Hidden Pattern: Toward Decision Support Fuzzy Systems

Nguyen Van Han[1], Phan Cong Vinh[1(✉)], Bui Minh Phung[2], and Tran Ngoc Dan[3]

[1] Faculty of Information Technology, Nguyen Tat Thanh University, 300A Nguyen Tat Thanh Street, Ward 13, District 4, Ho Chi Minh City, Vietnam
{nvhan,pcvinh}@ntt.edu.vn

[2] Faculty of Information Technology, Van Lang University, 45 Nguyen Khac Nhu Street, Ward Co Giang District 1, Ho Chi Minh City, Vietnam
phung.bm@vlu.edu.vn

[3] University of Labor - Society (CSII), 1018 To Ky, Tan Chanh Hiep Ward, District 12, Ho Chi Minh City, Vietnam
dantn@ldxh.edu.vn

Abstract. In this paper, we introduce a method for computing with words to find linguistic hidden pattern ($\mathbb{LHP}$) as well as decision support system ($\mathbb{DSS}$) based on hedge algebra ($\mathbb{HA}$) using linguistic cognitive map ($\mathbb{LCM}$). Our model consists of a set of vertices and edges whose values are linguistic variables that are constrained by a linguistic lattice. The algorithm for the system studied will convert to hidden pattern.

Keywords: Fuzzy logic · Hedge algebra · Hidden pattern · Decision support system

1 Introduction

Fuzzy set and fuzzy logic have been applied in neural network as well as machine learning. Fuzzy set or "computing with words" (CWW) was made in the 1990s by Zadeh's idea [1] which was just a tool to realize an intelligent system [2]. As Zadeh points out, human cognition is nothing more than CWW. In everyday life, we see the real world through words. Many intelligent systems that based on CWW such as fuzzy neural network, fuzzy machine learning, fuzzy classifying and so on have been studied [3–6].

The remainder of this paper is organized as follows: Sect. 2 reviews some of the main concepts of modeling with words based on $\mathbb{HA}$ [9,10,14]. Section 3 proposes a computational method for computing hidden pattern and decision support system. Section 4 outlines the conclusion and future work.

P. Cong Vinh and A. Rakib (Eds.): ICCASA 2021, LNICST 409, pp. 71–76, 2021.
https://doi.org/10.1007/978-3-030-93179-7_6

2 Preliminary: Linguistic Fuzzy Cognitive Map

Linguistic Fuzzy Cognitive Maps

Fuzzy cognitive map ($\mathbb{FCM}$) [7] is a combination of fuzzy logic and neural network, in which learning process depends on numerical domain in unit interval [0, 1]. Paper stands on $\mathbb{LCM}$ which is extended from fuzzy cognitive map $\mathbb{FCM}$ [7]. The $\mathbb{LCM}$ model, based on linguistic variables, is constructed from linguistic hedge of $\mathbb{HA}$ in [11–13,15].

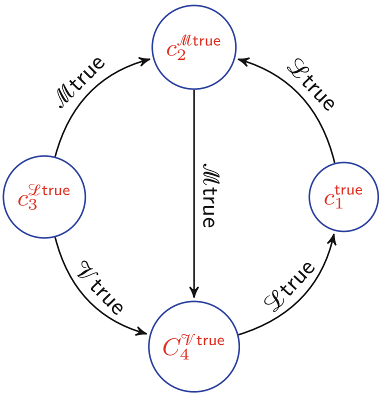
Definition 1. *A linguistic cognitive map ($\mathbb{LCM}$) is a 4- Tuple:*

$$\mathbb{LCM} = \{C, E, \mathbb{C}, f\} \tag{1}$$

In which:

1. $C = \{C_1, C_2, \ldots, C_n\}$ *is the set of N concepts forming the nodes of a graph.*
2. $E : (C_i, C_j) \longrightarrow e_{ij} \in \mathbb{L}$*;* e_{ij} = *weight of edge directed from C_i to C_j. The connection matrix* $E(N \times N) = \{e_{ij}\}_{N\times N} \in \mathbb{L}^{N\times N}$
3. *The map:* $\mathbb{C} : C_i \longrightarrow C_i^t \in \mathbb{L}, t \in N$
4. $\mathbb{C}^0 = [C_1^0, C_2^0, \ldots, C_n^0] \in \mathbb{L}^N$ *is the initial vector, recurring transformation function f is defined as:*

