

# A New Approach for Query Processing and Optimization Base on the Fuzzy Object Algebra and Equivalent Transformation Rules

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## ABSTRACT

For enhancing the efficiency of processing users' queries, all Database Management Systems (DBMSs) must conduct query pre-processing, or query optimizing. This paper proposes a new model for the Fuzzy Object Oriented DBMS (FOO-DBMS), which optimizes the query statements and processes the data before returning back to users based on Fuzzy-Object-Algebra and equivalent transformation rules. Discussions on this model are also presented with computation and analysis.

**Keywords:** Fuzzy association algebra; Fuzzy object algebra; Fuzzy Object Oriented Database; fuzzy object query language.

## 1 Introduction

The fuzzy object oriented database (FOO-DB) model contains unclear, uncertain, and inaccurate information. Hence, in order to deal with the ever-increasing and complex data, it is always time and resource consuming. Typically, a database management system works well if its components perform efficient processing (less processing time, less resources). This paper proposes a new approach to optimizing and processing query based on the fuzzy object algebra (FOA) expression and the rules of equivalent transformation. This approach is the main idea of our proposed model which is analyzed and discussed later in the paper.

A few propositions has been introduced on query translation and optimization [2]. Similar research in OODB has also been presented in [3], [4] are still very useful for the development of the concerning part of our study which are used to translate user queries from FOQL to fuzzy object algebra.

The remaining part of the paper includes of part 2 introduce about fuzzy algebraic operations in FOODB, part 3 proposes a new model for the Fuzzy Object Oriented DBMS (FOO-DBMS), which optimizes the query statements and processes the data before returning back to users based on Fuzzy-Object-Algebra and equivalent transformation rules, the analysis on several experiments using the proposed algorithm shows

better performance of query processing, which proves the efficiency enhancement of our method are presented in part 4, and the conclusion is stated in part 5.

## 2 Fuzzy Object Algebra In FOODB

### 2.1 Association operators

A new fuzzy class ( $\widetilde{FC}$ ) can be created by combining two existing fuzzy classes. Depending on the relationships between the attributes of the combination classes: There are six types of binary combination and two types unary operations can be defined such as (1) fuzzy union ( $\widetilde{\cup}$ ), (2) fuzzy intersection ( $\widetilde{\cap}$ ), (3) fuzzy join ( $\widetilde{\bowtie}$ ), (4) fuzzy Cross product/Cartesian ( $\widetilde{\times}$ ), (5) fuzzy difference ( $\widetilde{\simeq}$ ), (6) fuzzy division ( $\widetilde{\simeq}$ ), (7) fuzzy projection ( $\widetilde{\Pi}$ ), and (8) fuzzy selection ( $\widetilde{\sigma}$ ) are denote in [1]. For two fuzzy classes  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$  and let Attribute  $FA(fA_1)$  &  $FA(fA_2)$  sets, respectively. Thus a new fuzzy class  $\widetilde{FC}$  is created from the combination of two classes  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$  is defined as follows:

1.  $\widetilde{FC} = \widetilde{FC}_1 \widetilde{\cup} \widetilde{FC}_2$ , if  $FA'(\widetilde{FC}_1) = FA'(\widetilde{FC}_2)$
2.  $\widetilde{FC} = \widetilde{FC}_1 \widetilde{\cap} \widetilde{FC}_2$ , if  $FA'(\widetilde{FC}_1) = FA'(\widetilde{FC}_2)$
3.  $\widetilde{FC} = \widetilde{FC}_1 \widetilde{\bowtie} \widetilde{FC}_2$ , if  $FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2) \neq \emptyset$  and  $FA'(fA_1) \neq FA'(fA_2)$
4.  $\widetilde{FC} = \widetilde{FC}_1 \widetilde{\times} \widetilde{FC}_2$ , if  $FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2) = \emptyset$
5.  $\widetilde{FC} = \widetilde{FC}_1 \widetilde{\simeq} \widetilde{FC}_2$ , if  $FA'(\widetilde{FC}_1) = FA'(\widetilde{FC}_2)$
6.  $\widetilde{FC} = \widetilde{FC}_1 \widetilde{\simeq} \widetilde{FC}_2$ , if  $FA'(\widetilde{FC}_1) = FA'(\widetilde{FC}_2)$
7.  $\widetilde{FC}' = \widetilde{\Pi}_{sub}(\widetilde{FC})$
8.  $\widetilde{FC}'' = \widetilde{\sigma}_{sub}(\widetilde{FC})$

In which,  $FA'(\widetilde{FC}_1)$  &  $FA'(\widetilde{FC}_2)$  are achieved from  $FA(\widetilde{FC}_1)$  &  $FA(\widetilde{FC}_2)$ , by removing the degree of their respective fuzzy attributes  $FA(\widetilde{FC}_1)$  &  $FA(\widetilde{FC}_2)$ . the  $\mu_{\widetilde{FC}}$  represents the membership degree of attributes belongs to class  $\widetilde{FC}$ . Suppose that  $\mu_{\widetilde{FC}}(o)$  be the object of fuzzy class  $\widetilde{FC}$ , and  $\mu_{\widetilde{FC}}(o)$  stands for the value of  $\mu_{\widetilde{FC}}(o)$  object on  $\mu_{\widetilde{FC}}$ . Let  $fA_i$  be the attribute of class  $\widetilde{FC}$ .  $\mu_{\widetilde{FC}}(o)(A_i)$  is the fuzzy value of object  $\mu_{\widetilde{FC}}(o)$  on  $fA_i$ . If  $FA = \{fA_1, fA_2, \dots, fA_m\}$  is a set of fuzzy attributes, then  $\mu_{\widetilde{FC}}(o)(FA)$  stands for all values of  $\mu_{\widetilde{FC}}(o)$  object on attributes in FA. More generally  $\mu_{\widetilde{FC}}(o)(\widetilde{FC})$  represents all values of  $\mu_{\widetilde{FC}}(o)$  on attributes of  $\widetilde{FC}$ . The formal conditions of fuzzy association operations are shown as follows:

