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Proof by Demonstration of the Temporal Change in Concepts in Conceptual Knowledge

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Abstract: Concepts are the atomic ingredients of Conceptual Knowledge. Within the ambit of computer science and information theory, conceptual knowledge contains the understanding of the world of data that is being processed. Possessing a knowhow of concepts helps in machine learning and computational intelligence. In order to be machine readable, concepts have to be codified. The representation structure of concepts has been studied extensively and the structure has been crucial to the usability of conceptual knowledge. Conceptual Knowledge models the human understanding of the real world. The nature of concepts in the real world is very susceptible to change. This paper demonstrates this changing nature of concepts with a case study and a proof to stress the importance of embracing this change.

Keywords: Concept, Conceptual Knowledge, Temporal Change in Concepts, Change in Concepts

I. INTRODUCTION

This Conceptual Knowledge is a repository of concepts and connections in the domain of the knowledge. Constructing conceptual knowledge is a painstaking task and has to be meticulous for it to be usable. The knowledge captures meaning of the elements in the world view it is trying to freeze. The strength of the knowledge is in the representation [1] of the concepts. The definition of a concept is subject to interpretation [2] so there is no universality in the definition. Also, fixing one definition for the sake of simplicity makes the knowledge very rigid and limits its utility. It is therefore imperative to embrace the subjective variations which make the conceptual knowledge closest to the human understanding of the world [2] [3] [4]. Change is not only due to the subjective differences in the interpretation. With time, a concept can undergo considerable transformation due to extrinsic or intrinsic reasons. Extrinsic factors can include events that alter the understanding of a concept say, for example, a swimming pool is constructed over a plot of land that was a garden. Intrinsic factors include natural changes like a child growing into an adult or a sapling growing into a tree. These changes alter the conceptual knowledge as a whole and not just the concepts in isolation. This paper depicts a real world case where concepts undergo change over time and proves that embracing this change is inevitable.

In section II, a quick summary of literature is given on concepts and conceptual knowledge, its structure and the present state of research. Section III of the paper demonstrates the changing nature of concepts with a case study and highlights the impact of the changes in the overall scheme of things. Section IV gives a formal proof to show the time-variant nature of concepts. Section V concludes the paper with the lessons learnt from this study.

II. RELATED WORK

A formal definition of concepts was first propounded by Peter Gärdenfors in his paper published in Mind and Matter [1]. Peter claims that prior to his work, models based on symbols and representations in artificial neural network existed but were not sufficient for representing knowledge in the way human beings visualise knowledge and proposed the conceptual space model [5]. The conceptual space model represents concepts based on a number of quality dimensions [3] and this model was later improved by Raubal [6] [7]. Quality dimensions [6] are attributes of an object. For example, temperature, height, weight, width, depth. A point or mapping in the conceptual space represents an instance of each quality dimension. The introduction of conceptual space paved way to compare objects based on semantics [4] and not just structure. Contextual information [8] could also be accommodated in the conceptual space model using weights over the quality dimensions [5]. Raubal [6] in his work on formalizing conceptual spaces in the field of geography argued that concepts are mental entities that capture experience and support reasoning of the world [6]. He also claimed that concepts need not be static [7]. An adaption of conceptual space was earlier studied [9] by applying it over database tables to extract semantic relations.

III. PROOF BY DEMONSTRATION – CONCEPTS CHANGE OVER TIME

Concepts are defined based on a set of attributes or quality dimensions that best describe them.

In the conceptual space, quality dimensions can be scalar values or can span over a domain or multiple domains [6]. The conceptual space would comprise of a number of subspaces and even subspaces of these subspaces.

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A set of concepts C_n can defined as

$$C_n = \{(q_1, q_2, ..., q_n) \mid q_i \in C\} \quad (1)$$

where q_i are the quality dimensions.

If a quality dimension represents a domain, then

$$q_i = S_n = \{(s_1, s_2, ..., s_n) \mid s_k \in S\} \quad (2)$$

In this paper, for the sake of clarity in presentation, attributes that are just scalar values are written in *italicized* text and attributes that are in turn concepts are written in UPPERCASE text. The name of the concept is mentioned in the subscript along with the symbol C. For example, $C_{building}$ denoted the concept representing a building.

A BUILDING is taken as the concept of study for this demonstration.

The definition of the concept BUILDING as shown in Fig. 1 is $C_{building}$ which has the attributes *name* that denotes the name of the building, *address* that denotes the physical location of the building, *year of construction* denoting the year in which the building was constructed, HOUSE denoting that the building is a house. Note that HOUSE is also a concept whose definition is C_{house} having the attribute PRIVATE denoting that the house is for private use.

$C_{building}$ = {*name*, *address*, *year of construction*, HOUSE}

C_{house} = {PRIVATE}

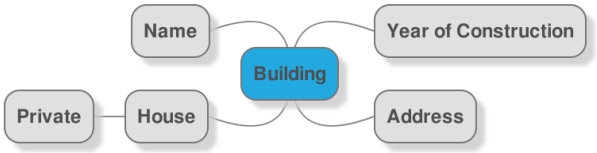

Fig. 1. Concept – Building

In general, the attributes of C_{house} can be either PRIVATE or PUBLIC as shown in Fig. 2 denoting that nature of use of the house. These attributes are themselves concepts which have their own definition.