$$C_j^{t+1} = f(\sum_{i=1}^{N} e_{ij} C_i^t) \in \mathbb{L} \tag{2}$$



Example 1. Figure 1 shows a simple $\mathbb{LCM}$. Let

$$\mathbb{HA} = <\mathscr{X} = \mathsf{truth}; c^+ = \mathsf{true}; \mathscr{H} = \{\mathscr{L}, \mathscr{M}, \mathscr{V}\}> \tag{3}$$

be an $\mathbb{HA}$ with order as $\mathscr{L} < \mathscr{M} < \mathscr{V}$ ($\mathscr{L}$ for less, $\mathscr{M}$ for more and $\mathscr{V}$ for very are hedges). $C = \{c_1, c_2, c_3, c_4\}$ is the set of 4 concepts with corresponding values $\mathscr{C} = \{\mathsf{true}, \mathscr{M}\mathsf{true}, \mathscr{L}\mathsf{true}, \mathscr{V}\mathsf{true}\}$

Fig. 1. A simple $\mathbb{LCM}$

3 Computational Fuzzy $\mathbb{DSS}$

Hidden Patterns (HP) in combined and adaptive knowledge networks, that was introduced by B. Kosko in [8] have been applied in both fuzzy logic and neural network as a foundation for development in artificial intelligence. Applications from HP in pattern classification as well as pattern recognition were presented in [3,4] in which patterns were studied numerical values.

This paper researches on a special HP that called $\mathbb{LHP}$ which uses linguistic variable for three computational phases: modeling, reasoning and verifying. $\mathbb{DSS}$ is the fuzzy $\mathbb{KB}$ which inferred from $\mathbb{LHP}$, the special state in state space $\mathfrak{C} = \{\mathbb{C}^0,\ \mathbb{C}^1, \ldots\ \mathbb{C}^N\}$ when system reaches stable state.

3.1 Computational Algorithm to Compute $\mathbb{DSS}$

Pseudo Algorithm for Computing Processes

With notation $\mathfrak{s}_{ij} \in \mathbb{Adj} \subset \mathbb{L}^N$ being strength of directed edge (C_i, C_j) or $\mathfrak{s}_{ij} \leftarrow \|(C_i, C_j)\|$ and $\mathbb{Adj}$ is the $\mathbb{LCM}$'s connection matrix. Algorithm 1 points out that the processes of computation to find $\mathbb{DSS}$ and $\mathbb{LHP}$ are implemented in some simple steps:

- Initial system to first state $\mathbb{C}^0$ in state space $\mathfrak{C}$ that uses linguistic variables.
- Recursive computation until system reaches final state.
- The final stable state $C_j^{\mathscr{T}ime+1} = C_j^{\mathscr{T}ime}$ and $\mathbb{LHP} \leftarrow C_j^{\mathscr{T}ime}$
- Finally, linguistic $\mathbb{DSS}$ is derived from $\mathbb{LHP}$: $\mathbb{DSS} \leftarrow \mathbb{LHP}$

Algorithm 1. Computational $\mathbb{DSS}$ algorithm

$\triangleright$ firstly, initialize first state vector $\mathbb{C}^0 \subset \mathfrak{C}$

for $\mathscr{T}ime \leftarrow 1$ to N **do**
  $\|C_i^0\| \leftarrow \mathscr{L}inguistic\ value \in \mathbb{L}$

$\triangleright$ Iterate on $\mathfrak{C}$ space by discrete-time $\mathscr{T}ime$

while $\|C_j^{\mathscr{T}ime+1}\| \neq \|C_i^{\mathscr{T}ime}\|$ **do**
  $\|C_j^{\mathscr{T}ime+1}\| \leftarrow \bigvee_{i=0}^{N} \|C_i^{\mathscr{T}ime}\| \wedge \mathfrak{s}_{ij}$
$\mathbb{DSS} \leftarrow \mathbb{LHP} \leftarrow C_j^{\mathscr{T}ime}$

An Example for Implementing Processes

Figure 2 is an example to illustrate the processes of the Algorithm 1, in which:

- System $\mathfrak{C}$ consists five states: $\mathbb{LCM}^0, \mathbb{LCM}^1, \mathbb{LCM}^2, \mathbb{LCM}^3, \mathbb{LCM}^4$
- The initial state is $\mathbb{LCM}^0$ and final stable state is $\mathbb{LCM}^4$
- Edges's linguistic values present *What-If* relation between $\mathbb{LCM}$'s
- System reaches stable state $\mathbb{LCM}^4$ after looping four times.
- And, finally: $\mathbb{DSS} \leftarrow \mathbb{LHP} \leftarrow \mathbb{LCM}^4$

