Steps Towards Modeling and Querying Based on Linguistic Fuzzy Graph Database

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Abstract

In this paper, we introduce a method for computing with words on linguistic fuzzy graph database (LFGD). Computation consists of two processes: Modeling and Querying. The former models LFGD as a fuzzy graph whose nodes contain linguistic data table and the later queries linguistic data from node’s data tables.

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1 Introduction

In everyday life, people use natural language (NL) for analyzing, reasoning, and finally, make their decisions. Computing with words (CWW) [2, 6, 8–11, 17] is a mathematical solution of computational problems stated in an NL. CWW based on fuzzy set and fuzzy logic, introduced by L. A. Zadeh is an approximate method on interval [0,1]. In linguistic domain, linguistic hedges play an important role for generating set of linguistic variables. A well known application of fuzzy set is fuzzy graph [3, 7, 14, 16], combined fuzzy set with graph theory. Fuzzy graph (F G) has a lots of applications in both modeling and reasoning fuzzy knowledge such as Human trafficking, in ternet routing, il legal immigration [13] on interval [0,1] but not in linguistic values. However, many applications cannot model in numerical domain, for example, linguistic summarization problems [10]. To solve this problem, in the paper, we use an abstract algebra, called hedge algebra (H A) as a tool for computing with words. The remainder of paper is organized as follows: Section 2 reviews some main concepts of computing with words based on H A. Important section 3 studies a graph database to model with words using H A and its properties. Section 4 outlines conclusions and future work.

2 Preliminaries

This section presents basic concepts of H A and some important knowledge used in the paper.

2.1 Hedge algebra

In this section, we review some H A knowledges related to our research paper and give basic definitions. First definition o fa n H A i s s pecified by 3-Tuple H A = (X, H, ≤ ) in [6]. In [5], to easily simulate fuzzy knowledge, two terms G and C are inserted to 3-Tuple so H A = (X, G, C, H, ≤ ) where X ≠ ∅ , G = [c , c ] , C = [0, W, 1]. Domain of X is L = Dom(X) = {δc | c ∈ G, δ ∈ H (hedge string over H)} , ≤ is a POSET (partial order set) and x = h n h n−1 . . . h 1 c is said to be a canonical string of linguistic variable x.

Example 1. Fuzzy subset X is Age, G = [c = young; c = old], H = [less; more; very] so term-set of linguistic variable Age X is L(X) or L for short: L = {very less young ; less young ; young ; more young ; very young ; very very young . . . } Fuzziness properties of elements in H A, specified by fm (fuzziness measure) [5] as follows:

Definition 2.1. A mapping fm : L → [0, 1] is said to be the fuzziness measure of L if:

1. \( \sum_{c \in [c^-, c^+]} fm(c) = 1 \), \( fm(0) = fm(w) = fm(1) = 0 \).
2. \( \sum_{h \in H} fm(h, c) = fm(c), x = h_n h_{n-1} . . . h_1 c \), the canonical form.
Consider linguistic variables:

**Example 2.** Consider linguistic variables: \\( \{ \text{true}, \text{very true}, \text{true}, \text{true} \} \) stand for: very true, possible true and less true are linguistic truth values generated from variable truth. Assume propositions \( p = "\text{Lucie is young is very true}" \) and \( q = "\text{Lucie is smart is true}" \), interpretations on \( \mathcal{HA} \) are:

- truth(\( p \)) = \( \text{very true} \) \( \in H \), truth is a unary function.
- \( p \land q = \text{very true} \land \text{true} = \text{true} \in H \), \( \land \) is a binary function.
- \( p \lor q = \text{very true} \lor \text{true} = \text{true} \in H \), \( \lor \) is a binary function.

### 2.2 Linguistic fuzzy graph

The first fuzzy graph was introduced in [16], which vertices and edges's values are in unit interval \([0, 1]\). Many fuzzy theories were developed in [12, 13] in which computational phases have a bit complex due to converting from linguistic to number value to compute. To reduce complexity, in [4] by applying computing with word method [10] on \( \mathbb{F} \) to produce \( \mathbb{L} \mathbb{G} \), in which \( \mathbb{L} \) is domain of both vertices \( \mathbb{V} \) and \( \mathbb{E} \) as in Fig. 1.

