1):264–278, 2019.
19. X. Wang, Y. Zhang, and R. Zhu. A brief review on algorithmic fairness. *Management System Engineering*, 1(1):7, 2022.
20. K. Yeung, A. Howes, and G. Pogrebna. Ai governance by human rights–centered design, deliberation, and oversight. *The Oxford handbook of ethics of AI*, pages 77–106, 2020.

Fingerprint Revolution: Unleashing the Potential of Modified Bacterial Memetic Evolution for a Paradigm Shift in Fingerprint Recognition and Optimization

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Abstract: Biometrics refers to the science of measuring and analyzing biological or behavioral characteristics to identify people. It has been used in many fields including digital forensics, identification systems, and security. The most common biometric nowadays is fingerprint, which has improved significantly in the last two decades. Several issues in fingerprint identification and authentication systems have been raised due to factors such as displacement of the finger while scanning, fingerprint rotation, major cuts, lowering the overall system efficiency. Evolutionary algorithms evolved in recent years to enhance the system performance over time. The proposed system uses a modified version of the bacterial memetic evolutionary algorithm to overcome the identification issues and to help and support forensic experts to make reliable decisions faster. The proposed system was evaluated on five different databases and the results demonstrated that the system succeeded in identifying the correct match from the first candidate in all cases among all examined databases.

Keywords: Biometrics · Fingerprint · Evolutionary algorithms · Bacterial algorithm· Memetic algorithm

References

1. F. Monrose and A. D. Rubin. Keystroke dynamics as a biometric for authentication. *Future Generation Computer Systems*, 16(4):351–359, 2000. https://doi.org/10.1016/S0167-739X(99)00059-X
2. M. A. Jayaram and H. Fleyeh. Soft Computing in Biometrics: A Pragmatic Appraisal. *American Journal of Intelligent Systems*, 2013(3):105–112, 2013. https://doi.org/10.5923/j.ajis.20130303.01
3. A. A. Momani and L. T. Kóczy. A Novel Fingerprint Identification Fuzzy System Using a Center-Distance Weighted Local Binary Pattern. *Computational Intelligence and Mathematics for Tackling Complex Problems 5*, vol. 1127, 2024. https://doi.org/10.1007/978-3-031-46979-4.
4. A. Lambora, K. Gupta, and K. Chopra. Genetic Algorithm- A Literature Review. in 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon), Faridabad, India: IEEE, Feb. 2019, pp. 380–384. https://doi.org/10.1109/COMITCon.2019.8862255

5. László T. Kóczy, Péter Földesi, and Boldizsár Tüű-Szabó. An effective discrete bacterial memetic evolutionary algorithm for the traveling salesman problem. *International Journal of Intelligent Systems*, 32(8):862–876, 2017.
6. A. A. Momani and L. T. Kóczy. A Robust Fingerprint Identification Fuzzy System Using a New Rotation Method and Adaptive Core-Distance Weighted Local Binary Pattern. *Pattern Recognition*. Under review.
7. S. Chikkerur, C. Wu, and V. Govindaraju. LNCS 3072 - A Systematic Approach for Feature Extraction in Fingerprint Images. Lecture Notes in Computer Science, Springer, Berlin, Heidelberg, vol. 3072, 2007. https://doi.org/10.1007/978-3-540-25948-0_48.
8. T. Ojala, M. Pietikäinen, and T. Mäenpää. Multiresolution Gray Scale and Rotation Invariant Texture Classification with Local Binary Patterns. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 24(7):971–987, 2000. https://doi.org/10.1109/TPAMI.2002.1017623
9. D. Maio, D. Maltoni, R. Cappelli, J. L. Wayman, and A. K. Jain. FVC2000: Fingerprint Verification Competition. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 24(3):402–412, 2000. https://doi.org/10.1109/34.990140
10. D. Maio, D. Maltoni, R. Cappelli, J. L. Wayman, and A. K. Jain. FVC2002: Second Fingerprint Verification Competition. 2002 International Conference on Pattern Recognition, Quebec City, QC, Canada: IEEE, Aug. 2002, pp. 811–814. https://doi.org/10.1109/ICPR.2002.1048144
11. D. Maio, D. Maltoni, R. Cappelli, J. L. Wayman, and A. K. Jain. FVC2004: Third Fingerprint Verification Competition. 2004. [Online]. Available: http://bias.csr.unibo.it/fvc2000

Comparison of text similarity techniques for power of attorney clauses for Polish banks

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Abstract: Text similarity techniques allow for close, but not exactly, matching strings to be compared and extracted from bodies of text. This functionality can be considered very useful in automated processing of the documents. In this paper existing algorithms such as Cosine similarity, Levenhstein distance, pre-trained models etc. are compared and summarised. Based on the attorney clauses from the banking sector - the official formats and given template - we consider the effectuality of each of them. An algorithm selection is made not only based on the similarity score, but also the simplicity of the given solution, often considered an advantage in a highly regulated industry. Nevertheless, this study demonstrated that pre-trained models, in certain instances, exhibit a performance that is twice as effective as other techniques that are more readily explicable in a business context.

Keywords: Machine learning · Natural language processing· Pre-trained language models · String matching · Levenshtein distance · Cosine Similarity

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References

1. Rana, A., Bisht, D., Pandey, S., Singh, R., Chhabra, G., Joshi, K.: Artificial intelligence indulgence in banking and financial sectors. pp. 1–5 (2023). https://doi.org/10.1109/InC457730.2023.10263088
2. Ustawa z dnia 29 sierpnia 1997 r. prawo bankowe (1997), z późniejszymi zmianami
3. Chowdhury, G.: Natural language processing. Annual Review of Information Science and Technology **37**(1), 51–89 (Jan 2003). https://doi.org/10.1002/aris.1440370103
4. Bhagya Sri, M., Bhavsar, R., Narooka, P.: String matching algorithms. International Journal of Engineering and Computer Science **7**(03), 23769–23772 (2018)
5. Boyer, R.S., Moore, J.S.: A fast string searching algorithm. Commun. ACM **20**(10), 762–772 (1977). https://doi.org/10.1145/359842.359859, `https://doi.org/10.1145/359842.359859`