#### 2.1.1 Fuzzy union ( $\widetilde{\cup}$ )

Through fuzzy union, new class  $\widetilde{FC}$  is made up of two fuzzy classes  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$ , requires  $FA'(fA_1) = FA'(fA_2)$ , it means that all related attributes of  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$  have the identical weights. Suppose the new  $\widetilde{FC}$  is the fuzzy union of  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$ . Then the  $\mu_{\widetilde{FC}}(o)$  of  $\widetilde{FC}$  are created from three types of  $\mu_{\widetilde{FC}}(o)$ . First, two types of  $\mu_{\widetilde{FC}}(o)$  are derived from the component class (for example, class  $\widetilde{FC}_1$ ) and do not coincide with any  $\mu_{\widetilde{FC}}(o)$  in the rest of component class (eg,  $\widetilde{FC}_2$ ) that satisfies the given threshold. Let  $\delta$  be the threshold.

$$\widetilde{FC} = \widetilde{FC}_1 \tilde{\cup} \widetilde{FC}_2 = \left\{ \mu_{\widetilde{FC}}(o) \left( \begin{array}{l} (\forall \mu_{\widetilde{FC}}(o)'') \left( \mu_{\widetilde{FC}}(o)'' \in \widetilde{FC}_2 \wedge \mu_{\widetilde{FC}}(o) \in \widetilde{FC}_1 \wedge \right. \\ \left. SE(\mu_{\widetilde{FC}}(o)(\widetilde{FC}_1), \mu_{\widetilde{FC}}(o)'(\widetilde{FC}_2)) < \delta \right)^\vee \\ (\forall o \mu_{\widetilde{FC}}(o)') \left( \mu_{\widetilde{FC}}(o)' \in \widetilde{FC}_1 \wedge \mu_{\widetilde{FC}}(o) \in \widetilde{FC}_2 \wedge \right. \\ \left. SE(\mu_{\widetilde{FC}}(o)(\widetilde{FC}_2), \mu_{\widetilde{FC}}(o)'(\widetilde{FC}_1)) < \delta \right)^\vee \\ \left( (\exists \mu_{\widetilde{FC}}(o)')(\exists \mu_{\widetilde{FC}}(o)'')(\mu_{\widetilde{FC}}(o)' \in \widetilde{FC}_1 \wedge \mu_{\widetilde{FC}}(o)'' \in \widetilde{FC}_2) \wedge \right. \\ \left. SE(\mu_{\widetilde{FC}}(o)'(\widetilde{FC}_1), \mu_{\widetilde{FC}}(o)''(\widetilde{FC}_2)) \geq \right. \\ \left. \delta \wedge \mu_{\widetilde{FC}}(o) = merge(\mu_{\widetilde{FC}}(o)', \mu_{\widetilde{FC}}(o)'') \right) \end{array} \right\} \quad (1)$$

In which,  $\mu_{\widetilde{FC}}(o)', \mu_{\widetilde{FC}}(o)''$  are two  $\mu_{\widetilde{FC}}(o)$  of  $\widetilde{FC}$  and  $\mu_{\widetilde{FC}}(o) = merge(\mu_{\widetilde{FC}}(o)', \mu_{\widetilde{FC}}(o)'')$ . Then  $\mu_{\widetilde{FC}}(o)(\widetilde{FC}) = \mu_{\widetilde{FC}}(o)'(\widetilde{FC})$  or  $\mu_{\widetilde{FC}}(o)(\widetilde{FC}) = \mu_{\widetilde{FC}}(o)''(\widetilde{FC})$  and  $\mu_{\widetilde{FC}}(o) = max(\mu_{\widetilde{FC}_1}(o)', \mu_{\widetilde{FC}_2}(o)'')$ .

### 2.1.2 Fuzzy intersection ( $\tilde{\cap}$ )

Through fuzzy intersection, new class  $\widetilde{FC}$  is made up of two fuzzy classes  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$ , request  $FA'(fA_1) = FA'(fA_2)$ . Let  $\delta$  be the threshold.