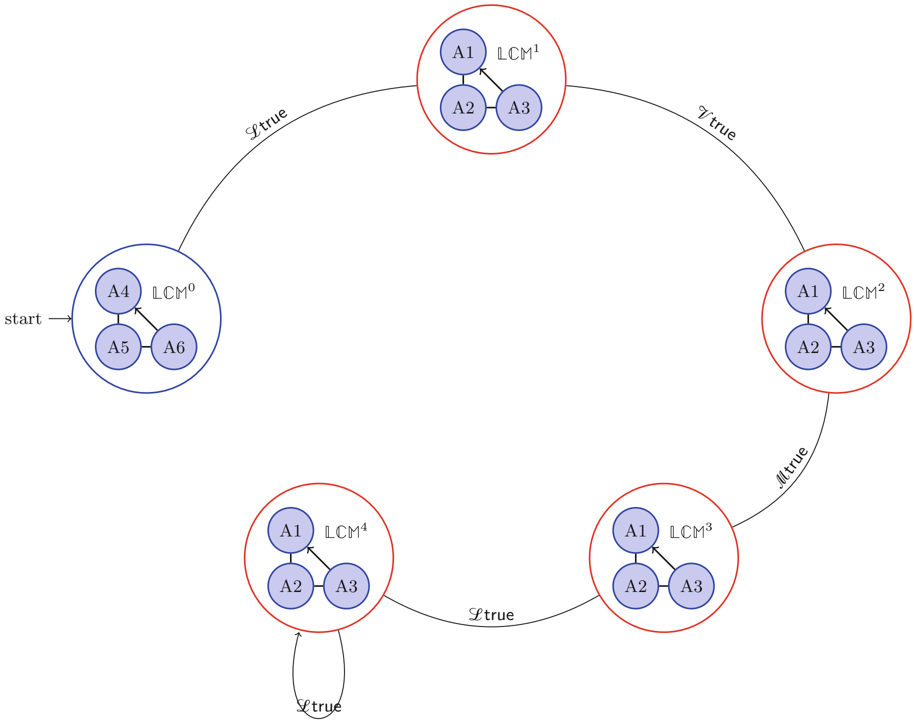


Fig. 2. State space $\mathfrak{C}: \mathbb{LCM}^0, \mathbb{LCM}^1, \mathbb{LCM}^2, \mathbb{LCM}^3, \mathbb{LCM}^4$ for finding $\mathbb{DSS}$

3.2 Applying Algorithm in Medical Decision Problem

Chondromalacia patellae problem (CPP) is modelled by $\mathbb{FCM}$ in [6]. By using domain transformation method as in [15], see Table 1. Concepts space is denoted in Table 2.

With converting as in Table 1, negative linguistic values are converted to linguistic variable in $\mathbb{L}$ of $\mathbb{HA}$ and CPP is remodeled in $\mathbb{LCM}$ form. This allows to use $\mathbb{HA}$ as tool for computing with word. From Table 2, CPP now is modeled by linguistic values in $\mathbb{LCM}$ form as Fig. 3.

Table 1. Domains conversion

Range $[-1,\ 1]$	Positive range $[0,\ 1]$	Domain of $\mathbb{L}$	Meaning
$[-1,\ -0.7)$	$[0,\ 0.15)$	$\mathscr{V}\mathscr{V}$low	Very very low
$[-0.7,\ -0.4)$	$[0.15,\ 0.3)$	$\mathscr{L}\mathscr{M}$low	Less more low
$[-0.4,\ -0.1)$	$[0.3,\ 0.45)$	$\mathscr{L}\mathscr{L}$low	Less less low
$[-0.1,\ 0.1)$	$[0.45,\ 0.55)$	$\mathscr{W}$	Trung hòa
$[0.1,\ 0.4)$	$[0.55,\ 0.7)$	$\mathscr{V}\mathscr{L}$high	Very less high
$[0.4,\ 0.7)$	$[0.7,\ 0.85)$	$\mathscr{L}\mathscr{M}$high	Less more high
$[0.7,\ 1]$	$[0.85,\ 1]$	$\mathscr{V}\mathscr{V}$high	More more high

Table 2. Table concept space.

