VERBKA: AN APPROACH TO BUILDING CAUSAL CONCEPT MAPS BASED ON VERBAL SEMANTICS

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Abstract. Organizations need to find strategies to deal with their challenges. Knowledge Management is a critical resource to the definition of these strategies. In order to do so, organizations use knowledge representation, which in turn is linked to a previous knowledge acquisition process. These processes must be complete and unambiguous. Concept maps are widely used to represent knowledge in organizations, simplifying knowledge storage, retrieval, and use. However, one of the significant gaps in knowledge representation is the comprehension of causal relationships between concepts. Whereas concept maps are able to model causal relationships, this capability is still sparsely explored. This occurs because causal relationships are not usually considered in traditional knowledge representation processes used in the construction of concept maps. To bridge this gap, we present a concept map modeling based on knowledge acquisition through verbal semantics. Results show that this modeling represents causal relationships between concepts, maintaining knowledge's original semantic structure, and allowing knowledge understanding as a whole. We conclude that this approach systematically acquires and represents the knowledge present in causal relationships, and may facilitate knowledge management in organizations and the definition of strategies for problem solving.

1 Introduction

Knowledge Management is essential to deal with problems. It studies how to create, acquire, share, store, and use knowledge in order to develop new ideas, make decisions and solve problems (Machlup, 2014). Knowledge is the result of complex and highly subjective information processing (Davenport & Prusak, 1998), composed by logical and non-logical mental processes such as beliefs, perceptions, experiences, deductions and decisions.

These elements compose what is defined in literature as implicit knowledge (Polanyi, 1962; Nonaka & Takeuchi, 1995). It is difficult to codify this kind of knowledge, because it is incorporated in each individual's actions, perceptions, and ideas. Explicit knowledge, in turn, possesses a formal structure and is codified in language. Thus, it is easier to share and explain than implicit knowledge. In this context, knowledge acquisition, i.e. the identification, capture and modelling of knowledge (Zhou & Li, 2012; Gruber, 2013) can use processes which externalize implicit knowledge through already explicit knowledge.

Organizations need to represent the knowledge they possess in a way that can be easily understood and shared. There are some widely accepted techniques in industry and academia for knowledge representation, such as mind maps (Buzan & Buzan, 2000) and concept maps (Novak, 2010). Concept maps can be used as diagnostic tools for strategic planning, as they allow building consistent scenarios with logical connections. Nonetheless, when causal structures are needed, further research is required. Concept maps might be able to model causal relationships, but this potential is still to be explored (Vasques et al., 2016; Vasques, 2016).

Within this context, we propose a concept map modeling approach based on verbal semantics. We call maps generated through this modeling causal concept maps, since they are able to codify both explicit and implicit causal relationships between concepts. The rest of this paper is organized as follows: Section 2 addresses concept maps; Section 3 presents the main proposition of Verbka. Due to space limitations, a more detailed description of the process can be found in Vasques et al. (2016) and Vasques (2016). Section 4 shows the application of Verbka and the conclusions are presented in Section 5.

2 Background: Concept Maps

Concept maps were created in order to deal with knowledge. In concept maps, concepts are labelled through a reduced number of words, defining a perceived regularity in objects and events (Novak & Cañas, 2008). These concepts are placed inside circles or boxes, connected by labeled arrows. Concepts linked by an arrow create a proposition, representing a logical thinking system (Novak, 2010).

This logical thinking system uses natural language as its base to add meaning to relationships between concepts, thus structuring the map's topic. This is why concept maps are widely used in Knowledge Management to visualize relationships between knowledge components, facilitating new knowledge generation.

To Safayeni, Derbentseva, and Cañas (2005), concept maps are ideal to represent static and hierarchical relationships. Nonetheless, for the representation of functional or dynamic relationships, the same authors propose the use of cyclic concept maps. Cyclic concept maps are not necessarily hierarchical and thus they allow a more dynamic and flexible knowledge modeling (Cañas, Novak, & Reiska, 2012). Within this context, our approach uses this kind of knowledge representation.

3 Verbka

There is a large amount of already explicit knowledge in documents. In order to objectively use this knowledge, it is convenient to use a process based on semantic rules. Within this context, Verbka is a knowledge acquisition process capable of decoding text through semantic information, to later recode this text in the form of a causal concept map (Vasques et al., 2016; Vasques, 2016). Verbka is an acronym for "**Verb**-based **K**nowledge **A**cquisition" and it aims to maintain semantic fidelity from the original text as much as possible, avoiding misinterpretation of represented knowledge while improving reading comprehension. This knowledge acquisition and representation process has its foundations on Linguistic theory (Langacker, 1987, 1991). This process allows the insertion of inferences corresponding to original text's implicit knowledge, and the creation of new knowledge (Novak & Gowin, 1984). Verbka is also independent from a specific domain or knowledge area.