$$\widetilde{FC} = \widetilde{FC}_1 \tilde{\cap} \widetilde{FC}_2 = \left\{ \mu_{\widetilde{FC}}(o) \left( \begin{array}{l} (\forall \mu_{\widetilde{FC}}(o)'') \left( \mu_{\widetilde{FC}}(o)'' \in \widetilde{FC}_2 \vee \mu_{\widetilde{FC}}(o) \in \widetilde{FC}_1 \wedge \right. \\ \left. SE(\mu_{\widetilde{FC}}(o)(\widetilde{FC}_1), \mu_{\widetilde{FC}}(o)''(\widetilde{FC}_2)) < \delta \right)^\wedge \\ (\forall \mu_{\widetilde{FC}}(o)') \left( \mu_{\widetilde{FC}}(o)' \in \widetilde{FC}_1 \vee \mu_{\widetilde{FC}}(o) \in \widetilde{FC}_2 \vee \right. \\ \left. SE(\mu_{\widetilde{FC}}(o)(\widetilde{FC}_2), \mu_{\widetilde{FC}}(o)'(\widetilde{FC}_1)) < \delta \right)^\wedge \\ \left( (\exists \mu_{\widetilde{FC}}(o)')(\exists \mu_{\widetilde{FC}}(o)'') \left( \mu_{\widetilde{FC}}(o)' \in \widetilde{FC}_1 \vee \mu_{\widetilde{FC}}(o)'' \in \widetilde{FC}_2 \vee \right. \right. \\ \left. \left. SE(\mu_{\widetilde{FC}}(o)'(\widetilde{FC}_1), \mu_{\widetilde{FC}}(o)''(\widetilde{FC}_2)) \geq \right. \right. \\ \left. \left. \delta \wedge \mu_{\widetilde{FC}}(o) = minimize(\mu_{\widetilde{FC}}(o)', \mu_{\widetilde{FC}}(o)'') \right) \right) \end{array} \right\} \quad (2)$$

In which,  $\mu_{\widetilde{FC}}(o)', \mu_{\widetilde{FC}}(o)''$  are two  $\mu_{\widetilde{FC}}(o)$  of  $\widetilde{FC}$  and  $\mu_{\widetilde{FC}}(o) = minimize(\mu_{\widetilde{FC}}(o)', \mu_{\widetilde{FC}}(o)'')$ , we have  $\mu_{\widetilde{FC}}(o)(\widetilde{FC}) = \mu_{\widetilde{FC}}(o)'(\widetilde{FC})$  or  $\mu_{\widetilde{FC}}(o)(\widetilde{FC}) = \mu_{\widetilde{FC}}(o)''(\widetilde{FC})$  and  $\mu_{\widetilde{FC}}(o) = minimize(\mu_{\widetilde{FC}_1}(o)', \mu_{\widetilde{FC}_2}(o)'')$ .

### 2.1.3 Fuzzy join ( $\tilde{\bowtie}$ )

Through fuzzy join, new class  $\widetilde{FC}$  is made up of two fuzzy classes  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$ , in which  $FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2) \neq \emptyset$  and  $FA'(\widetilde{FC}_1) \neq FA'(\widetilde{FC}_2)$ .  $FA'(\widetilde{FC}_1) \cup (FA'(\widetilde{FC}_2) - (FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2)))$  are attributes for  $\widetilde{FC}$  and the membership degree of the attributes.  $\mu_{\widetilde{FC}}(o)$  of  $\widetilde{FC}$  are made up of a combination of  $\mu_{\widetilde{FC}}(o)$  in  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$  that are equivalent in semantics on  $FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2)$  under a given threshold. Let  $\delta$  be a the threshold.

$$\begin{aligned} \widetilde{FC} &= \widetilde{FC}_1 \bowtie \widetilde{FC}_2 \\ &= \left\{ \mu_{\widetilde{FC}}(o) \left( \begin{array}{l} (\exists \mu_{\widetilde{FC}}(o)')(\exists \mu_{\widetilde{FC}}(o)'') \\ \mu_{\widetilde{FC}}(o)' \in \widetilde{FC}_1 \wedge \mu_{\widetilde{FC}}(o)'' \in \widetilde{FC}_2 \wedge \\ SE \left( \begin{array}{l} \mu_{\widetilde{FC}}(o)' (FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2)), \\ \mu_{\widetilde{FC}}(o)'' (FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2)) \end{array} \right) \\ \geq \delta \wedge \mu_{\widetilde{FC}}(o) (FA'(\widetilde{FC}_1)) = \\ \mu_{\widetilde{FC}}(o)'(\widetilde{FC}_1) \wedge \mu_{\widetilde{FC}}(o) (FA'(\widetilde{FC}_2) - (FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2))) = \\ \mu_{\widetilde{FC}}(o)'' (FA'(\widetilde{FC}_2) - (FA'(\widetilde{FC}_1) \cap FA'(\widetilde{FC}_2))) \wedge \mu_{\widetilde{FC}}(o) = \\ op \left( (\mu_{\widetilde{FC}_1}(o)', \mu_{\widetilde{FC}_2}(o)'') \right) \end{array} \right) \right\} \quad (3) \end{aligned}$$

In which, operations of  $op$  are not defined. In most cases,  $op(\mu_{\widetilde{FC}_1}(o)', \mu_{\widetilde{FC}_2}(o)'')$  either  $\min(\mu_{\widetilde{FC}_1}(o)', \mu_{\widetilde{FC}_2}(o)'')$  or  $\mu_{\widetilde{FC}_1}(o)' \times \mu_{\widetilde{FC}_2}(o)''$ .