6. Knuth, D.E., Morris, Jr., J.H., Pratt, V.R.: Fast pattern matching in strings. SIAM Journal on Computing **6**(2), 323–350 (1977). https://doi.org/10.1137/0206024, https://doi.org/10.1137/0206024
7. Karp, R.M., Rabin, M.O.: Efficient randomized pattern-matching algorithms. IBM Journal of Research and Development **31**(2), 249–260 (1987). https://doi.org/10.1147/rd.312.0249
8. Szeto, W.M., Wong, M.H.: Stream segregation algorithm for pattern matching in polyphonic music databases. Multimedia Tools Appl. **30**, 109–127 (07 2006). https://doi.org/10.1007/s11042-006-0011-9
9. Shrivastav, S., Kumar, S., Kumar, K.: Towards an ontology based framework for searching multimedia contents on the web. Multimedia Tools and Applications **76**, 1–30 (2017). https://doi.org/10.1007/s11042-017-4350-5
10. Rajkumar Kundu, K.K.: Contextual plagiarism detection using latent semantic analysis. International Research Journal of Advanced Engineering and Science **2**, 214–217 (2017)
11. Gipp, B., Meuschke, N., Beel, J.: Comparative evaluation of text- and citation-based plagiarism detection approaches using guttenplag. In: Proceedings of 11th annual international ACM/IEEE-CS Joint Conference on Digital Libraries (JCDL'11). ACM, Ottawa, Canada (2011). https://doi.org/10.1145/1998076.1998124
12. Mawardi, V.C., Rudy, R., Naga, D.S.: Fast and accurate spelling correction using trie and damerau-levenshtein distance bigram. TELKOMNIKA : Indonesian Journal of Electrical Engineering **16**, 827–833 (2018)
13. Bayardo, R.J., Ma, Y., Srikant, R.: Scaling up all pairs similarity search. In: Proceedings of the 16th International Conference on World Wide Web. p. 131–140. Association for Computing Machinery, New York, NY, USA (2007). https://doi.org/10.1145/1242572.1242591, https://doi.org/10.1145/1242572.1242591
14. Dey, D., Sarkar, S., De, P.: A distance-based approach to entity reconciliation in heterogeneous databases. IEEE Trans. Knowl. Data Eng. **14**, 567–582 (2002)
15. Krzeszewska, U., Poniszewska-Marańda, A.: Data structures analysis for text processing in the framework of nlp classification in polish. In: 2022 International Conference on Software, Telecommunications and Computer Networks (SoftCOM). pp. 1–6 (2022). https://doi.org/10.23919/SoftCOM55329.2022.9911412
16. Boiński, T., Chojnowski, A.: Towards facts extraction from text in polish language. In: 2017 IEEE International Conference on INnovations in Intelligent SysTems and Applications (INISTA). pp. 13–17 (2017). https://doi.org/10.1109/INISTA.2017.8001124
17. Ustawa z dnia 1 marca 2018 r. o przeciwdziałaniu praniu pieniędzy oraz finansowaniu terroryzmu (2018), przeciwdziałanie praniu pieniędzy oraz finansowaniu terroryzmu.
18. Navarro, G.: A guided tour to approximate string matching. ACM Comput. Surv. **33**(1), 31–88 (mar 2001). https://doi.org/10.1145/375360.375365, https://doi.org/10.1145/375360.375365
19. Infor website. https://www.infor.pl/prawo/umowy/finanse/751744,Upowaznienie-do-przekazania-danych-objetych-tajemnica-bankowa.html, accessed: 2023-12-10
20. Qaiser, S., Ali, R.: Text mining: Use of tf-idf to examine the relevance of words to documents. International Journal of Computer Applications **181** (07 2018). https://doi.org/10.5120/ijca2018917395

21. Piskorski, J., Sydow, M.: Usability of String Distance Metrics for Name Matching Tasks in Polish. Wydawnictwo Poznanskie Sp. z o. o., Poznan (Poland) (2007), http://www.ltc.amu.edu.pl/content.en.html
22. Charalampopoulos, P., Kociumaka, T., Wellnitz, P.: Faster approximate pattern matching: A unified approach (2020)
23. Peng, J.: Research on the text similarity algorithms in automatic scoring of subjective questions. Journal of Physics: Conference Series **1952**(4), 042039 (jun 2021). https://doi.org/10.1088/1742-6596/1952/4/042039
24. Levenshtein, V.I.: Binary codes capable of correcting deletions, insertions and reversals. Soviet Physics Doklady **10**(8), 707–710 (1966), doklady Akademii Nauk SSSR, V163 No4 845-848 1965
25. Jurafsky, D., Martin, J.: Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition, vol. 2. Prentice Hall (02 2008)
26. Bahl, L., Jelinek, F., Mercer, R.: A maximum likelihood approach to continuous speech recognition. Pattern Analysis and Machine Intelligence, IEEE Transactions on **PAMI-5**, 179 – 190 (04 1983). https://doi.org/10.1109/TPAMI.1983.4767370
27. Devlin, J., Chang, M.W., Lee, K., Toutanova, K.: BERT: Pre-training of deep bidirectional transformers for language understanding. In: Burstein, J., Doran, C., Solorio, T. (eds.) Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long and Short Papers). pp. 4171–4186. Association for Computational Linguistics, Minneapolis, Minnesota (Jun 2019). https://doi.org/10.18653/v1/N19-1423, https://aclanthology.org/N19-1423

Using Human-Computer Interaction Data for Continuous Authentication in High-stake Electronic Assessments

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Abstract: As electronic assessments become more prevalent in high-risk and online environments, ensuring the reliability of user authentication becomes increasingly important. In this research we examine the potential for using human-computer interaction (HCI) data for improving the reliability of authentication process in electronic assessments. By analyzing user interaction patterns with assessment interfaces, we try to improve the robustness of the authentication system. Our approach uses machine learning algorithms to discern subtle behavioral signals, primarily response times, to establish a user profile. This profile is then compared against the profile claimed within the primary authentication. The main characteristic of the interaction we used in this initial research is response time. The results indicate that the data collected from participants during a typical test (49 participants and 35 questions with provided answers, in the Health Management course) are not sufficient to enhance authenticity verification as proposed. Therefore, it is necessary to develop a more comprehensive profile of participants for such an approach to make sense.

Keywords: Human-Computer Interaction · Authenticity · High-stake Electronic Assessments

References

1. S. Adamovic, M. Milan, V. Mladen, S. Marko, and J. Aleksandar. Fuzzy commitment scheme for generation of cryptographic keys based on iris biometrics. iet biometrics, 6 (2): 89-96, 2016.
2. M. Antonijević, G. Shimic, A. Jevremović, M. Veinović, and S. Arsić. The potential for the use of eeg data in electronic assessments. *Serbian Journal of Electrical Engineering*, 15(3):339–351, 2018.
3. A. J. Bidgoly, H. J. Bidgoly, and Z. Arezoumand. A survey on methods and challenges in eeg based authentication. *Computers & Security*, 93:101788, 2020.

4. M. Diaz, M. A. Ferrer, D. Impedovo, M. I. Malik, G. Pirlo, and R. Plamondon. A perspective analysis of handwritten signature technology. *ACM Comput. Surv.*, 51(6), jan 2019.
5. J. Frey, C. Mühl, F. Lotte, and M. Hachet. Review of the use of electroencephalography as an evaluation method for human-computer interaction. *arXiv preprint arXiv:1311.2222*, 2013.
6. M. Galis, M. Milosavljević, A. Jevremović, Z. Banjac, A. Makarov, and J. Radomirović. Secret-key agreement by asynchronous eeg over authenticated public channels. *Entropy*, 23(10):1327, 2021.
7. A. Jevremovic, S. Arsic, M. Antonijevic, A. Ioannou, and N. Garcia. Human-computer interaction monitoring and analytics platform–wisconsin card sorting test application. In *International Conference on IoT Technologies HealthCare (EAI), HealthyIoT*, 2018.
8. S. Li, S. Savaliya, L. Marino, A. M. Leider, and C. C. Tappert. Brain signal authentication for human-computer interaction in virtual reality. In *2019 IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC)*, pages 115–120, 2019.
9. M. Milosavljević, S. Adamović, and A. Jevremović. Secret keys generation from mouse and eye tracking signals. In *Proceedings of the 6th International Conference on Electrical, Electronic and Computing Engineering–IcETRAN*, pages 1065–1068, 2019.
10. J. Roth, X. Liu, and D. Metaxas. On continuous user authentication via typing behavior. *IEEE Transactions on Image Processing*, 23(10):4611–4624, 2014.
11. R. Ryu, S. Yeom, S.-H. Kim, and D. Herbert. Continuous multimodal biometric authentication schemes: A systematic review. *IEEE Access*, 9:34541–34557, 2021.
12. B. Sayed, I. Traoré, I. Woungang, and M. S. Obaidat. Biometric authentication using mouse gesture dynamics. *IEEE systems journal*, 7(2):262–274, 2013.
13. K.-H. Yeh, C. Su, W. Chiu, and L. Zhou. I walk, therefore i am: Continuous user authentication with plantar biometrics. *IEEE Communications Magazine*, 56(2):150–157, 2018.

