Concept Lattices and Attribute Implications for Patient Outcomes after Cardiac Arrest

Daniela Pillárová, Nicol Fedurcová, Roland Marek Rak,
Viktor Pristaš, Manohar Gowdru Shridhara, Ľubomír Antoni,
Ondrej Krídlo, and Stanislav Krajči

Institute of Computer Science, Faculty of Science
Pavol Jozef Šafárik University in Košice, 041 80 Košice, Slovakia
daniela.pillarova@student.upjs.sk, nicol.fedurcova@student.upjs.sk,
roland.marek.rak@student.upjs.sk, viktor.pristas@upjs.sk,
manohar.gowdru.shridhara@student.upjs.sk, lubomir.antoni@upjs.sk,
ondrej.kridlo@upjs.sk, stanislav.krajci@upjs.sk

Abstract Formal concept analysis [1] can be seen as a method based on the theory of lattices, which investigates an object-attribute block of relational data in bivalent form, whereby the theoretical foundations arise in several applications.

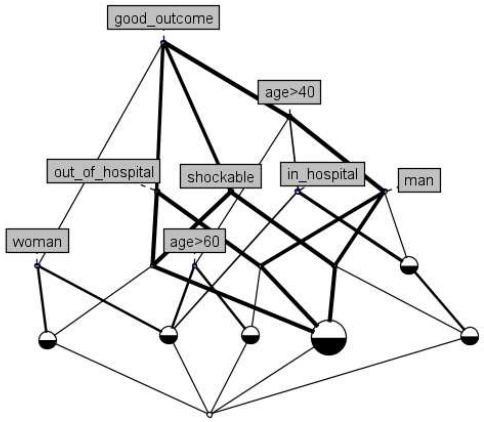

Fig. 1. Concept lattice of patients after cardiac arrest

Data analysis of EEG recordings is important since it is possible to study headaches, migraines, epilepsy, various sleep disorders (e.g., narcolepsy), brain damage, and how neuronal connections in the brain develop in newborns or the first six months of a child's life [2]. In our contribution, we analyzed metadata of patients from George B. Moody PhysioNet Challenge 2023, which aimed to apply EEG recordings to predict poor and good patient outcomes after cardiac arrest [3]. In particular, we generated a set of formal concepts based on data from 607 patients. Patient metadata includes information recorded at the time

of admission (age>40, age>60, gender), the location of arrest (out or in-hospital), the type of cardiac rhythm recorded at the time of resuscitation (shockable or not), and outcome (good or poor).

In our solution, we considered the non-empty sets B, A, and a crisp binary relation $R \subseteq B \times A$. A triple $\langle B, A, R \rangle$ is called a formal context. The elements of the sets B, A are called objects and attributes, respectively. A relation R is called an incidence relation. The operators that act on the input data are defined to discover the hidden information in the formal context. We can compute the so-called formal concepts, including the pairs of subsets of objects and attributes. The example of concept lattice for metadata of patients is shown in Figure 1. Moreover, we present several interesting attribute implications in Table 1.

Table 1. Attribute implications for patients after cardiac arrest

Association rule	Support	Confidence
$\{\text{man}, \text{shockable}, \text{good-output}\} \rightarrow \{\text{out-hospital}\}$	117	90%
$\{\text{out-hospital}, \text{good-output}, \text{age>40}\} \rightarrow \{\text{shockable}\}$	151	87 %

We interpret the obtained results based on patients' poor and good outcomes. From the theoretical point of view, we investigate the additional properties of the decomposition of fuzzy formal contexts, the properties of formal concepts in a fuzzy setting, and the heterogeneous attribute implications. Our inspiration comes from the papers [4, 5].

Keywords: Formal concept analysis · Attribute implications · EEG recordings.

Acknowledgements The paper was supported by the Slovak Research and Development Agency under contract No. APVV-21-0468. It was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic under contract VEGA 1/0645/22.

References

1. Ganter, B., Wille, R.: Formal concept analysis: mathematical foundations. Springer Science & Business Media (2012)
2. Hirsch L. J., Fong M. W., Leitinger M., et al.: American Clinical Neurophysiology Society's standardized critical care EEG terminology. J. Clin. Neurophysiol. 38(1), 1 (2021)
3. Goldberger, A.L., Amaral, L.A., Glass L., et al.: PhysioBank, PhysioToolkit, and PhysioNet: Components of a new research resource for complex physiologic signals. Circulation. 101(23): e215-e220 (2023)
4. Aragón, R.G., Medina, J., Ramírez-Poussa, E.: Factorizing formal contexts from closures of necessity operators. Comput. Appl. Math. 43(3): 124 (2024)
5. Ojeda-Hernández, M., Cabrera, I.P., Cordero, P., Muñoz-Velasco, E.: Fuzzy closure structures as formal concepts. Fuzzy Sets Syst. 463: 108458 (2023)