#### 2.1.4 Fuzzy Cross product/Cartesian ( $\widetilde{\times}$ )

Through fuzzy product, new class  $\widetilde{FC}$  is made up of two fuzzy classes  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$ , and membership degree attribute.

$$\begin{aligned} \widetilde{FC} &= \widetilde{FC}_1 \widetilde{\times} \widetilde{FC}_2 \\ &= \left\{ \mu_{\widetilde{FC}}(o) \left( \begin{array}{l} (\forall \mu_{\widetilde{FC}}(o)')(\forall \mu_{\widetilde{FC}}(o)'') \\ \mu_{\widetilde{FC}}(o)' \in \widetilde{FC}_1 \wedge \mu_{\widetilde{FC}}(o) (FA'(\widetilde{FC}_1)) = \\ \mu_{\widetilde{FC}}(o)'(\widetilde{FC}_1) \wedge \mu_{\widetilde{FC}}(o) (FA'(\widetilde{FC}_2)) = \\ \mu_{\widetilde{FC}}(o)''(\widetilde{FC}_1) \wedge \mu_{\widetilde{FC}}(o) = op(\mu_{\widetilde{FC}_1}(o)', \mu_{\widetilde{FC}_2}(o)'') \end{array} \right) \right\} \quad (4) \end{aligned}$$

In which, operations of  $op$  are not defined. In most cases,  $op(\mu_{\widetilde{FC}_1}(o)', \mu_{\widetilde{FC}_2}(o)'')$  either  $\min(\mu_{\widetilde{FC}_1}(o)', \mu_{\widetilde{FC}_2}(o)'')$  or  $\mu_{\widetilde{FC}_1}(o)' \times \mu_{\widetilde{FC}_2}(o)''$ .

#### 2.1.5 Fuzzy difference ( $\simeq$ )

The fuzzy difference of  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$  request  $FA'(fA_1) = FA'(fA_2)$ , which pulls all the properties in  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$  with the same weight numbers. For new class  $\widetilde{FC}$  is the fuzzy subtraction of  $\widetilde{FC}_1$  &  $\widetilde{FC}_2$ . Then, the objects of  $\widetilde{FC}$  are made up of two types of objects. The first type of object is derived from class  $\widetilde{FC}_1$  and does not appear in  $\widetilde{FC}_2$  satisfying the given threshold. The second type of object obtained by moving duplicate objects in  $\widetilde{FC}_1$  satisfies the given threshold. Let  $\delta$  be a the threshold.

$$\begin{aligned} \widetilde{FC} &= \widetilde{FC}_1 \simeq \widetilde{FC}_2 = \left\{ \mu_{\widetilde{FC}}(o) \left( \begin{array}{l} (\forall \mu_{\widetilde{FC}}(o)'') \left( SE \left( \mu_{\widetilde{FC}}(o)'' \in \widetilde{FC}_2 \wedge \mu_{\widetilde{FC}}(o) \in \widetilde{FC}_1 \wedge \right. \right. \\ \left. \left. SE \left( \mu_{\widetilde{FC}}(o) (\widetilde{FC}_1), \mu_{\widetilde{FC}}(o)'' (\widetilde{FC}_2) \right) < \delta \right) \vee \right. \\ \left. \left. \left( (\exists \mu_{\widetilde{FC}}(o)')(\exists \mu_{\widetilde{FC}}(o)'') (\mu_{\widetilde{FC}}(o)' \in \widetilde{FC}_1 \wedge \mu_{\widetilde{FC}}(o)'' \in \widetilde{FC}_2) \wedge \right. \right. \\ \left. \left. SE \left( \mu_{\widetilde{FC}}(o)' (\widetilde{FC}_1), \mu_{\widetilde{FC}}(o)'' (\widetilde{FC}_2) \right) \geq \delta \wedge \mu_{\widetilde{FC}}(o) = \right. \right. \\ \left. \left. remove(\mu_{\widetilde{FC}}(o)', \mu_{\widetilde{FC}}(o)'') \right) \right) \right\} \quad (5) \end{aligned}$$

### 2.1.6 Fuzzy division ( $\tilde{\div}$ )

The fuzzy division is written as ( $\tilde{\div}$ ), to extract data tuples of a relational relation with all remaining relations.

$$\widetilde{FC} = \widetilde{FC}_1 \tilde{\div} \widetilde{FC}_2 = \left\{ \mu_{\widetilde{FC}}(o) [fA_1 \dots fA_n] : \mu_{\widetilde{FC}}(o) \in \widetilde{FC}_1 \wedge \forall \widetilde{FC}_2 \in \widetilde{FC}_2 \left( (\mu_{\widetilde{FC}}(o) [fA_1 \dots fA_n] \cup \widetilde{FC}_2) \in \widetilde{FC}_1 \right) \right\} \quad (6)$$

In which, the  $\tilde{\div}$  of  $\widetilde{FC}_1$  and  $\widetilde{FC}_2$  requires  $FA'(fA_1) = FA'(fA_2)$  and  $\widetilde{FC}$  is composed with attribute  $[fA_1 \dots fA_n]$  and  $\mu_{\widetilde{FC}}(o) [fA_1 \dots fA_n]$  is the limitation of  $\mu_{\widetilde{FC}}(o)$ .

### 2.1.7 Fuzzy projection ( $\tilde{\Pi}$ )

The new  $\widetilde{FC}''$  composed with membership degree attribute is created from the fuzzy projection on the attribute subset sub.

$$\widetilde{FC}'' = \tilde{\Pi}_{sub}(\widetilde{FC}') = \left\{ \mu_{\widetilde{FC}}(o) \mid (\forall \mu_{\widetilde{FC}}(o)') (\mu_{\widetilde{FC}}(o)' \in \widetilde{FC}' \wedge \mu_{\widetilde{FC}}(o) = \cup_{\exists} \mu_{\widetilde{FC}}(o)') \right\} \quad (7)$$

Here, the removal of redundant  $\mu_{\widetilde{FC}}(o)$  in the fuzzy set of  $\mu_{\widetilde{FC}}(o)'$  is used by the  $\cup_{\exists} \mu_{\widetilde{FC}}(o)'$  operation.