Belief Change: Axiomatic Characterization of KM-Erasure

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Abstract: One of the most important models in the literature of belief change is *update*, defined by Katsuno and Mendelzon in 1992. In their work, KM mentioned *erasure* as the counterpart change of update. However, erasure was only defined at the basic level. In this paper: (1) we complete the axiomatics of erasure and provide its relation with update via the Levi and Harper Identities, and (2) we provide a semantics in terms of possible worlds.

Keywords: Belief Change · Katsuno and Mendelzon Update · Erasure · Axiomatic Characterization · possible world semantics

References

1. Alchourrón, C., Gärdenfors, P., Makinson, D.: On the logic of theory change: Partial meet contraction and revision functions. Journal of Symbolic Logic **50**, 510–530 (1985)
2. Eiter, T., Gottlob, G.: On the complexity of propositional knowledge base revision, updates, and counterfactuals. Artificial Intelligence **57**, 227–270 (1992)
3. Fermé, E., Gonçalves, S.: On the logic of theory change iteration of km-update. International Journal of Approximate Reasoning **162**, 109005 (2023)
4. Fermé, E., Konieczny, S., Pérez, R.P., Schwind, N.: Credible models of belief update. In: 20th International Conference on Principles of Knowledge Representation and Reasoning {KR-2023}. pp. 252–261. International Joint Conferences on Artificial Intelligence Organization (2023)
5. Harper, W.L.: Ramsey test conditionals and iterated belief change. In: Harper, W.L., Hooker, C.A. (eds.) Foundations of Probability Theory, Statistical Inference, and Statistical Theories of Science, Volume 1, pp. 117–136. D. Reidel Publishing Co., Dordrecht (1976)
6. Herzig, A., Rifi, O.: Propositional belief base update and minimal change. Artificial Intelligence **115**(1), 107–138 (1999)
7. Katsuno, H., Mendelzon, A.: On the difference between updating a knowledge base and revising it. In: Gärdenfors, P. (ed.) Belief Revision, pp. 183–203. No. 29 in Cambridge Tracts in Theoretical Computer Science, Cambridge University Press (1992)
8. Keller, A.M., Winslett, M.: On the use of an extended relational model to handle changing incomplete information. IEEE Transactions on Software Engineering **11**(7), 620–633 (1985)
9. Lang, J.: Belief update revisited. In: IJCAI. vol. 7, pp. 6–12 (2007)
10. Levi, I.: Subjunctives, dispositions, and chances. Synthèse **34**, 423–455 (1977)

11. Peppas, P., Williams, M.A.: Constructive modelings for theory change. Notre Dame Journal of Formal Logic **36**(1), 120–133 (01 1995). https://doi.org/10.1305/ndjfl/1040308831, http://dx.doi.org/10.1305/ndjfl/1040308831
12. Slota, M., Leite, J.: On semantic update operators for answer-set programs. In: ECAI 2010, pp. 957–962. IOS Press (2010)
13. Winslett, M.: Reasoning about action using a possible models approach. In: AAAI. pp. 89–93 (1988)

Stable Reasoning, ASP and the Interrogative Model of Inquiry

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Abstract: In this note we explore the relation between question-answering in answer set programming and the interrogative model of scientific inquiry proposed by Jaakko Hintikka. To this end we extend the fixpoint property of propositional equilibrium models to the first order case. In this manner we obtain a rather close agreement between the interrogative model and question-answering in ASP; this may be relevant to the topic of explanatory ASP.

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References

1. P M Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning and logic programming. In Ruzena Bajcsy, editor, *Proc of the 13th Int Joint Conf on Artificial Intelligence. 1993*, pages 852–859. Morgan Kaufmann, 1993.
2. J. Hintikka. The logic of science as a model-oriented logic. In P. D. Asquith and P. Kitcher, editors, *PSA 1984*, volume 1, pages 177 – 185, 1984.
3. L. Laudan. *Progress and its Problems*. University of California Press, 1977.
4. Wiktor Marek and Miroslaw Truszczynski. *Nonmonotonic Reasoning: Context-Dependent Reasoning*. Springer, 1993.
5. J Fandinno P Cabalar and B Muñiz. A system for explainable answer set programming. *Electronic Proceedings in Theoretical Computer Science*, 325:124–136, September 2020.
6. D. Pearce. From here to there: Stable negation in logic programming,. In D Gabbay & H Wansing, editor, *What is Negation?* Kluwer, 1999.
7. D Pearce and A Valverde. Quantified equilibrium logic and foundations for answer set programs. In M Garcia de la Banda and E Pontelli, editors, *Proc. ICLP 2008,*, volume 5366 of *LNCS*, pages 546–560. Springer, 2008.
8. R. Stalnaker. A note on non-monotonic modal logic. *Art. Intell.*, 64(2):183–196, 1993.
9. D. van Dalen. *Logic and Structure*. Universitext. Springer London, 2012.

Hypergraph logic program representation versus stratified programs

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Abstract: Multi-adjoint normal logic programming is a general non-monotonic logic programming framework, which makes it ideal for modeling complex scenarios. Hypergraph representation has been proved to be an appropriate tool in the study of different properties of a logic program, whereas the use of a stratification has provided interesting results related to the existence and unicity of stable models. In this paper, we will see the relation between the p-condensation graph of a program and its "optimal" stratification.

Keywords: Logic Programming · Hypergraphs · Negation operator

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References

1. K. R. Apt, H. A. Blair, and A. Walker. Towards a theory of declarative knowledge. In *Foundations of Deductive Databases and Logic Programming*, pages 89–148. Morgan Kaufmann, 1988.
2. C. Berge. *Graphs and Hypergraphs*. Elsevier Science Ltd, 1985.
3. P. Cabalar, J. Fandinno, and Y. Lierler. Modular answer set programming as a formal specification language. *Theory and Practice of Logic Programming*, 20(5):767–782, 2020.
4. M. E. Cornejo, D. Lobo, and J. Medina. Syntax and semantics of multi-adjoint normal logic programming. *Fuzzy Sets and Systems*, 345:41 – 62, 2018.
5. M. E. Cornejo, D. Lobo, and J. Medina. Extended multi-adjoint logic programming. *Fuzzy Sets and Systems*, 388:124–145, 2020. Logic.
6. M. E. Cornejo and J. Medina. Impact Zadeh's theory to algebraic structures. multi-adjoint algebras. *Journal of Pure and Applied Mathematics*, 12:126–141, 2021.
7. M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Multi-adjoint algebras versus non-commutative residuated structures. *International Journal of Approximate Reasoning*, 66:119–138, 2015.