At first, the process needs to fragment the original text until its minimum building linguistic blocks become available. These blocks are concepts that construct propositions. To fragment text into blocks, Verbka is composed by a set of extraction rules, i.e. rules to systematically acquire knowledge from documents. These rules create a concept model composed by causal propositions, defined as sentences structured in the following format: X (Agent) affects Y(Patients).

Each proposition (P) is composed by a verb or phrasal verb, its external complement (subject), and its internal complements (direct object, indirect object, and adverb complements). Therefore, there will always be an agent affecting all complementary concepts that compose a proposition. This flow affects all components through a verbal (verb-based) relationship, which consequently, extends to other semantic relationships marked by prepositions and conjunctions present in the proposition. Each of these concepts form the map's underlying structure. They are placed into rectangles, which in turn, are connected by arrows representing linking phrases.

These propositions are modeled through a causal concept map. This process allows an expansion (Section 4) of traditional concept maps by distinguishing between three types of relationships among concepts, according to the verb used: ***a.*** *agent-patient* relations, where it is necessary to establish the difference between the participant who performs the action (agent) and the participant who receives it (patient); ***b.*** *static relationships*, which are not based on action, i.e. they describe objects' properties or attributes, and ***c.*** *reflexive relationships*, in which the agent's action only affects itself.

In this way, the causal concept maps construction process in Verbka is founded on a semantic approach focused on verbs. It is clear that the traditional concept maps are able to represent knowledge as a dynamic model, in which concepts are constantly under change. However, we are not aware of any work in the literature of Knowledge Engineering where a systematic process towards the construction of the maps is formulated and detailed as proposed in this work and its preceding paper (Vasques et al., 2016; Vasques, 2016).

4 Application and Results

To illustrate how Verbka creates a causal concept map from text, we selected a text fragment from an organizational knowledge management reference (Aarikka-Stenroos & Jaakkola, 2012) shown in Table 1. Verbka follows a set of rules to transform that text into a causal concept map. These rules standardize text, explicit all propositions present in the text, fragment these propositions into concepts and their relationships, and finally create a map following the order in which propositions and relationships were extracted from text.

The causal concept map generated from text using Verbka is shown in Figure 1. All concepts and verbs present in the original text remain in the resulting map. Thus, Verbka does not lose information from original text. In the generated map, all relationships between concepts are shown. It is also possible to capture the author´s chain of thought by following the path from one concept to the other. Thereby, this map reveals knowledge structure schematically.

"Recent research increasingly emphasizes that value emerges from the reciprocal interaction processes between customers and suppliers, and not only through the use of the good or service. At the same time, specialization, knowledge intensiveness and technological complexity are growing in many industries, making the supplier and the customer more dependent on each other's knowledge and resources."

Table 1: Input text (Aarikka-Stenroos & Jaakkola, 2012).

A causal concept map adds to the cyclic concept map the connection of concepts using a cause-effect relationship. Verbka shows this kind of relationship between concepts, considering the verbal typology connecting the subject and the verbal complements. We differentiate among the distinct types of relationships through colors. Red arrows indicate relationships in which the agent clearly affects the patient through an action (transitive verbs). Blue arrows indicate reflexive relationships, i.e. they affect the same agent who perform them (some transitive verbs of perception, reflexive verbs, and intransitive verbs). Finally, black arrows show connections that inflict no action (verbs of state). It is also possible to detect the most prominent concepts, how they are affected, and how they influence the entire network. They appear in bold in Figure 1.

