Advance Journal of Food Science and Technology 10(11): 870-873, 2016
DOI: 10.19026/ajfst.10.2278
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: July 2, 2015 Accepted: August 2, 2015 Published: April 15, 2016

Research Article

Concept Lattices in Green Farmland Databases and Concept Intent Reduction for the Mass Food Production

[1]Yuxia Lei and [2]Jingying Tian
[1]School of Computer Science and Technology, Qufu Normal University,
[2]School of Architectual Engineering, Rizhao Politechnic, Rizhao 276826, China

Abstract: Formal Concept Analysis (FCA) in green farmland databases and Concept Intent Reduction for the mass food production provides a method for extracting concepts from binary contexts. However, FCA-concepts cannot describe negations and disjunctions of attributes. Hence, we take the logic operators into consideration in the process of constructing concepts and obtain new extended concepts, which are more expressive than FCA-concepts. This study mainly discusses the connections between FCA-concepts and concepts with logic values in green farmland databases and concept intent reduction for the mass food production and provides a method for reducing concepts. The reduction does not lose essential information. Results can be used in data mining and construction of architecture ontology.

Keywords: Concept lattices, concept intent reduction, green farmland databases, mass food production

INTRODUCTION

In Computer Science and architecture, the semantics of data can be advantageously exploited to better retrieve and efficiently discover relevant patterns which are a concise and semantically rich representation of data. Patterns can be clusters, concepts and so on. In this study we present alternate ways to extract concepts from binary green farmland databases.

Formal Concept Analysis (FCA) (Ganter and Wille, 1999) is a data technique which automatically generates concept lattices from binary relations. A node of concept lattices is an objects/attributes pair, called a formal concept, consisting of two parts: the extent (objects the concept covers) and intent (attributes describing the concept). Concept lattices have already been applied to a wide range of disciplines such as knowledge discovery (Belohlavek *et al*., 2014; Berghammer and Winter, 2013; Huchard *et al*., 2007; Jiang and Deogun, 2007; Lei *et al*., 2009; Missaoui *et al*., 2012; Poelmans *et al*., 2010), information retrieval, software engineering (Jay *et al*., 2008; Tilley and Eklund, 2007), rough set theory (Jiang *et al*., 2010; Qu *et al*., 2007; Yao, 2004; Wei and Qi, 2010; Zhou and Yao, 2010), knowledge ontology (Ge *et al*., 2012; Chunping and Liu, 2012) and the connections with description logics (Bazin and Ganascia, 2012; Ma *et al*., 2012).

Recently, a main axis of research on FCA has aimed at extending the classical FCA, either by scaling methods (Ganter and Wille, 1999; Lei *et al*., 2009) or by extending the definition of the Galois connection (Huchard *et al*., 2007; Jiang *et al*., 2010). One of the disadvantages of scaling methods is that it is very sensitive to user's selection of scale attributes. Our main contributions in this study are to propose an approach towards constructing concepts, which can extract more interesting concepts from binary relations, without using any scaling method. For example, for the binary relation of an educational film "Living Beings and Water" described, the classical FCA can only describe that Leech, Bream, Frog, Spike-weed and Reed live in water, but not describe that all of Dog, Bean and Maize do not live in water. Similar to conjunction, negation and disjunction are also important logic operators, which are common in human language (e.g., not young). Therefore, it is necessary to extend the classical FCA-concepts to improve the expressiveness of concepts. Hence, we take the logic operators into consideration in the process of constructing concepts and obtain new extended concepts, which are more expressive than the classical FCA-concepts.

This study mainly provides some properties of the extended concepts and a method for reducing their intents. The reduction not only simplifies concept representation, but does not lose essential information.