**Definition 2.3.** In [4], a linguistic graph \( \mathbb{L} \mathbb{G} = (\mathbb{V}, \rho, \delta) \) consists of set \( \mathbb{V} \), a fuzzy vertex set \( \rho \) on \( \mathbb{V} \) and a fuzzy edge set \( \delta \) on \( \mathbb{V} \) so that \( \delta(u, v) \leq \rho(u) \land \rho(v) \) for every \( u, v \in \mathbb{V} \).

\[
\mathbb{L} \mathbb{G} = \{(\mathbb{V}, \rho, \delta) : \rho \supseteq \mathbb{V}; \delta \supseteq \mathbb{E}\} \tag{3}
\]

**Example 3.** Fig. 1 shows a simple \( \mathbb{L} \mathbb{G} \). Let

\[
\mathcal{HA} = \langle \mathcal{X} = \text{truth}; c^\ast = \text{true}; \mathcal{H} = \{\mathcal{L}, \mathcal{M}, \mathcal{Y}\} \rangle \tag{4}
\]

be an \( \mathcal{HA} \) with order as \( \mathcal{L} < \mathcal{M} < \mathcal{Y} \) (\( \mathcal{L} \) for less, \( \mathcal{M} \) for more and \( \mathcal{Y} \) for very are hedges).

\[
\mathbb{V} = \frac{\mathcal{Y} \text{true}}{c_1} + \frac{\mathcal{L} \text{true}}{c_2} + \frac{\mathcal{Y} \text{true}}{c_3} + \frac{\mathcal{M} \text{true}}{c_4}
\]

![Fig. 1. a simple \( \mathbb{L} \mathbb{G} \)](image)

### 3 Linguistic fuzzy graph database

Fuzzy graph database (FGDB) is a main trend in French research and not yet finished [1, 15]. As advance in computing with words on \( \mathbb{L} \mathbb{G} \) [4], this paper studies the FGDB on linguistic domain \( \mathbb{L} \).

Let \( \mathcal{ALR}, \mathcal{Key}, \mathcal{Val} \) be in order to represent for attributes, keys and values in an \( \mathbb{L} \mathbb{G} \) database.
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Fig. 2. a simple model for LGD with two nodes and one edge

Definition 3.1. A linguistic graph database \( \mathbb{LGD} = (V, E, \rho, \delta, Atr) \), in which:

1. \( V \) represents for a set of vertices whose attributes are \( Atr \)
2. \( E \) represents for a set of edges whose attributes are \( Atr \)
3. \( \rho \) stands for a fuzzy set on \( Atr \) for vertex’s attributes.
4. \( \delta \) stands for a fuzzy set on \( Atr \) for edge’s attributes.

\[ \mathbb{LGD} = \{(V, E, \rho, \delta, Atr) : \rho \subseteq Atr; \delta \subseteq E\} \] \hspace{1cm} (5)

Fig. 2 shows a \( \mathbb{LGD} \) with tow nodes \( v_1, v_2 \in V; e \in E \) is a relation between \( v_1 \) and \( v_2 \). Attributes for \( V \) and \( E \) are presented in three tables.

Property 3.1. Always modeling a linguistic graph database \( \mathbb{LGD} \) from a \( \mathbb{FGD} \) to apply advance properties from computing with word methods.

Proof. It is straightforward to prove the property 3.1 by applying domain convergent method [5, 6] \( \square \)

Table 1 presents a domain convergent from \([0, 1]\) to linguistic value in \( \mathbb{L} \) with hedges meaning as:

\[
\begin{array}{c|c|c}
\text{Hedge} & \text{Meaning} \\
\hline
\mathcal{V} & \text{very} \\
\mathcal{W} & \text{neutral element} \\
\mathcal{L} & \text{less} \\
\mathcal{M} & \text{more} \\
\end{array}
\]

Example 4. By using linguistic domain for fuzzy sets \( \rho \) and \( \delta \), a simple \( \mathbb{LGD} \) is illustrated as in Fig. 3.

4 Conclusions and future work
We have introduced a fuzzy graph model so-called \( \mathbb{FG} \) with the following two advantages

1. Modeling fuzzy graph uses linguistic variable by applying hedge algebra
2. Computing with words on linguistic variable is not converting to numeric values therefore reducing number of operators for computation phases.

Our next study will investigate algorithms to construct and compute \( \mathbb{LG} = (V, \rho, \delta) \)
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