Concepts $C \in \mathbb{C}$	Meaning	Linguistic domain
C_1	Extracellular matrix	Linguistic value in $\mathbb{L}$
C_2	Chondromalacia	Linguistic value in $\mathbb{L}$
C_3	Cells	Linguistic value in $\mathbb{L}$
C_4	Physical exercises	Linguistic value in $\mathbb{L}$
C_5	Weight	Linguistic value in $\mathbb{L}$

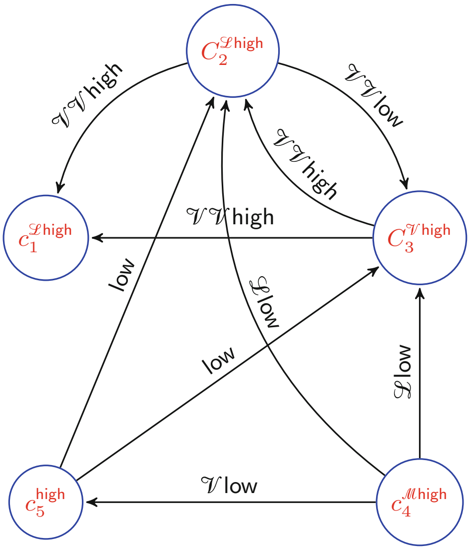


Fig. 3. $\mathbb{LCM}$ models Chondromalacia

Property 1. Following the Algorithm 1, CPP always converges to hidden pattern $\mathbb{LHP}$

Proof. This property is immediately inferred from convergence in Theorem 2 [15].

4 Conclusion and Future Work

We have introduced a method to computational linguistic fuzzy $\mathbb{DSS}$ as well as making $\mathbb{DSS}$ In the future, two studies will be:

- Considering a complete algorithm to construct $\mathbb{DSS}$.
- Verifying soundness and completeness for the algorithms.

References

1. Zadeh, L.A., Kacprzyk, J.: Computing with Word in Information Intelligent System 1. Springer, Heidelberg (1999). https://doi.org/10.1007/978-3-7908-1873-4
2. Zadeh, L.A.: Computing with Words - Principal Concepts and Ideas. Studies in Fuzziness and Soft Computing, Springer, Heidelberg (2012). https://doi.org/10.1007/978-3-642-27473-2
3. Glykas, M.: Fuzzy Cognitive Maps, Advances in Theory, Tools and Applications. Springer, Heidelberg (2010). https://doi.org/10.1007/978-3-642-03220-2
4. Papageorgiou, E.I.: Fuzzy Cognitive Maps for Applied Science and Engineering From Fundamentals to Extensions and Learning Algorithms. Springer, Heidelberg (2014). https://doi.org/10.1007/978-3-642-39739-4
5. Caarvalho, J.: On the semantics and the use of fuzzy cognitive maps and dynamic cognitive maps in social sciences. Fuzzy Sets Syst. **214**, 6–19 (2013)
6. Frias, M., Yaima, F., Nápoles, G., Vahoof, K., Bello, R.: Fuzzy cognitive maps reasoning with words based on triangular fuzzy numbers. In: ISFUROS (2017)
7. Kosko, B.: Fuzzy cognitive maps. Int. J. Man-Mach. Stud. **24**, 65–75 (1986)
8. Kosko, B.: Hidden patterns in combined and adaptive knowledge networks. Int. J. Approx. Reason. **2**(4), 377–393 (1988)
9. Ho, N.C., Wechler, W.: Hedge algebras: an algebraic approach to structure of sets of linguistic truth values. Fuzzy Sets Syst. **35**(3), 281–293 (1990)
10. Ho, N.C., Son, T.T., Khang, T.D., Viet, L.X.: Fuzziness measure, quantified semantic mapping and interpolative method of approximate reasoning in medical expert systems. J. Comput. Sci. Cybern. **18**(3), 237–252 (2002)
11. Han, N.V., Vinh, P.C.: Toward modeling and reasoning with words based on hedge algebra. EAI Endor. Trans. Context-aware Syst. Appl. **5**(15), e5 (2018)
12. Van Han, N., Vinh, P.C.: Modeling with words based on hedge algebra. In: Cong Vinh, P., Alagar, V. (eds.) ICCASA/ICTCC -2018. LNICST, vol. 266, pp. 211–217. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-06152-4_18
13. Van Han, N., Hao, N.C., Vinh, P.C.: Toward aggregating fuzzy graphs a model theory approach. In: Vinh, P.C., Rakib, A. (eds.) ICCASA/ICTCC -2019. LNICST, vol. 298, pp. 215–222. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-34365-1_17
14. Ho, N.C., Long, N.V.: Fuzziness measure on complete hedge algebras and quantifying semantics of terms in linear hedge algebras. Fuzzy Sets Syst. **158**(4), 452–471 (2007)
15. Han, N.V., Vinh, P.C.: Reasoning with words: a hedge algebra linguistic cognitive map approach. Concurr. Comput. Pract. Exp. **33**(2), e5711 (2020)