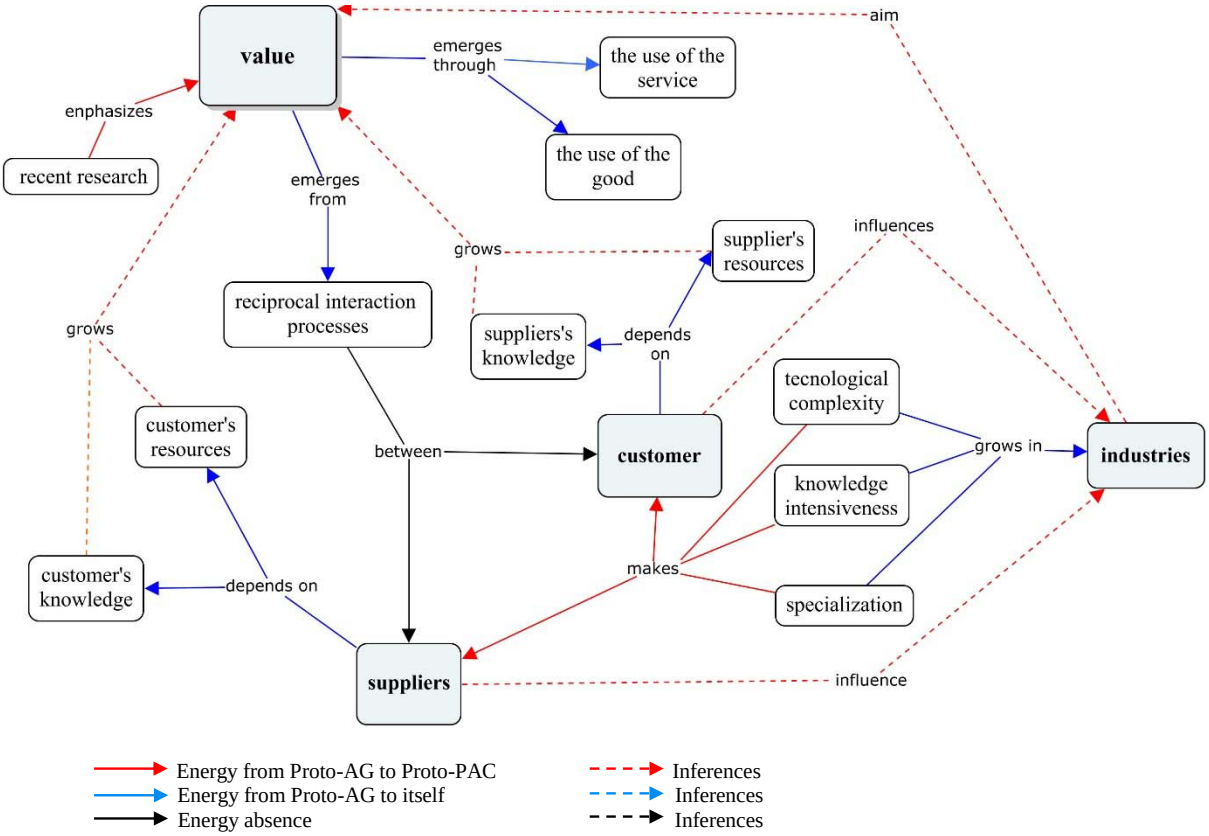

Figure 1. Causal Concept Map.

Verbka may significantly facilitate the inference of implicit connections (due to the map's layout/structure), i.e. connections that were not present in the original text (but instead derived from text comprehension or from context) by detecting missing connections between concepts. Therefore, it is possible to more easily explicit implicit knowledge and to create new knowledge, adding them up to existing knowledge. This is called meaningful learning (Ausubel, 2012). As an example, new connections are shown in Figure 1 as dashed lines.

This type of representation is able to reveal the structure of knowledge, which is immerse in a network composed of different propositions related to the same context. Therefore, this representation allows a more analytical reading of the system that goes beyond the bare reading of the propositions themselves.

5 Conclusions

Knowledge is a dynamic system under constant transformation and needs to be acquired, modeled and represented as such. Mapping based on actions allows the reader to change the way he or she regards and analyzes a problem because it allows a general view and comprehension of that problem, showing not only isolated concepts and actions, but also the relationships between them. Verbka is a flexible process that can be used in different text typologies. Its application showed that it is able to preserve the knowledge semantics in texts written in natural language, allowing their modeling in causal concept maps.

This work's contributions are related to the fact that Verbka aims not only to extract or model knowledge, but also to add a qualitative (semantic) and systematic approach to the acquired and represented knowledge. This reduces the empirical work (i.e. guesswork) in knowledge acquisition and modeling. By applying Verbka, it was possible to realize the versatility that concept maps have in representing different types of knowledge, including procedural and causal knowledge, creating the base for a more dynamic knowledge representation. In conclusion, this work presented a new way to build, use and interpret concept maps based on verbal semantic relationships. The capability of representing semantic knowledge is a further step in supporting organizations to more efficiently deal with knowledge and problem solving. Future work includes automatization of the process.

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