A Study on Fuzzy Relational Database Model using Relational Calculus

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論　文　内　容　の　要　旨

The relational database models was first introduced by Codd in 1970 and developed by Atzeni in 1993. One of the advantage of relational model is soundness and consistency of data. A procedure of data processing is sometime described by dynamic sequences of operations which may have ambiguities in its implementation. Since a procedure in the relational database model are defined by a static formula, we can avoid inconsistencies in their implementations. In 2000, Okuma formulated the relational database model using a theory of relational calculus on the Dedekind Category. Since the Dedekind Category includes the category of fuzzy relations, we can formulate a fuzzy relational database model using the relational calculus on the category of fuzzy relations. In 1988, Kawahara introduced several applications of relational calculus in computer mathematics. Later a theory of relational calculus have been developed by Mizoguchi, Mori, Furusawa and Okuma et al.

This thesis composed of five Chapters.

In Chapter 1, we presents basic terminologies and key results related of fuzzy relations and its operations, which will be used throughout this thesis.

In Chapter 2, we introduce a formalization of a fuzzy relational database model using relational calculus on the category of fuzzy relations. We also introduce general formulas for notions of database operations such as 'projection', 'selection', 'injection' and 'natural join' which can be used for both traditional and fuzzy database models. We prove several elementary properties of database operations using relational calculus.

In Chapter 3, we show the soundness and the completeness of Armstrong's inference rules of the functional dependency (implication or association rule) with respect to fuzzy relational databases.

Okuma and Kawahara improved relational database aspects using Dedekind category.

In 2009, Ishida et al. presented relational formulations for Armstrong's inference rules and implication in a Dedekind category. They showed a proof of the completeness theorem for Armstrong's inference rules in Schrőder category. We follow their approach introduced by Okuma, Kawahara and Ishida especially focusing on fuzzy relations using relational calculus. Ganter and Wille investigated formal concept analysis in 1999, they introduced properties such as equivalence relation, implication dependency, functional dependency, etc. We also extend the notions using our relational calculus framework. We introduce a formalization of fuzzy equivalence relation, fuzzy implication dependency and functional dependency. The formalization can be use to analyze equivalence condition between functional and implication. We prove theorems in our formalization of fuzzy concepts using relational calculus. Since our proof is using relational calculus, it is simple and its correctness can be easily verified. We also show some logical comparison theorems between a fuzzy implication and a functional dependency. Further, we show the comparison theorems have important aspects for making algorithm of fuzzy functional and implication dependency. Finally, we explain implemented operations in our fuzzy formal concept analysis using

Mathematica software. We show some examples in the application of data analysis. Since formal concept analysis is an important theory for data analysis, our formalization is useful for data analysis. Future work includes to construct a theory of fuzzy relational database theory with computer verified formal proofs using relational calculus. We try to summarize them, providing uniform proofs in a simple way.

In Chapter 4**,** we formalize an equivalence class (FEC) of the fuzzy relational database (FRDB). As an extension of the degree of membership concept for sets elements, we have similarity relationship. Here the domain elements are considered as having varying degrees of similarity, replacing the idea of exact equality / inequality. To deal with fuzzy data constraint, In 1971, Zadeh has introduced the concept of particularization (restriction) of fuzzy relation due to a fuzzy proposition. The particularization of fuzzy relational database due to a set of fuzzy integrity constraints can be computed by combining the fuzzy propositions associated with these integrity using relational calculus. In 1990, Shenoi and Melton tried to implement the fuzzy equivalence relation to the relational database using fuzzy similarity relation from Zadeh's model. In this chapter, each definition of notion in their paper are redefined formally using relational formulas, and also we show corresponding theorem using relation calculus.

In Chapter 5, we showed the experimental results about some application using our formalization using fuzzy relational calculus. In 1992, Kong and Kosko introduced the simple control problem of truck backer-upper. The truck can be moved automatically from an initial position with an angle of truck to a target position. So, we control the angle of steer, then the truck will move step by step. In 1994, Freeman has been solved the problem using fuzzy logic. Then, we apply our formulation to an example of the truck backer-upper problem using fuzzy logic introduced by Freeman. In our framework, every fuzzy states, procedures are describe as database tables of the fuzzy relational database theory. Problem solving procedures are also described by static formulas of the relational calculus on the category of fuzzy relations. We use database operations to operate the fuzzy system. We also define every process using relational calculus such as membership function, mamdani's procedure, defuzzication process, etc. We showed an example of simple industry problem in which our formalization can be applied.