8. J. C. Díaz-Moreno, J. Medina, and J. R. Portillo. Towards the use of hypergraphs in multi-adjoint logic programming. *Studies in Comp. Intelligence*, 796:53–59, 2019.
9. J. C. Díaz-Moreno, J. Medina, and J. R. Portillo. Fuzzy logic programs as hypergraphs. termination results. *Fuzzy Sets and Systems*, 445:22–42, 2022.
10. J. C. Díaz-Moreno, J. Medina, and J. R. Portillo. Hypergraphs in logic programming. In Z. Bouraoui and S. Vesic, editors, *Symbolic and Quantitative Approaches to Reasoning with Uncertainty*, pages 442–452, Cham, 2024. Springer.
11. M. Fitting. The family of stable models. *The Journal of Logic Programming*, pages 17(2–4):197–225, 1993.
12. G. Gallo, G. Longo, S. Pallottino, and S. Nguyen. Directed hypergraphs and applications. *Discrete Appl. Math.*, 42(2-3):177–201, apr 1993.
13. F. Harary, R. Z. Norman, and D. Cartwright. *Structural Models: An Introduction to the Theory of Directed Graphs*. John Wiley & Sons, New York, 4 edition, 1965.
14. J. Lloyd. *Foundations of Logic Programming*. Springer Verlag, 1987.
15. N. Madrid and M. Ojeda-Aciego. On the existence and unicity of stable models in normal residuated logic programs. *International Journal of Computer Mathematics*, 89(3):310–324, 2012.
16. J. Medina, M. Ojeda-Aciego, and P. Vojtáš. Multi-adjoint logic programming with continuous semantics. *Lecture Notes in Artificial Intelligence*, 2173:351–364, 2001.
17. A. Van Gelder. Negation as failure using tight derivations for general logic programs. *The Journal of Logic Programming*, 6(1-2):109–133, 1989.
18. C. Zhang, L. Chen, Y.-P. Zhao, Y. Wang, and C. L. P. Chen. Graph enhanced fuzzy clustering for categorical data using a bayesian dissimilarity measure. *IEEE Transactions on Fuzzy Systems*, 31(3):810–824, 2023.

A preliminary taxonomy of explanations in problem solving

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Abstract: An important subarea of Knowledge Representation and Reasoning (KRR) in Artificial Intelligence is the field of (model-based) Declarative Problem solving. In that context, we start from some real world problem and state its premises in terms of some KRR language, so that models of that language keep a correspondence to solutions of the original problem. This is, for instance, the usual methodology followed in *Answer Set Programming* (ASP) [2], a paradigm for practical KRR typically used for problem solving in a wide range of domains and applications [4]. Explanations become crucial for the final persons that are expected to use the solutions obtained from our ASP encoding in a real world scenario. Expressing the results obtained in the answer sets in terms of the target user becomes an important requisite, and this was explored in different applications or systems for explainability in ASP [5,3,1]. However, explanations in these systems only cover some types of questions a final user may perform, but not other topics that have been studied in more technical approaches to ASP explainability. For instance, user oriented ASP systems do not normally deal with questions of the form "why does this problem have no solution?".

In this extended abstract, we consider a preliminary taxonomy of the type of explanations that seem more common in these situations. To this aim, we use as a guide the stable roommate problem [6] where we must decide pairs of students to be assigned to double rooms in a university accommodation system according to some input preferences. Suppose we start obtaining a given solution that is presented to the user, perhaps a university administrative or a student.

The first distinction is between questions of the form *why* (positive or *real*) versus form *why-not* (negative or *alternative*). In a *why* context, the question "why X matches Y?" is read as "how come X matches Y?" and the expected answer is a justification that allowed us to perform such a matching: for instance X preferred Y and vice versa. On the other hand, a *why-not* asks about an alternative scenario: "why does X not match Z?" can be read as, "could we get a matching of X and Z instead?". Note the difference between a positive "why p?" where we ask why p was derived in the current solution and a negative "why not $\neg p$?" where we ask about another solution in which p could be false.

Second, consider again the question "why does X not match Z?" and suppose that, indeed, there are solutions in which X matches Z. It is then reasonable to display one of those solutions, but also, to look for one *as close as possible* to the original one presented to the user. Moreover, it may be convenient to only display the main differences: for instance, if having 1000 students, the new solution only involves the reassignment of 4 of them, we would not want to see again the rest of 996 repeated assignments (we might not even notice the relevant changes among them!).

Third, suppose that instead, there is *no solution* where X matches Z at all. We could perhaps consider *hypothetical scenarios* where something exceptional is allowed. These exceptional situations could include relaxing some of the constraints (like allowing some exceptional matches), adding or deleting preferences, or even modifying the room configurations. In that way, one example of explanation could have the form "X cannot match Z, but they could if Y had not preferred Z or if we had one more extra room". We may call this kind of explanation a "*repair*" in the sense that we imagine a hypothetical change that removes the unsolvability. If the repair is obtained from an initial solution and a *why-not* query, it makes sense, again, to include in the explanation only the relevant changes with respect to the initial solution. For instance, we have 1000 assigned students, and we ask "why X does not match Z?", if the repair means only a few changes, we do not want to see the rest of unchanged information.

Finally, if no repair is possible (or the user does not allow such a possibility) then the explanation can focus on the *source of unsolvability*. This may mean displaying a minimal subset of rules (or premises) that are causing the lack of solution or using other techniques to display which parts of a given scenario are involved in the unsatisfiability.

References

1. Arias, J., Carro, M., Chen, Z., Gupta, G.: Justifications for goal-directed constraint answer set programming. In: International Conference on Logic Programming, ICLP (2020)
2. Brewka, G., Eiter, T., Truszczyński, M.: Answer set programming at a glance. Communications of the ACM **54**(12), 92–103 (2011)
3. Cabalar, P., Fandinno, J., Muñiz, B.: A system for explainable answer set programming. In: et al, F.R. (ed.) Proc. 36th International Conference on Logic Programming (Technical Communications), UNICAL, Rende, Italy, 2020. EPTCS, vol. 325 (2020)
4. Erdem, E., Gelfond, M., Leone, N.: Applications of answer set programming. AI Magazine **37**(3), 53–68 (2016)
5. Erdem, E., Öztok, U.: Generating explanations for biomedical queries. Theory and Pracice of Logic Programming **15**(1), 35–78 (2015)
6. Fidan, M., Erdem, E.: Knowledge-based stable roommates problem: A real-world application. Theory and Practice of Logic Programming **21**(6), 852–869 (2021). https://doi.org/10.1017/S1471068421000302

Efficiency of decision rule sets in classification problems

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Abstract: Decision algorithms [4] are considered in Rough Set Theory in order to extract non-redundant and exhaustive information from relational datasets in terms of decision rules. These algorithms are analyzed by using the notion of efficiency [5], which provides their classification quality through a value in the unit interval. Recently, we have introduced the notion of decision algorithm and efficiency in Fuzzy Rough Set Theory [1,2,3]. The first one to model and obtain the most relevant information from the dataset, and the second one to determine the suitability of the considered algorithm. However, it can be difficult to interpret the fuzzy notion of efficiency because it takes values greater than one, unlike the classical efficiency. In order to overcome this drawback, this work introduces a normalized efficiency, whose values belong to the unit interval. Moreover, the normalized efficiency is defined from a new relevance indicator of strength of decision rules, which highlights the most supported rules in the algorithm. Finally, some properties satisfied by the normalized efficiency are presented, which facilitate its interpretation.