Corresponding Author: Yuxia Lei, School of Computer Science and Technology, Qufu Normal University, Rizhao 276826, China

Table 1: Relation between objects and ϕ-statements

Objects	*a*	*b*	*c*
r_1	1	1	0
r_2	0	1	1
r_3	1	0	0
r_4	0	0	1

CONCEPTS WITH LOGIC VALUES AND CORRESPONDING CONCEPT LATTICES

Given a binary relation R = (G, M, I), we can built complex statements from attributes in M inductively with negation (¬), disjunction (∨), conjunction (∧) and implication (→). Because for any statements ϕ and φ, "ϕ → φ ⇔ ¬ϕ ∨ φ", we can define ϕ-statements with negation and disjunction as follows: ϕ = *a*|¬*a*|ϕ1∨ϕ2, where *a*∈M. Let Φ be the set of ϕ-statements. For any *r*∈G and *a*∈M, *r* always possesses or does not have *a*, that is, *r* always satisfies the property *a*∨(¬*a*). Hence, we delete all of ϕ-statements with the form *a*∨(¬*a*) from Φ.

Example 1: Given the following binary relation R = (G, M, I), we obtain some ϕ-statements such as *a*, ¬*a*, *a* ∨*b*, *b* ∨(¬*c*) and *a* ∨(¬*b*) ∨*c* (Table 1).

Then, we define the satisfaction relation between objects and ϕ-statements as follows: for any object *r*∈ G and ϕ-statement ϕ∈Φ, we say that r satisfies ϕ, denoted by r| = R ϕ, if:

$$\begin{Bmatrix} r(a)=1, & if\ \phi=a \\ r(a)=0, & if\ \phi=\neg a \\ r|=\delta\, or\, r|=\varphi, & if\ \phi=\delta\vee\varphi \end{Bmatrix}$$

Which correspondingly induces the following two maps α and β between the power P(G) of G and the power set P(Φ) of Φ. For any X⊆G, α(X) is defined as follows: α(X) = {ϕ∈Φ: ∀r∈G, r| = Rϕ}, which is the set of ϕ-statements satisfied by the objects in X. For any Y⊆Φ, β(Y) is defined as follows: β(Y) ={r∈G: ∀ϕ∈Φ, r|=R ϕ}, which is the set of objects which satisfy all ϕ-statements in Y.

Definition 1: The pair (X, Y) is called a R_L-concept, if X = β(Y) and Y = α(X). We call X and Y the extent and the intent of (X, Y), respectively. *LL*(R) denotes the set of all R_L-concepts.

For any two R_L-concepts (X1,Y1) and (X2,Y2), (X2,Y2) is called a super-concept of (X1, Y1), denoted by (X1,Y1) ≤ (X2,Y2), if X1 ⊆ X2(⇔ Y2 ⊆ Y1). Therefore, we have (X1, Y1) ≤ (X2, Y2) ⇔ X1 ⊆ X2 ⇔ Y2 ⊆ Y1. Specially, for any object *r*∈G, (βα(r), α(r)) is always a RL-concept, called an atomic R_L-concept. The set of all atomic RL-concept is denoted by L(Atom(R)).

Example 2: The binary relation R in Example 1 has 16 R_L-concepts. For example, ({r_1, r_3}, {*a*,¬*c*}), which is the reduced form.

Similar to the classical FCA-concepts, the intersection of any number extents (intents) of R_L-concepts is always an extent (intent). Generally, the union of extents of the classical FCA-concepts does not result in an extent, while the union of extents of R_L-concepts is exactly the extent of some R_L-concept. The reasons are as follows: from the logic point of view, each intent is actually equivalent to the conjunction of some ϕ-statements, that is, each intent is represented as a Conjunctive Normal Form (CNF). Thus, given two RL-concepts, we immediately obtain two CNFs from their intents and the disjunction of them can be transformed into a CNF. The set of objects satisfying the CNF is exactly the union of the two extents. Based on the above description, there is therefore the following proposition:

Proposition 1: β (Y1∩(Y2∪Y3)) = X1∪(X2∩X3)