### 2.1.8 Fuzzy selection ( $\tilde{\sigma}$ )

The new  $\widetilde{FC}''$  composed with membership degree attribute is created from the fuzzy selection on the attribute subset sub.

$$\widetilde{FC}'' = \tilde{\sigma}_{sub}(\widetilde{FC}') = \left\{ \mu_{\widetilde{FC}}(o) \mid \mu_{\widetilde{FC}}(o) \in (\widetilde{FC}'), \varphi(\mu_{\widetilde{FC}}(o)) \right\} \quad (8)$$

Here, the removal of redundant  $\mu_{\widetilde{FC}}(o)$  in the fuzzy set of  $\mu_{\widetilde{FC}}(o)'$  is used by the  $\varphi o'$  operation.

## 2.2 Structured fuzzy object Query Language

Structure of a fuzzy object-oriented query consisting of three clauses:

SELECT <attribute list>

FROM <Class WITH threshold Class WITH threshold>

WHERE <query condition WITH threshold>.

Example for a  $\widetilde{FC}$  OldSalesPersons as follows.

CLASS OldSalesPersons WITH DEGREE OF 1.0 INHERITS SalesPersons WITH DEGREE OF 1.0

ATTRIBUTES ID: TYPE OF string WITH DEGREE OF 1.0

Name: TYPE OF string WITH DEGREE OF 1.0 Age: FUZZY DOMAIN {very young, young, old, very old}:

TYPE OF integer WITH DEGREE OF 1.0 Sex: FUZZY DOMAIN {male, female}: TYPE OF

character WITH DEGREE OF 1.0 DOB: FUZZY DOMAIN {day, month, year}: TYPE OF

integer WITH DEGREE OF 1.0 Membership\_Attribute name

WEIGHT w (ID) = 0.1w (Name) = 0.1w (Age) = 0.9w (Sex) = 0.1w (DOB) = 0.6 METHODS END

A query based on the class is issued by using:

SELECT Name

FROM OldSalesPerson, SalesPersons WITH 0.6  
 WHERE OldSalesPerson.FIOD = SalesPersons.FOID AND  
 OldSalesPersons. Age = 'very old' WITH 0.7.

### 3 Fuzzy Query Processing Architectures and Optimization

To unify the execution steps of a query in a certain process. We propose a query processing architecture for FOODB, represented in fig.1.

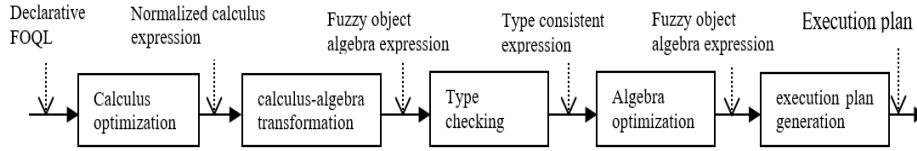


Figure.1: Fuzzy Query Processing Architecture

When the user submits a FOQL, it is first parsed by the FOODBs, which verifies the syntax and type correctness of the FOQL. Being a declarative language, FOQL does not suggest concrete ways to evaluate its queries. Therefore, a parsed FOQL has to be converted into a fuzzy object algebra expression, which can be evaluated directly using the algorithms. A typical FOQL query such as

SELECT Name  
 FROM OldSalesPerson, SalesPersons WITH 0.6  
 WHERE OldSalesPerson.FIOD = SalesPersons.FOID AND OldSalesPersons. Age = 'very old' WITH 0.7.

Is normally translated into the following fuzzy object algebraic expression:

$$\tilde{\pi}_{Name} \left( \begin{matrix} \tilde{\sigma}^{OldSalesPersons.foid=SalesPersons.foid \wedge OldSalesPersons.Age='very\ old'} \\ (OldSalesPersons \bowtie SalesPersons) \end{matrix} \right)$$

The above architecture is described through the steps as follows. First, users submit a fuzzy query that they do not need knowledge of fuzzy objects. Next, the system receives the fuzzy query and performs the removal of duplicate predicates and applies the identities and rewriting. Next, the system performs the conversion of the query to the fuzzy algebraic expression. Next, the system expresses this fuzzy algebraic expression a nested expression in the form of an fuzzy algebraic tree. Next in the fuzzy query processing process is to apply the same rewrite rules equivalent to preserving the equivalent of algebraic expressions for fuzzy fuzzy objects. Finally, an implementation plan that takes into account the implementation of fuzzy objects is generated from the optimized fuzzy algebraic expression.

#### 3.1 Equivalent transformation rules

Assume that  $\mu_{\tilde{FC}}(o), \mu_{\tilde{FC}_1}(o), \mu_{\tilde{FC}_2}(o), \mu_{\tilde{FC}_3}(o)$  are the set for fuzzy object: e, f, g, h are algebraic expressions, operations  $op \in \{u\ non\ diff\}$ . These rules apply only on the fuzzy object operations, math sets, set operations and multi-set operations (bag). On signs, we only use math Notations in a form [1] operations can be setup with a changes in a number of different models.