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References

1. F. Chacón-Gómez, M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Efficiency of fuzzy rough set decision algorithms. *Studies in Computational Intelligence*, 1127:17–24, 2024.
2. F. Chacón-Gómez, M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Fuzzy rough set decision algorithms. *Communications in Computer and Information Science*, 1601:63–76, 2022.
3. F. Chacón-Gómez, M. E. Cornejo, J. Medina, and E. Ramírez-Poussa. Rough set decision algorithms for modeling with uncertainty. *Journal of Computational and Applied Mathematics*, 437:115413, 2024.
4. Z. Pawlak. *Rough Sets: Theoretical Aspects of Reasoning About Data*. Kluwer Academic Publishers, Norwell, MA, USA, 1992.
5. Z. Pawlak. Rough sets and decision algorithms. In W. Ziarko and Y. Yao, editors, *Rough Sets and Current Trends in Computing*, pages 30–45, Springer Berlin Heidelberg, 2001.

***Keynote speech*:**

Sensitivity Analysis as a Method for Explaining AI (XAI) in the Artificial Neural Networks Domain

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Abstract: The field of Explainable Artificial Intelligence (XAI) has gained prominence as the adoption of complex models, such as Artificial Neural Networks (ANNs), continues to grow. Sensitivity Analysis emerges as a pivotal method within the XAI framework, offering a systematic approach to unravelling the intricate inner workings of ANNs. This invited talk delves into the significance of Sensitivity Analysis as a method for explaining AI in the domain of Artificial Neural Networks. The presentation explores how sensitivity analysis techniques contribute to transparency, interpretability, and trust in AI systems, shedding light on the factors that influence model predictions. Through illustrative examples and case studies, the talk aims to provide valuable insights into the practical application of sensitivity analysis, bridging the gap between the complex nature of ANNs and the need for comprehensible AI systems. The talk will showcase both global and local approaches of Sensitivity Analysis, providing a comprehensive understanding of how these methods can be employed to dissect the decision-making processes within ANNs. Attendees will gain insights into the application of Sensitivity Analysis to various types of neural networks, including Multilayer Perceptrons (MLPs), Probabilistic Neural Networks (PNNs), and Convolutional Neural Networks (CNNs). Through illustrative examples and case studies, the presentation aims to demonstrate the versatility of sensitivity analysis in dissecting the complex structures of different neural network architectures. By focusing on specific neural network models, namely MLPs, PNNs, and CNNs, the talk will highlight the adaptability of sensitivity analysis across diverse AI applications. The presentation underlines a deeper understanding of how global and local sensitivity analysis techniques can enhance the interpretability and explainability of ANNs, contributing to the responsible deployment of AI systems.

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Enhancement of Discrete Bacterial Memetic Evolutionary Algorithm for Solving The Travelling Repairman Problem

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Abstract: The Traveling Repairman Problem (TRP) is concerned with repairing a set of locations rather than visiting them. In this paper, we propose an enhanced version of the Discrete Bacterial Memetic Evolutionary Algorithm (DBMEA) to solve TRP. DBMEA is combining with a new method for generating the initial individual candidate solution which is called Circle Group Heuristic (CGH). CGH is constructed with the help of Genetic Algorithm (GA). The enhanced version of DBMEA with CGH has been tested for several benchmark reference data of TRP. The results show that the enhanced version has a faster and better solutions for most cases in comparison to state-of-the-art heuristics mentioned in the literature. Furthermore, for larger benchmark instances, it provided better solutions than the previously best-known results. These test results support the claim that the DBMEA with CGH is the most effective approach and recommend its use for the Traveling Repairman Problem, particularly for large instances.

Keywords: TRP · CGH · DBMEA · Memetic algorithm.

References

1. R. Araujo, I. M.Coelho, and L. Marzulo. A dvnd local search implemented on a dataflow architecture for the minimum latency problem. In *2018 IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW*, pages 1250–1259, Vancouver, BC, Canada.
2. B. H.Ban and D. Nguyen. A meta-heuristic algorithm combining between tabu and variable neighborhood search for the minimum latency problem'.
3. A. Ibada, B. Tüu-Szabó, and L. Kóczy. Effect of the initial population construction on the dbmea algorithm searching for the optimal solution of the traveling salesman problem". *Infocommunications Journal*, XIV(3):72–78.
4. A. Ibada, B. Tüu-Szabó, and L. Kóczy. A new efficient tour construction heuristic for the traveling salesman problem. In *Proceedings of the 2021 5th International Conference on Intelligent Systems, Metaheuristics & Swarm Intelligence (ISMSI '21). Association for Computing Machinery*, pages 71–76, New York, NY, USA.

5. L. Kóczy, P. Földesi, and B. Tüű-Szabó. A discrete bacterial memetic evolutionary algorithm for the traveling salesman problem. In *IEEE World Congress on Computational Intelligence (WCCI 2016*, pages 3261–3267. Vancouver, Canada.
6. F. Ramadhan and A. Imran. A two-phase metaheuristic method for solving travelling repairman problem. In *2019 International Conference on Sustainable Engineering and Creative Computing (ICSECC*, pages 155–159, Bandung, Indonesia.
7. A. Salehipour, K. Sörensen, P. Goos, and OBräysy. Efficient grasp+vnd and grasp+vns metaheuristics for the traveling repairman problem. *4OR. A Quarterly Journal of Operations Research*, 9(2):189–209.
8. M. Silva, A. Subramanian, T. Vidal, and L. Ochi. A simple and effective metaheuristic for the. *Minimum Latency Problem,European Journal of Operational Research*, 221(ue 3).
9. C. S.Ngueveu and R. Calvo. An effective memetic algorithm for the cumulative capacitated vehicle routing problem. *Computers & Operations Research*, 37(ue 11).
10. B. Tüu-Szabó, P. Földesi, and L. Kóczy. An efficient evolutionary metaheuristic for the traveling repairman (minimum latency) problem. *Int. J. Comput. Intell. Syst*, 13:781–793.
11. B. Tüű-Szabó, P. Földesi, and L. Kóczy. Improved discrete bacterial memetic evolutionary algorithm for the traveling salesman problem. In *Proceedings of the Computational Intelligence in Information Systems Conference (CIIS 2016*, pages 27–38, Bandar Seri Begawan,Brunei.
12. A. V.Aho and J. Hopcroft. *The Design and Analysis of Computer Algorithms.* Pearson Education India.
13. `http://comopt.ifi.uni-heidelberg.de/software/TSPLIB95/`

Simulated Annealing and Bacterial Foraging for Probabilistic Neural Network parameters adjustment

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Abstract: Probabilistic Neural Networks (PNNs), a category of Feedforward Neural Networks, leverage Kernel Density Estimators (KDEs) and the Bayesian conditional probability theorem for estimating conditional probabilities. Initially designed for classification, these networks exhibit commendable performance in both classification and regression tasks. The training process involves determining optimal or suboptimal values for the KDE smoothing parameter, commonly accomplished through analytical methods such as the Plug-in technique. Additionally, metaheuristic approaches like Particle Swarm Optimisation and Krill Herd Algorithm have been employed for smoothing parameter optimisation in PNNs due to the absence of gradient calculations. This contribution proposes the integration of Bacterial Foraging Optimisation (BFO) and Simulated Annealing (SA) for enhancing PNNs. The efficiency of these techniques in optimising PNNs is compared with the conventional Plug-in method, employing benchmark classification datasets sourced from UCI and Kaggle repositories. The results reveal that SA surpasses other methods in specific benchmarking tasks, suggesting its efficacy in training PNNs for specific problem domains.