Proof: On the one hand, it is easily inferred that X1∪(X2∩X3) ⊆ β(Y1∩(Y2∪Y3)) holds. On the other hand, β(Y1∩(Y2∪Y3)) ⊆ X1 ∪ (X2∩X3). Or else, there is an object r∈β(Y1∩(Y2∪Y3)) but r∉X1∪(X2∩X3) and hence r∉X1 and r∉X2∩X3. By r∉X1, there is ϕ1∈Y1 satisfying r0|≠Rϕ1. By r∉X2∩X3, there is r∉X2 or r∉X3. Hence, there are the three cases as follows:

Case 1: r∉X2 and r∈X3. There is ϕ2∈Y2 satisfying r0|≠Rϕ2. Hence, there is r0|≠Rϕ1∨ϕ2. Because ϕ1∨ϕ2 ∈Y1∩(Y2∪Y3), there is r0|=Rϕ1∨ϕ2, which leads to a contradiction.

Case 2: r∈X2 and r∉X3. There is ϕ3∈Y3 satisfying r0|≠Rϕ3. Hence, there is r0|≠Rϕ1∨ϕ3. Because ϕ1∨ϕ3∈ Y1∩(Y2∪Y3), there is r0|=Rϕ1∨ϕ3, which leads to a contradiction.

Case 3: r∉X2 and r∉X3. There are ϕ2∈Y2 and ϕ3∈Y3 satisfying r0|≠Rϕ2 and r0|≠Rϕ3, respectively. Hence, r0|≠Rϕ1∨ϕ2∨ϕ3. Because ϕ1∨ϕ2∨ϕ3∈Y1∩(Y2∪Y3), there is r0|=Rϕ1∨ϕ2∨ϕ3, which leads to a contradiction.

REDUCTION OF R_L-CONCEPTS

Now, we discuss the intents of R_L-concepts and provide a method for reducing the intents of R_L-concepts. Our idea is as follows: We regard ϕ-statements as formulas in predicate logic and then apply the inference rules to reducing the intents of R_L-concepts.

We assume that the ϕ-statements in intents are drawn from a linearly ordered set. That is, we write the ϕ-statement according to the numbers of positive attributes and negative ones contained in these statements. For example, an intent Y can be represented as a set {a, b, a∨b, b∨c, b∨c∨(¬d)} or {b, a, b∨c, a∨b, b∨c∨(¬d)} but not {a∨b, a, b, b∨c, b∨c∨(¬d)}. Now, we introduce formal inference rules as follows:

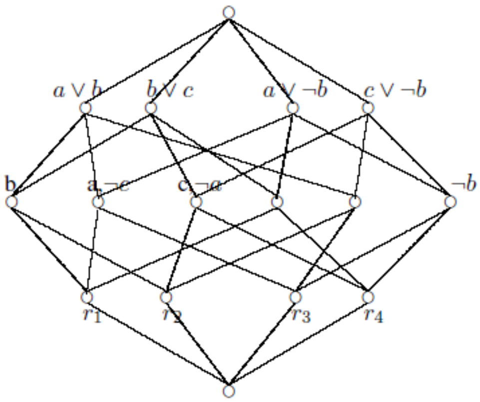

Fig. 1: Concept lattice with operators

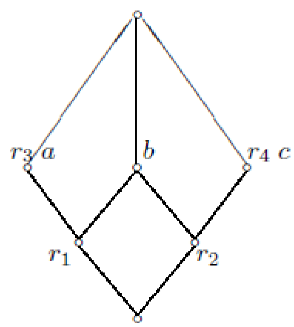

Fig. 2: Concept lattice

(Reflexivity)	$\phi \vdash \phi$
$(\vee^{+})$	If $\phi \vdash \phi_1$, then $\phi \vdash \phi_1 \vee \phi_2$ and $\phi \vdash \phi_2 \vee \phi_1$.

