Formal Concept Analysis and Attribute Implications for Electricity Consumption

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Abstract Formal concept analysis [1] is a set of mathematical and computational data analysis methods based on algebraic and set theory. These biclustering methods can be useful for discovering hidden patterns and providing thorough insights into the data in many areas. Analyzing the formal concepts and their relationships can discover meaningful dependencies and associations (or so-called attribute implications), which might not be apparent through other data analysis methods.

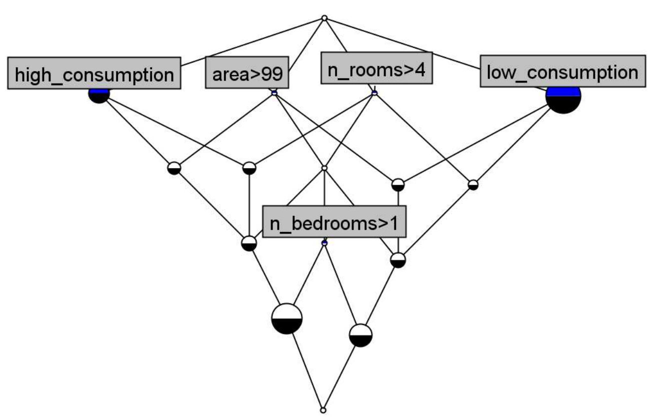

Fig. 1. Concept lattice of data analysis of electricity consumption

Data analysis of electricity consumption is important for several reasons [2]. It impacts energy management, environmental sustainability, and economic planning. In this paper, we analyze electrical power consumption using a multifamily residential electricity dataset in the Northeastern United States [3] by Formal concept analysis. In particular, we consider a set of 26 groups of apartments $O = \{o_1, o_2, \ldots, o_{26}\}$ and index of timestamp $T = \{t_1, t_2, \ldots, t_{35040}\}$ at 15 minutes time resolution. Thus, the value $P(o, t)$ expresses the instantaneous real power of the group $o \in O$ in the time $t \in T$. Analogously, the value $Q(o, t)$ is used for the instantaneous reactive power of the group $o \in O$ in the time $t \in T$.

The example of concept lattice for aggregated attributes of number of rooms, number of bedrooms, area of apartment, or type of consumption is shown in Figure 1. Moreover, we present several interesting attribute implications in Table 1.

Table 1. Attribute implications for electricity consumption

Association rule	Support	Confidence
{area>99, high_consumption} → {n_rooms>4}	96	95%
{n_bedrooms>1, n_rooms>4} → {high_consumption}	120	65%

As a natural continuation of our research, we analyze the active and reactive power data of 70,000 households provided by the distribution system operator „Východoslovenská distribučná a.s.“ located in the eastern part of Slovakia. Since the input data are object-attribute tables, we apply Formal concept analysis and its fuzzy extensions [4, 5] to detect data anomalies or cluster the households based on their electricity consumption. From the theoretical point of view, we investigate the additional properties of attribute implications in a fuzzy setting.

Keywords: Formal concept analysis · Attribute implications · Electricity

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References

1. Ganter, B., Wille, R.: Formal concept analysis: mathematical foundations. Springer Science & Business Media (2012)
2. Aragón, R.G., Cornejo, M.E., Medina, J., García, J.M., Ramírez-Poussa, E.: Decision Support System for Photovoltaic Fault Detection Avoiding Meteorological Conditions. Int. J. Inf. Technol. Decis. Mak. 21(3): 911-932 (2022)
3. Meinrenken, C. J., Rauschkolb, N., Abrol, S., et al. MFRED, 10 second interval real and reactive power for groups of 390 us apartments of varying size and vintage. *Scient. Data* **7**, 375 (2020). ISSN 2052-4463. `doi:10.1038/s41597-020-00721-w`
4. Ojeda-Hernández, M., Cabrera, I.P., Cordero, P., Muñoz-Velasco, E.: Fuzzy closure structures as formal concepts. Fuzzy Sets Syst. 463: 108458 (2023)
5. Cordero, P., Enciso, M., López-Rodríguez, D., Mora, A: fcaR, Formal Concept Analysis with R. R J. 14(1): 341-361 (2022)