R1. Selection operations are commutative:

$$\sigma_{\lambda_t.g} \left( \sigma_{\lambda_s.f} \left( \mu_{\tilde{FC}}(o) \right) \right) = \sigma_{\lambda_s.f} \left( \sigma_{\lambda_s.g} \left( \mu_{\tilde{FC}}(o) \right) \right)$$

R2. Conjunctive selection operations can be deconstructed into a sequence of individual selections; cascade of  $\sigma$ :

$$\sigma_{\lambda s.(f \wedge g \wedge \dots h)}(\mu_{\widetilde{FC}}(o)) = \sigma_{\lambda s.f} \left( \sigma_{\lambda t.g} \left( \dots \left( \sigma_{\lambda u.h}(\mu_{\widetilde{FC}}(o)) \right) \dots \right) \right)$$

R3. Only the final operations in a sequence of projection operations is needed, the others can be omitted, cascade of  $\Pi$ :

$$\Pi_{(a_1 \dots a_n)} \left( \Pi_{(b_1 \dots b_n)}(\mu_{\widetilde{FC}}(o)) \right) = \Pi_{(a_1 \dots a_n)}(\mu_{\widetilde{FC}}(o)) \mid \{a_1, \dots, a_n\} \subset \{b_1, \dots, b_n\}$$

R4. Permutation selection and projection:

$$\sigma_{\lambda s.e} \left( \Pi_{(a_1, \dots, a_n)}(\mu_{\widetilde{FC}}(o)) \right) = \Pi_{(a_1, \dots, a_n)} \left( \sigma_{\lambda s.e}(\mu_{\widetilde{FC}}(o)) \right)$$

R5. Permutation and a projection over union, on a set / multiset:

$$\Pi_{(a_1, \dots, a_n)}(\mu_{\widetilde{FC}_1}(o) \text{ op } \mu_{\widetilde{FC}_2}(o)) = \Pi_{(a_1, \dots, a_n)}\mu_{\widetilde{FC}_1}(o) \text{ op } \Pi_{(a_1, \dots, a_n)}\mu_{\widetilde{FC}_2}(o)$$

R6. The selection operation distributes over the union, and Difference, on a set / multiset

$$\sigma_{\lambda s.f}(\mu_{\widetilde{FC}_1}(o) \text{ op } \mu_{\widetilde{FC}_2}(o)) = \sigma_{\lambda s.f}(\mu_{\widetilde{FC}_1}(o)) \text{ op } \mu_{\widetilde{FC}_2}(o), \text{ if } f \text{ is related to } \mu_{\widetilde{FC}_1}(o)$$

Generality:

$$\begin{aligned} & \sigma_{\lambda s.(f \wedge g \wedge h)}(\mu_{\widetilde{FC}_1}(o) \text{ op } \mu_{\widetilde{FC}_2}(o)) \\ &= \sigma_{\lambda u.h} \left( \sigma_{\lambda s.f}(\mu_{\widetilde{FC}_1}(o)) \text{ op } \sigma_{\lambda t.g}(\mu_{\widetilde{FC}_2}(o)) \right), \text{ if } f \text{ is related to } \mu_{\widetilde{FC}_1}(o), \\ & \quad g \text{ is related to } \mu_{\widetilde{FC}_2}(o) \text{ and } h \text{ related to both } \mu_{\widetilde{FC}_1}(o) \text{ and } \mu_{\widetilde{FC}_2}(o) \end{aligned}$$

R7. Permutation between selection operation and apply operation: if conditions only contain attributes selected by the operation returns apply:

$$\text{apply}_{\lambda_{\mu s.e}} \left( \sigma_{\lambda t.f}(\mu_{\widetilde{FC}}(o)) \right) = \sigma_{\lambda t.f} \left( \text{apply}_{\lambda_{\mu s.e}}(\mu_{\widetilde{FC}}(o)) \right)$$

R8. Permutation between flat and apply on set and multiset: Suppose that  $\mu_{\widetilde{FC}}(o)$  is an instance of a class and x is a complex set of attributes of the class:

$$\begin{aligned} & \text{flat} \left( \text{apply}_{\lambda s.} \left( \text{apply}_{\lambda t.e} \left( \Pi_{(x)} \left( \Pi_V(\mu_{\widetilde{FC}}(o)) \right) \right) \right) (\mu_{\widetilde{FC}}(o)) \right) \\ &= \text{apply}_{\lambda t.e} \left( \text{flat} \left( \text{apply}_{\lambda s.} \left( \Pi_{(x)} \left( \Pi_V(\mu_{\widetilde{FC}}(o)) \right) \right) (\mu_{\widetilde{FC}}(o)) \right) \right) \end{aligned}$$

R9. Set union is associative:

$$(\mu_{\widetilde{FC}_1}(o) \text{ union } \mu_{\widetilde{FC}_2}(o)) \text{ union } \mu_{\widetilde{FC}_3}(o) = \mu_{\widetilde{FC}_1}(o) \text{ union } (\mu_{\widetilde{FC}_2}(o) \text{ union } \mu_{\widetilde{FC}_3}(o))$$

R10. The inheritance laws to allow the selection and apply: if  $\widetilde{FC}_2$  is a subclass of  $\widetilde{FC}_1$ , instance of  $\mu_{\widetilde{FC}_2}(o)$  is a subset of instance of  $\mu_{\widetilde{FC}_1}(o)$ .

$$\begin{aligned} \sigma_{\lambda_s.f}(\mu_{\overline{FC}_1}(o)) \cup \text{non}\sigma_{\lambda_s.f}(\mu_{\overline{FC}_2}(o)) &= \sigma_{\lambda_s.f}(\mu_{\overline{FC}_1}(o)) \text{apply}_{\lambda_s.e}(\mu_{\overline{FC}_1}(o)) \cup \text{non}\text{apply}_{\lambda_s.e}(\mu_{\overline{FC}_2}(o)) \\ &= \text{apply}_{\lambda_s.e}(\mu_{\overline{FC}_1}(o)) \end{aligned}$$

### 3.2 FOQL to fuzzy object algebra translation

The transformation equivalence between FOQL queries and Fuzzy object Algebra.