For any three ϕ-statements ϕ, ϕ1 and ϕ2, the inference rules are sound, that is, if ϕ|–ϕ1, then for any object r∈G, r|=Rϕ implies r|=Rϕ1. Given a R_L-concept (X, Y), for any ϕ∈Y, we define Thus, we provide the following algorithm for reducing intents.

Algorithm for reducing intents:
Input: A R_L-concept (X, Y)
Output: The reduced form Core(Y) of the intent Y
Process
1. Core(Y) ← { }
2. Begin
3. While Y≠ ∅ Do
4. Begin
5. For the first ϕ-element ϕ∈Y, computing $\Gamma_Y(\phi)$
6. Y ← Y − $\Gamma_Y(\phi)$
7. Core(Y) ← {ϕ}
8. End
9. End

Example 3: Let Y = {a, b, a∨b, b∨c, b∨c∨(¬d)} be an intent. By the algorithm, we can obtain Core(Y) = {a, b} by the following two loops:

Loop 1: The attribute a is the first element in Y and $\Gamma_Y(a)$ ={ a, a∨b}. Hence, new Y = {b, b∨c, b∨c∨(¬d)} and Core(Y) = {a}.

Loop 2: The attribute b is the first element in Y and $\Gamma_Y(b)$ = {b, b∨c, b∨c∨(¬d)}. Hence, new Y = ∅ and Core(Y) = {a, b}.

In fact, the union/intersection of extents of RL-concepts always results in an extent. The relation R in EXAMPLE 1 has 7 concepts. We use the reduced labelling in order to improve the readability of the lattice. The line diagram in Fig. 1 represents the concept lattice with logic operators. Figure 2 is the concept lattice.

By proposition 1, it is easily inferred that *LL*(R) is a distributive lattice. Furthermore, for R_L-concepts, the set of any number objects is always an extent of some R_L-concept. Hence, given a R_L-concept (X, Y), (G-X, α(G-X)) is also a R_L-concept, called complement R_L-concept of (X, Y) and denoted by ~(X, Y). Thus, each R_L-concept has corresponding complement R_L-concept and hence *LL*(R) is a complement distributive lattice.

By Stone representation theorem, *LL*(R) is isomorphic to the power-set lattice P(Atom(R)).

Proposition 2: Given a binary relation R, (*LL*(R), ∨, ∧, ~) ≅ (P(Atom(R)), ∪, ∩, −).

THE CONNECTION BETWEEN CONCEPT LATTICES

Now, we discuss the connection between *L*(R) and *LL*(R). From example 3, we find that the extent of each classical FCA-concept in R is also the extent of some RL-concept. Thus, for any classical FCA-concept (X, Y), we can construct a R_L-concept (X, α(X)). Hence, there is a natural mapping from *L*(R) to *LL*(R), which is an infimum-preserving order-embedding, as shown in proposition.

Proposition 3: For any FCA-concept (X, Y)∈*L*(R), let τ((X,Y)) = (X, α(X))∈*LL*(R). Then τ is an infimum-preserving order-embedding.

Proof: Firstly, it is easily inferred that τ is an order-embedding and ∨-preserving. Conversely, for any RL-concept (X, Y), Y∩M is the maximal set of attributes common to the objects in X and then Y∩M is the intent of some concept of R. Thus, we can obtain a supremum-preserving order-preserving map from *L*(R) to *LL*(R), which can be proved in a similar fashion.

Proposition 4: There is a map from LL(R) to *L*(R) such that for any (X, Y) ∈*LL*(R):

$$\gamma((X,Y)) = (h(Y \cap M), Y \cap M)$$

which is surjective supremum-preserving order-preserving.

CONCLUSION

This study provides a kind of extended FCA-concepts. Compared with the classical FCA-concepts, the extended concepts are more expressive. We provide some interesting connections between *L*(R) and *LL*(R). Our results can be used to extract discovery from data and construct architecture ontology.