C_{house} = {PRIVATE, PUBLIC}

Fig. 2. Concept - House

The BUILDING at a later point of time becomes MUSEUM. A MUSEUM is a PUBLIC LANDMARK. Note that the words MUSEUM, PUBLIC, LANDMARK qualify the HOUSE which is a BUILDING and hence they redefine the definition of the BUILDING. Each of these words are concepts themselves.

The concept LANDMARK can be defined as $C_{landmark}$ with attributes POLITICAL, HISTORICAL, CULTURAL, NATURAL, RELIGIOUS, FUNCTIONAL.

$C_{landmark}$ = {POLITICAL, HISTORICAL, CULTURAL, NATURAL, RELIGIOUS, FUNCTIONAL}

$C_{historical}$ = {MUSEUM}

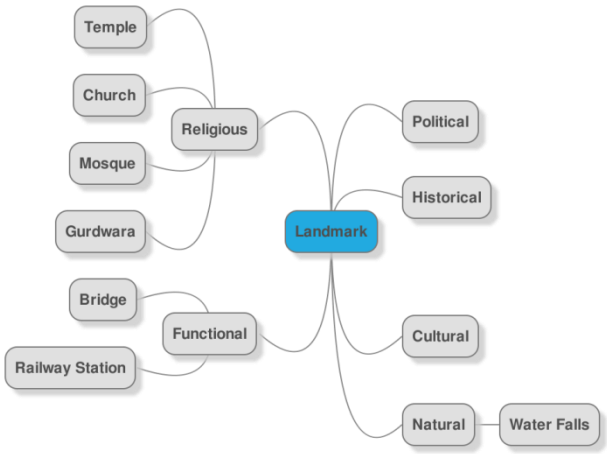

Fig. 3. Concept - Landmark

In the definition of LANDMARK as shown in Fig. 3, since MUSEUM relates to history, it is defined under the attributes HISTORICAL which by itself a concept denoted by $C_{historical}$

After the BUILDING becomes a MUSEUM, its new definition $C_{building}$ would be

$C_{building}$ = {*name*, *address*, *year of construction*, HOUSE, LANDMARK}

C_{house} = {PUBLIC}

$C_{landmark}$ = {HISTORICAL}

$C_{historical}$ = {MUSEUM}

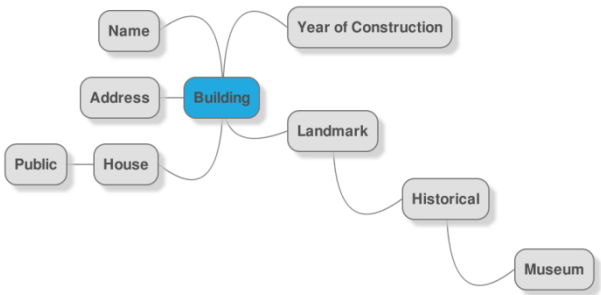

Fig. 4. Concept – Building after becoming a Landmark

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The MUSEUM is now a LANDMARK that is HISTORICAL in nature defined by $C_{landmark}$ which is now PUBLIC and hence C_{house} contains PUBLIC as shown in Fig. 4.

The other attributes of LANDMARK can also be defined likewise as given in $C_{natural}$, $C_{religious}$ and $C_{functional}$

$C_{natural}$ = {WATER FALLS}

$C_{religious}$ = {TEMPLE, CHURCH, MOSQUE, GURUDWARA}

$C_{functional}$ = {BRIDGE, RAILWAY STATION}

The final definition of BUILDING has undergone significant semantic changes due to the inclusion of the LANDMARK attribute. This change in semantics can have cascading ramifications on all knowledge bases that contain this concept as an ingredient. This spiraling consequence is staggering if the knowledge is comprehensive. Hence the definition of concept at every stage must be such that change is anticipated and accommodated.

IV. Formal Proof - Concepts Change Over Time

In [10], the discussion on the challenges and opportunities in defining concepts using linear algebra threw light on the time-variant nature of concepts. A simple proof of the time-variant nature of concepts is as follows.

Let $c(t)$ be a concept involving time whose equation is (3)

$$c(t) = t\ x(t) \tag{3}$$

where $x(t)$ is an input function, t is time

Delaying the input by δ gives

$$x_d(t) = x(t+\delta)$$

$$c_1(t) = t\ x_d(t)$$

$$c_1(t) = t\ x(t+\delta) \tag{4}$$

Delaying the output by δ gives

$$c_2(t) = c(t+\delta)$$

$$c_2(t) = (t+\delta)x(t+\delta) \tag{5}$$

from (4),(5)

$$c_1(t) \neq c_2(t) \tag{6}$$

$Q.E.D$

V. Conclusion

This paper demonstrated with a case that the nature of concepts in the conceptual knowledge is very dynamic and the impact of even a small change in the definition of one concept can have huge ramifications in the entire knowledge system. Providing structural room to accommodate the changes increases the life and utility of existing knowledge bases and knowledge based systems and also obviates the time and effort required to rebuild knowledge or to keep them updated. Effort is underway to devise methods to embrace this change in all possible ways.

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