Keywords: Probabilistic Neural Networks · Metaheuristics · Simulated Annealing · Bacterial Foraging Optimisation

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References

1. AL-Hadi, I.A.A., Hashim, S.Z.M., Shamsuddin, S.M.H.: Bacterial foraging optimization algorithm for neural network learning enhancement. In: 2011 11th International Conference on Hybrid Intelligent Systems (HIS). pp. 200–205 (2011)
2. Ciarelli, P., Krohling, R., Oliveira, E.: Particle Swarm Optimization Applied to Parameters Learning of Probabilistic Neural Networks for Classification of Economic Activities, chap. 19, pp. 313–328. InTech (01 2009)

3. Dua, D., Graff, C.: UCI machine learning repository (2017), http://archive.ics.uci.edu/ml
4. Kan, W.: Ghouls, goblins, and ghosts... boo! (2016), https://kaggle.com/competitions/ghouls-goblins-and-ghosts-boo
5. Kirkpatrick, S., Gelatt, C., Vecchi, M.: Optimization by simulated annealing. Science (New York, N.Y.) **220**, 671–80 (06 1983)
6. Kowalski, P.A., Kusy, M., Kubasiak, S., Łukasik, S.: Probabilistic neural network - parameters adjustment in classification task. pp. 1–8 (07 2020)
7. Kowalski, P.A., Wadas, K.: Triggering probabilistic neural networks with flower pollination algorithm. Computational Intelligence and Mathematics for Tackling Complex Problems (2019)
8. Kulczycki, P.: Kernel Estimators in Industrial Applications, vol. 226, pp. 69–91. Springer, Berlin, Heidelberg (01 2008)
9. Kusy, M., Zajdel, R.: Application of reinforcement learning algorithms for the adaptive computation of the smoothing parameter for probabilistic neural network. IEEE Transactions on Neural Networks and Learning Systems **26**(9), 2163–2175 (2015)
10. Naik S.M., Jagannath R.P.K., K.V.: Bat algorithm-based weighted laplacian probabilistic neural network. Neural Comput & Applic **32**, 1157–1171 (2020)
11. Passino, K.: Biomimicry of bacterial foraging for distributed optimization and control. ieee control systems magazine 22(3), 52-67. Control Systems, IEEE **22**, 52 – 67 (07 2002)
12. Pedregosa, F., Varoquaux, G., Gramfort, A., Michel, V., Thirion, B., Grisel, O., Blondel, M., Prettenhofer, P., Weiss, R., Dubourg, V., Vanderplas, J., Passos, A., Cournapeau, D., Brucher, M., Perrot, M., Duchesnay, E.: Scikit-learn: Machine learning in Python. Journal of Machine Learning Research **12**, 2825–2830 (2011)
13. Rere, L., Fanany, M.I., Arymurthy, A.: Simulated annealing algorithm for deep learning. vol. 72 (11 2015)
14. Shah, H.: Using new artificial bee colony as probabilistic neural network for breast cancer data classification. Frontiers in Engineering and Built Environment **ahead-of-print** (07 2021)
15. Specht: Probabilistic neural networks for classification, mapping, or associative memory. In: IEEE 1988 International Conference on Neural Networks. pp. 525–532 vol.1 (1988)

Extreme Learning Machine as a New Learning Paradigm: Pros and Cons

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Abstract: We analyze the validity of the Extreme Learning Machine principles proposed in [2] as a new learning methodology for Single Layer Feedforward Neural Network. We show that despite the empirical success of ELM, its theoretical platform does not have a rigorous mathematical justification. To do this, we show that two main statements in [2] do not have correct proofs and are in fact incorrect. Moreover, we create a dataset that provides a counterexample to the theoretical assertions done in [2] about the ELM learning algorithm.

Keywords: Extreme Learning Machine · Single Layer Feedforward Neural Network · Activation function

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References

1. J. Cao, Z. Lin: Extreme Learning Machines on High Dimensional and Large Data Applications: A Survey. Mathematical Problems in Engineering, `http://dx.doi.org/10.1155/2015/103796` (2015)
2. Huang, G.B.,Zhu, Q.Y., Siew, C.K.: Extreme learning machine: theory and applications. Neurocomputing, **70**, 489–501 (2006)
3. Liang, N.Y., Huang, G.B., Saratchandran, P.; Sundararajan, N.: A fast and accurate online sequential learning algorithm for feedforward networks. IEEE Trans. Neural Networks, **17/6**, 1411–1423 (2006)
4. Google Scholar blog. Classic papers: Articles that have stood the test of time. URLdate 14-06-2017. Last Checked 11-1-2024
`https://$scholar.google.com/citations?view_op=list_classic_articles&hl=en&by=2006&vq=eng_artificialintelligence$`
5. Wang, L. P.; Wan, Chunru R.: Comments on 'The Extreme Learning Machine'. IEEE Trans. Neural Networks, **19/8** 1494–1495 (2008)

6. A. N. Kolmogorov: On the representation of continuous functions of many variables by superposition of continuous functions of one variable and addition (Russian). Dokl. Akad. Nauk SSSR **114**, 953-956 (1957)
7. G. Cybenko, Approximation by superpositions of a sigmoidal function. Math. Control Signals Systems, **2**/**4**, 303-314 (1989)
8. Hornik, K., Stinchcombe, M., White, H.: Multilayer feedforward networks are universal approximators. Neural Networks, **2**, 359–366 (1989)
9. Lorke, A., Schneider, F., Heck, J., Nitter, P.: Cybenko's Theorem and the capability of a neural network as function approximator, `https://www.mathematik.uni-wuerzburg.de/fileadmin/10040900/2019/Seminar-Artificial-Neural-Network-24-9-.pdf` (2019)
10. R. Penrose: On best approximate solution of linear matrix equations. In: Proc. Cambridge Philosophical Society, 52/1, pp. 17–19. Cambridge (1956)

Inheritance of completeness between systems of strong and weak implications

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Abstract: The study of unknown information in formal contexts can be done from two extremely different points of view: working just with the information available at the moment, or exploring all the different values that the unknown information can take. From these two perspectives, we obtain two kinds of attribute implications: the weak ones which are the attribute implications that hold with the current amount of information, and the strong ones which will also hold under any update of the context. We study whether, given a complete system of weak implications concerning partial formal context, one can extract a complete system of strong ones concerning the same partial formal context.