Two of the interesting problems are how to define concepts in relations with imprecise information. Future works focus on these questions.

ACKNOWLEDGMENT

This study is supported by the Natural Science Foundation of Shandong Province under Grant No.ZR2011FQ026.

REFERENCES

Bazin, A. and J.G. Ganascia, 2012. Completing terminological axioms with formal concept analysis. Proceeding of the International Conference on Formal Concept Analysis (ICFCA, 2012). Lewen, Belgique, 2: 29-40.

Belohlavek, R., B. De Baets and J. Konecny, 2014. Granularity of attributes in formal concept analysis. Inform. Sciences, 260: 149-170.

Berghammer, R. and M. Winter, 2013. Decomposition of relations and concept lattices. Fund. Inform., 126(1): 37-82.

Chunping, O. and Y.B. Liu, 2012. Formal concept analysis supporting ontology learning from database. Adv. Sci. Lett., 7(5): 473-477.

Ganter, B. and R. Wille, 1999. Formal Concept Analysis: Mathematical Foundation. Springer-Verlag, Berlin, NY.

Ge, J.K., Z.S. Li and T.F. Li, 2012. A novel chinese domain ontology construction method for petroleum exploration information. J. Comput., 7(6): 1445-1452.

Huchard, M., M.R. Hacene, C. Roume and P. Valtchey, 2007. Relational concept discovery in structured datasets. Ann. Math. Artif. Intell., 49: 39-76.

Jay, N., F. Kohler and A. Napoli, 2008. Using formal concept analysis for mining and interpreting patient flows within a healthcare network. In: Yahia, S., E. Nguifo and R. Belohlavek (Eds.), Concept Lattices and their Applications. LNAI 4923, Springer, Berlin, Heidelberg, pp: 263-268.

Jiang, F., Y.F. Sui and C.G. Cao, 2010. Relational contexts and relational concepts. Fund. Inform., 99(3): 293-314.

Jiang, L.Y. and J. Deogun, 2007. SPICE: A new framework for data mining based on probability logic and formal concept analysis. Fund. Inform., 78(4): 467-485.

Lei, Y., Y. Sui and C. Cao, 2009. Normalized-scale relations and their concept lattices in relational databases. Fund. Inform., 93(4): 393-409.

Ma, Y., Y. Sui and C. Cao, 2012. The correspondence between the concepts in description logics for contexts and formal concept analysis. Sci. China Inform. Sci., 55(5): 1106-1122.

Missaoui, R., L. Nourine and Y. Renaud, 2012. Computing implications with negation from a formal context. Fund. Inform., 115: 357-375.

Poelmans, J., P. Elzinga, S. Viaene and G. Dedene, 2010. Formal Concept Analysis in knowledge discovery: A survey. In: Croitoru, M., S. Ferré and D. Lukose (Eds.), ICCS, 2010. LNAI 6208, Springer-Verlag, Berlin, Heidelberg, pp: 139-153.

Qu, K.S., Y.H. Zhai, J.Y. Liang and D.Y. Li, 2007. Representation and extension of rough set theory based on formal concept analysis. J. Softw., 18: 2174-2182.

Tilley, T. and P. Eklund, 2007. Citation analysis using formal concept analysis: A case study in software engineering. Proceeding of the 18th International Conference on Database and Expert Systems Applications.

Wei, L. and J.J. Qi, 2010. Relation between concept lattice reduction and rough set reduction. Knowl-Based Syst., 23: 934-938.

Yao, Y.Y., 2004. A Comparative Study of Formal Concept Analysis and Rough Set Theory in Data Analysis. In: Tsumoto, S., R. Slowinski, H.J. Komorowski, J.W. Grzymala-Busse (Eds.), RSCTC, 2004. LNAI 3066, Springer-Verlag, Berlin, Heidelberg, pp: 59-68.

Zhou, B. and Y.Y. Yao, 2010. Inform. Sci. Refer., United States, 1: 325.