**Definition.** If E is an fuzzy object algebraic expression and Q fuzzy query object is FOQL together define a sets fuzzy object , we say Q represent E and the opposite, we call E equivalent to Q. Symbol  $E \approx Q$ .

Equal representation between the query language and algebra FOQL fuzzy object is expressed through two theorems 1 and 2 as follows:

**Theorems 1.** Every algebraic expressions are fuzzy object represented by the object query in FOQL.

**Theorems 2.** Every Fuzzy object in FOQL queries are represented by algebraic expressions fuzzy object

Thus, the rewrite a given query into algebraic expressions with algebraic set objects are equivalent. The algebraic expressions can be estimated with different abatement costs. So theoretically we wanted to find an algebraic expression equivalent to a query so that it can achieve a plan for more effective enforcement. However, in the solution installed, because the number of queries equivalent too large, that we only need a subset of this query. Therefore, in order to find other similar queries, we will need a set of rules to transform the equivalent algebraic expressions. However, the model fuzzy object oriented data does not have a standard fuzzy algebraic objects applicable to all models of fuzzy object-oriented, so the expectation to have a normal training include modified protection laws Full equivalent does not exist. So, we wanted to prove that the transformation preserved on a basis equivalent algebraic fuzzy objects that may be acceptable. Some law transform is presented [1].

### 3.3 Heuristic optimization based on algebraic equivalences

#### 3.3.1 Search space and transformation rules.

The most important advantage of processing and optimizing fuzzy algebra is that through the algebraic expression of the object we can use algebraic properties such as transformation, distribution. Therefore, each fuzzy query has the number of different equivalent expressions that depends on the input of the query from the user's request. These expressions are corresponding to the results they created, but different from their costs. However, fuzzy query optimizers modify fuzzy query expressions through using algebraic transformation rules to achieve the same results at the possible lowest cost. The transformation rules depend a lot on specific objects, as they are determined properly for each object algebra and their combinations.

#### 3.3.2 Search algorithm

**Heuristic:**

1. The parser of a high-level fuzzy query creates an initial internal representation;
2. Apply heuristics rules to optimize the internal representation.
3. A fuzzy query execution plan is generated to execute groups of operations based on the access paths available on the files involved in the fuzzy query.

The main heuristic is to apply first the operations that reduce the size of intermediate results.



E.g., Apply fuzzy SELECT and fuzzy PROJECT operations before applying the fuzzy JOIN, or other binary operations.

**Outline of a heuristic fuzzy object algebraic optimization algorithm:**

1. Using rule R2, break up any select operations with conjunctive conditions into a cascade of select operations.
2. Using inheritance laws for projection (R3), the selection and allows apply (R10) combination of projection, select a projection and a selection.
3. For each selection, use the law (R4, R6, R7, R10) "pushed" to allow select components to classes or "through" connection nodes and allows creation group.
4. For each projection (objects, sets, sets), using legislation (R3, R4, R5) to projection move down as far as possible. If the projected attributes include all the attributes of the expression, we remove that projection.
5. Using the law (R8, R9, R10) on the object class, to remove duplicate elements in the object class; move allows flattened (flat), lets remove duplicates in multiple files (bagtset) ahead of the group or connection operations.
6. Creating a sequence of steps for estimating change in an order every star team for no group is evaluated, its subgroups.

**3.4 Generation of fuzzy query execution plans**

After translating the fuzzy query into an fuzzy algebra expression, the query processor passes the expression to the query optimizer, generates different execution plans, or a combination of Operators.

There are some of algebraic transformations that are performed in the query optimizer to create equivalent (rational) query plans. By removing of  $(\tilde{\times})$  and Push  $(\tilde{\sigma})$ .

**3.4.1 Execution plan**

The query processor converts the query to an equivalent fuzzy algebra expression for the input query and forwards it to the query optimizer. The first fuzzy algebraic object created by the query processor involves in the fuzzy Cartesian product called execution plan execution.

**Example 1:** returns the list of names of OldSalesPersons whose Age are 'very old'.

In FOQL it can be represented as:

```
SELECT OldSalesPersons FROM OldSalesPerson, SalesPersons WITH 0.6
WHERE OldSalesPersons.FIOD=SalesPersons.FOID AND OldSalesPersons. Age = 'very old' WITH 0.7.
```

In Fuzzy object Algebra above FOQL statement is represented as:

$$\tilde{\pi}_{Name} \left( \tilde{\sigma}_{\text{OldSalesPersons.foid=SalesPersons.foid} \wedge \text{OldSalesPersons.Age='very old'}} \left( \text{SalesPersons} \tilde{\times} \text{OldSalesPersons} \right) \right)$$

The above expression is represented by the algebraic tree as Fig.2:

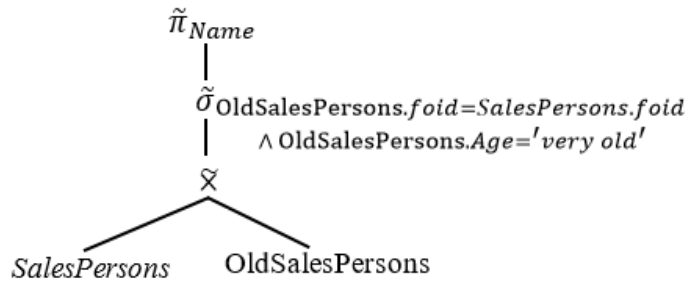


Figure .2. Implementation plan concern in ( $\tilde{\times}$ )