Keywords: Formal Concept Analysis · Unknown information · Attribute implication · Completeness

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References

1. G. Lang, Y. Yao, Formal concept analysis perspectives on three-way conflict analysis, International Journal of Approximate Reasoning 152 (2023) 160–182.
2. M. Felde, G. Stumme, Interactive collaborative exploration using incomplete contexts, Data and Knowledge Engineering 143 (2023) 102104.
3. D. Dubois, J. Medina, H. Prade, E. Ramírez-Poussa, Disjunctive attribute dependencies in formal concept analysis under the epistemic view of formal contexts, Information Sciences 561 (2021) 31–51.
4. F. Pérez-Gámez, P. Cordero, M. Enciso, Á. Mora, Simplification logic for the management of unknown information, Information Sciences 634 (2023) 505–519.
5. J. Guigues, V. Duquenne, Familles minimales d'implications informatives résultant d'une tables de données binaires, Mathématiques et Sciences Humaines 95 (1986) 5–18.
6. G. Birkhoff, Lattice Theory, 1st Edition, Math. Soc., Providence, 1940.
7. B. Davey, H. Priestley, Introduction to lattices and order, 2nd Edition, Cambridge University press, Cambridge, 2002.
8. B. Ganter, S. Obiedkov, Conceptual Exploration, Springer, Berlin, 2016.

9. B. Ganter, R. Wille, 'Formal Concept Analysis' Mathematical Foundations, Springer, Berlin, 1996.
10. F. Perez-Gamez, P. Cordero, M. Enciso, A. Mora, A galois connection between partial formal contexts and attribute sets, The 16th International Conference on Concept Lattices and Their Applications, (2022) 45–55.
11. F. Pérez-Gámez, P. Cordero, M. Enciso, Á. Mora, Defining strong implications in partial formal context, Submitted to Journal.
12. S. O. Kuznetsov, S. A. Obiedkov, Some decision and counting problems of the Duquenne-Guigues basis of implications, Discrete Applied Mathematics 156 (11) (2008) 1994–2003.

Connections between attribute implications in heterogeneous formal contexts and GUHA association rules

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Abstract: Formal concept analysis [1] is a powerful method of data analysis based on object-attribute relational data. This method outputs hierarchically ordered objects and attributes' bi-clusters based on lattice theory. In Formal concept analysis, several important generalizations regarding fuzzy sets and fuzzy logic were investigated [2,3,4,5,6,7,8,9,10,11,12,13]. Recently, we proposed extensions working with formal contexts of heterogeneous data structures [14,15,16,17]. Attribute implications can be seen as the expressions describing particular dependencies among attributes in relational data. The dependencies between attributes in a formal context were thoroughly investigated in [19,20,21]. Moreover, association rules (an extension of attribute implications) express the probability of relationships between data items within large data sets in different databases. One of the most popular association rule generation algorithms is the Apriori [22]. General Unary Hypotheses Automaton (GUHA) [23] provides association rules that extend the Apriori algorithm in several ways. In this paper, we explore the connections between attribute implications in heterogeneous formal contexts, association rules, and their extension provided by GUHA. In particular, we defined attribute implications in heterogeneous formal contexts, which allow us to apply different structure of values for each attribute. We explored the properties of attribute implications in heterogeneous formal contexts. Moreover, we explored the possibility of incorporating several types of quantifiers from GUHA association rules into fuzzy extensions of Formal concept analysis.

Keywords: Formal Concept Analysis · Heterogeneous formal context · Attribute implications · Association rules

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References

1. Ganter, G., Wille, R.: Formal Concept Analysis, Mathematical Foundation. Springer Verlag (1999)
2. Burusco, A., Fuentes-González, R.: The study of L-fuzzy concept lattice. Mathw. Soft Comput. **3**, 209–218 (1994)
3. Bělohlávek, R.: Concept lattices and order in fuzzy logic. Ann. Pure Appl. Logic **128**, 277–298 (2004)
4. Ben Yahia, S., Jaoua, A.: Discovering knowledge from fuzzy concept lattice. In: Kandel, A., Last, M., Bunke, H. (eds.) Data Mining and Computational Intelligence, pp. 169–190. Physica-Verlag (2001)
5. Medina, J., Ojeda-Aciego, M., Vojtáš, P.: Similarity-based unification: a multi-adjoint approach. Fuzzy Sets Syst. **146**, 43–62 (2004)
6. Cornejo, M. E., Medina, J., Ramírez, E.: A comparative study of adjoint triples. Fuzzy Sets Syst. **211**, 1–14 (2013)
7. Cornejo, M. E., Medina, J., Ramírez, E.: Characterizing reducts in multi-adjoint concept lattices. Inf. Sci. **422**, 364–376 (2018)
8. Madrid, N., Ojeda-Aciego, M.: Multi-adjoint lattices from adjoint triples with involutive negation. Fuzzy Sets Syst. **405** 88–105 (2021)
9. Medina, J., Ojeda-Aciego, M.: Multi-adjoint t-concept lattices. Inf. Sci. **180**, 712–725 (2010)
10. Medina, J., Ojeda-Aciego, M.: On multi-adjoint concept lattices based on heterogeneous conjunctors. Fuzzy Sets Syst. **208**, 95–110 (2012)
11. Medina, J., Ojeda-Aciego, M., Ruiz-Calviño, J.: Formal concept analysis via multi-adjoint concept lattices. Fuzzy Sets Syst. **160**, 130–144 (2009)
12. Pócs, J.: Note on generating fuzzy concept lattices via Galois connections. Inf. Sci. **185**, 128–136 (2012)
13. Pócs, J.: On possible generalization of fuzzy concept lattices using dually isomorphic retracts. Inf. Sci. **210**, 89–98 (2012)
14. Krajči, S.: A generalized concept lattice, Logic J. IGPL **13**, 543–550 (2005)
15. Krídlo, O., Krajči, S., Antoni, Ľ.: Formal Concept Analysis of higher order. Int. J. Gen. Syst. **45**(2), 116–134 (2016)
16. Antoni, Ľ., Krajči, S., Krídlo, O., Macek, B., Pisková, L.: On heterogeneous formal contexts. Fuzzy Sets Syst. **234**, 22–33 (2014)
17. Antoni, Ľ., Eliaš, P., Krajči, S., Krídlo, O.: Heterogeneous formal context and its decomposition by heterogeneous fuzzy subsets. Fuzzy Sets Syst. **451**, 361–384 (2022)
18. Cordero, P., Enciso, M., Mora, Á., Ojeda-Aciego, M., Rossi, C.: A Formal Concept Analysis Approach to Cooperative Conversational Recommendation. Int. J. Comput. Intell. Syst. **13**(1), 1243–1252 (2020)
19. Dubois, D., Medina, J., Prade, H., Ramírez-Poussa, E.: Disjunctive attribute dependencies in formal concept analysis under the epistemic view of formal contexts. Inf. Sci. **561**, 31–51 (2021)
20. Cornejo, M. E., Medina, J., Ramírez-Poussa, E.: Implication operators generating pairs of weak negations and their algebraic structure. Fuzzy Sets Syst. **405** (2021) 18–39.

21. Bělohlávek, R., Cordero, P., Enciso, M., Mora, Á., Vychodil, V.: Automated prover for attribute dependencies in data with grades. Int J Approx Reason. **70** (2016) 51–67.
22. Agrawal, R., Srikant, R.: Fast algorithms for mining association rules. In: Proc. 20th Int. Conf. Very Large Data Bases, pp. 487-499. VLDB, Vol. 1215 (1994)
23. Hájek, P., Holeňa, M., Rauch, J.: The GUHA method and its meaning for data mining. J. Comput. Syst. Sci. **76**(1) (2010) 34–48.

Migrative properties for triangular conorms and fuzzy implications

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Abstract: Migrative and cross-migrative properties of t-norms have widely been analyzed in the literature. However, few works exist on migrative properties on t-conorms over fuzzy implications. This paper presents different features and remarks of these properties, which also justify the interconnected relationship between them.

Keywords: Migrativity · cross-migrativity · t-conorm · fuzzy implication

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References

1. J. Aczél and C. Alsina. Characterizations of some classes of quasilinear functions with applications to triangular norms and to synthesizing judgements. *Aequationes mathematicae*, 25:313–315, 1982.
2. M. Baczyński and B. Jayaram. *Fuzzy Implications*, volume 231. Springer, 2008.
3. M. Baczyński, B. Jayaram, and R. Mesiar. Fuzzy implications: alpha migrativity and generalised laws of importation. *Information Sciences*, 531:87–96, 2020.
4. H. Bustince, B. De Baets, J. Fernandez, R. Mesiar, and J. Montero. A generalization of the migrativity property of aggregation functions. *Information Sciences*, 191:76–85, 2012. Data Mining for Software Trustworthiness.
5. H. Bustince, J. Montero, and R. Mesiar. Migrativity of aggregation functions. *Fuzzy Sets and Systems*, 160:766–777, 2009.
6. F. Durante and P. Sarkoci. A note on the convex combinations of triangular norms. *Fuzzy Sets and Systems*, 159:77–80, 2008.
7. B. W. Fang. On alpha-cross-migrativity of t-conorms over fuzzy implications. *Fuzzy Sets and Systems*, 466, 2023.
8. J. Fodor, E. P. Klement, and R. Mesiar. Cross-migrative triangular norms. *International Journal of Intelligent Systems*, 27:411–428, 2012.
9. J. Fodor and I. J. Rudas. On continuous triangular norms that are migrative. *Fuzzy Sets and Systems*, 158:1692–1697, 2007.

10. J. C. Fodor and T. Keresztfalvi. A characterization of the hamacher family of t-norms. *Fuzzy Sets and Systems*, 65(1):51–58, 1994.
11. M. J. Frank. On the simultaneous associativity ot $f(x, y)$ and $x + y - f(x, y)$. *Aequationes Mathematicae*, 19:194–226, 1979.
12. E. P. Klement, R. Mesiar, and E. Pap. A characterization of the ordering of continuous t-norms. *Fuzzy Sets and Systems*, 86(2):189–195, 1997.
13. E. P. Klement, R. Mesiar, and E. Pap. Triangular norms. position paper i: Basic analytical and algebraic properties. volume 143, pages 5–26. Elsevier B.V., 2004.
14. M. Mas, M. Monserrat, D. Ruiz-Aguilera, and J. Torrens. On migrative t-conorms and uninorms. In *International Conference on Information Processing and Management of Uncertainty*, 2012.
15. D. Pan, H. Zhou, and X. Yan. Characterizations for the migrativity of continuous t-conorms over fuzzy implications. *Fuzzy Sets and Systems*, 456:173–196, 2023.
16. J. Qiao and B. Q. Hu. On generalized migrativity property for overlap functions. *Fuzzy Sets and Systems*, 357:91–116, 2019. Theme: Aggregation Functions.
17. S. Saminger-Platz, R. Mesiar, and D. Dubois. Aggregation operators and commuting. *IEEE Transactions on Fuzzy Systems*, 15:1032–1045, 2007.
18. S. Saminger-Platz, P. Sarkoci, and B. D. Baets. The dominance relation on the class of continuous t-norms from an ordinal sum point of view. 2006.
19. B. Schweizer and A. Sklar. *Probabilistic metric spaces*. Courier Corporation, 2011.
20. Y. Su, W. Zong, H. wen Liu, and F. Zhang. On migrativity property for uninorms. *Information Sciences*, 300:114–123, 2015.
21. C. Y. Wang, L. Wan, and B. Zhang. Notes on alpha-cross-migrativity of t-conorms over fuzzy implications. *Fuzzy Sets and Systems*, 473:108741, 2023.
22. W. Zong, Y. Su, and H. Liu. Migrative property for nullnorms. *Int. J. Uncertain. Fuzziness Knowl. Based Syst.*, 22:749–760, 2014.

Masonry strength assessment based on Fuzzy signature model

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Abstract: Fuzzy signatures have been successfully used for various engineering applications including the strength and condition assessment of structural mate-rials. In this paper, fuzzy signatures were used to determine the compressive strength of masonry based on groups of related measured values. Handling the uncertainty this way seemed useful because of the subjective parts and influencing noise factors of the measurements which are incorporated as leaves in the signature. For such modeling the structure from where the al-gebraic framework can be obtained which allows making computations with the fuzzy signatures thus determined. Since multiplicative type aggre-gations are applied on the various material test results assigned to the leaves of the signatures for the determination of the compressive strength of masonry, fuzzy arithmetic multiplication based on Zadeh's extension prin-ciple was applied here. To perform the fuzzy signature calculations, the sca-lar product and the n-th root of fuzzy numbers were used.

Keywords: Fuzzy signatures · Weighted geometric aggregations· Compressive strength· Masonry.

References

1. E. A, M. Shams, N. Yaqoob, N. Kausar, Y. Gaba, and N. Rafiq. Numerical scheme for finding roots of interval-valued fuzzy nonlinear equation with application in optimization. *Journal of Function Spaces*.
2. B. Bede and J. Fodor. Product type operations between fuzzy numbers and their applications in geology. *Acta Polytechnica Hungarica*, pages 123–139,.
3. A. Bukovics. Structural health analysis and fuzzy signature based intervention decision support modelling.
4. A. Dormány and Z. Orbán. Experimental investigation of the sonic velocity in historical masonry walls, pollack periodica: An international journal for engineering and information sciences.
5. E.N. *Eurocode 6: Design of masonry structures - Part 1-1: General rules for reinforced and unreinforced masonry structures*. European Committee For Standardization, Brussels.
6. J. Goguen. L-fuzzy sets. *J. Math. Anal. Appl*, 18:145–174.
7. L. Kóczy, M. Cornejo, and J. Medina. Algebraic structure of fuzzy signatures. *Fuzzy Sets and Systems*, 418:25–50.
8. G. Molnárka and L. Kóczy. Decision support system for evaluating existing apartment buildings based on fuzzy signatures. *Int. J. Comput. Commun. Control*, 6(3):442–457.
9. L. Zadeh. Fuzzy sets. *Inform. and Control*, 8:338–353.