### 3.4.2 Elimination of fuzzy Cartesian product

The ( $\tilde{\times}$ ) operations can be combined with ( $\tilde{\sigma}$ ) operations (and sometimes, with fuzzy projection operations) which use data from both relations to form joins. After replacing ( $\tilde{\times}$ ) with ( $\tilde{\bowtie}$ ), fuzzy object algebra for the query given in example 1 can be presented as.

$$\tilde{\pi}_{Name} \left( \left( \begin{array}{c} \tilde{\sigma}_{OldSalesPersons.Age='very old'} \\ (SalesPersons \tilde{\bowtie}_{OldSalesPersons.foid=SalesPersons.foid} \\ OldSalesPersons) \end{array} \right) \right)$$

Figure .3 shows gives the operator tree of the above algebraic expression:

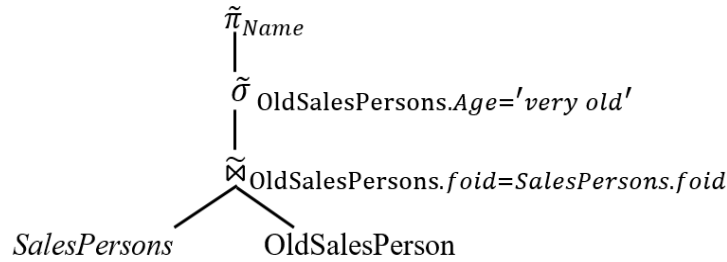


Figure .4. Implementation plan using ( $\tilde{\bowtie}$ )

### 3.4.3 Push ( $\tilde{\sigma}$ )

By pushing ( $\tilde{\sigma}$ ) operation down the expression tree, we actually reduce the size of relations we need to do before. The fuzzy object algebra for the fuzzy query written in example under push fuzzy selection strategy can be presented as:

$$\tilde{\pi}_{Name} \left( \begin{array}{c} (SalesPersons \tilde{\bowtie}_{OldSalesPersons.foid=SalesPersons.foid} \\ \left( \begin{array}{c} \tilde{\sigma}_{OldSalesPersons.Age='very old'} \\ OldSalesPersons \end{array} \right) \end{array} \right)$$

Figure.4 Below is a description of their above Fuzzy object Algebra expression:

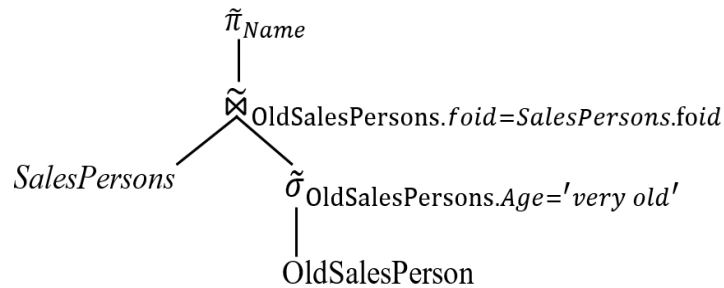


Figure.5. Pushing  $\tilde{\sigma}$  down the tree.

#### 4 Performance evaluation

To provide preliminary performance evaluation on implementation of query processing has been proposed based on fuzzy object algebra [1]. We defined the three queries processed condition extract filter data for two cases of single conditions, most conditions and implement them on the same dataset.

The fuzzy query processor first extract filter data for single condition processing cases. Request query processing engine return all employees age is very old. Such queries are written as follows.

```
SELECT * FROM OldSalesPersons, SalesPersons WITH 0.6
WHERE AND OldSalesPersons.Age = 'very old' WITH 0.7.
```

The second query processing the extract filter data for single-case conditions and enable a natural join. Request query processing engine return all employees age is very old. Such queries are written as follows.

```
SELECT Name FROM OldSalesPerson, SalesPersons WITH 0.6 WHERE OldSalesPersons.FIOD=
SalesPersons.FOID AND OldSalesPersons.Age = 'very old' WITH 0.7.
```

The third query processing the extract filter data for single-case conditions and enable a natural join. After performing the optimization algebra objects. Request query processing engine return all employees age is very old. Such queries are written as follows.

```
SELECT Name FROM SalesPersons inner join OldSalesPersons on
OldSalespersons.FIOD=SalesPersons.FOID WITH 0.6 WHERE
OldSalesPersons.Age = 'very old' WITH 0.7.
```



Figure. 6. Query performance

Three queries performed on the same data size. The query processing on files available is 10KB, 100KB, 1M,10M and contains 60,972 fuzzy objects. Performance assessment testing is done on a computer is intel (R) Core(TM)i3 370 M.

From the above experiments, results achieved confirm that the performance of this method is effective. As an example, we evaluate the query according to this approach from the chart the way the query results shown in Fig.5.

## 5 Conclusion

This paper present a new model for optimizing the efficiency of query processing by semantic analyzing and FO algebra transforming. Specifically, we develop a heuristic fuzzy object algebraic optimization algorithm relied on equivalent transformation rules and Fuzzy-Object-Algebra transformation. Analysis on several experiments using the proposed algorithm shows better performance of query processing, which proves the efficiency enhancement of our method.

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