User centered cognitive maps

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Abstract A cognitive map is a graphical representation of an influence network between different concepts. Such a map provides a mechanism to a user to compute the influence from any concept to another. One major drawback of cognitive maps is that large maps are difficult to understand. This paper introduces the notion of an ontological cognitive map that associates an ontology to a cognitive map so that concepts are organized. A scale is a subset of the concepts from the ontology. It can be used to compute a view for a cognitive map, reducing the number of concepts to make it more easily understandable for the user. This article also proposes a way to compute influences between two concepts of an ontological cognitive map for different sets of values associated to the influences.

1 Introduction

Two kinds of influence graphs are commonly used in artificial intelligence to modelize influence networks: bayesian networks [Naïm et al.(2004)Naïm, Wuillemin, Leray, Pourret, and Becker] and cognitive maps [Tolman(1948)]. Influence graphs provide mechanisms to highlight the influence between concepts. *Cognitive maps* represent a *concept* by a text and an *influence* by an arc to which a value is associated. These values generally belong to sets of symbols like $\{+,-\}$ [Axelrod(1976), Chauvin et al.(2008b)Chauvin, Genest, and Loiseau], $\{$*none*;*some*;*much*;*a lot*$\}$ [Dickerson and Kosko(1994), Zhou et al.(2003)Zhou, Zhang, and Liu] or belong to sets of numeric values like $[-1,+1]$ [Kosko(1986), Satur and Liu(1999)]. For symbolic set of values, a cognitive map can be represented as a conceptual graph [Baget and Mugnier(2001)] where concepts of a cognitive map are concepts of a conceptual graph and influences are particular relations. The difference is that cognitive map provides specific semantic for the influences. In cognitive map models the influences and their values are used in the computation of the *propagated influence*

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from a concept to another, according to the paths between these concepts. Cognitive maps have been used in many fields such as ecology [Celik et al.(2005)Celik, Ozesmi, and A. Akdogan], biology [Tolman(1948)], sociology [Poignonec(2006)], politics [Levi and Tetlock(1980)]. They are used to help a user to take a decision by understanding the consequences of it.

Cognitive maps have the drawback of not being so easy to exploit in practical applications. The main reason is the important number of concepts which makes cognitive maps difficult to construct and to apprehend. The main idea of this paper is to provide a solution to obtain views of a cognitive map adapted to what the user wants to do.

Our first contribution is to introduce the notion of scale in the cognitive map model, in order to let the user select the level of detail of the map he wants to visualize. To do that, we associate an *ontology* to an initial cognitive map. The ontology is a taxonomy that organizes the concepts using a specialization relation. The most specialized concepts are called *elementary concepts*: these concepts are the only ones represented in the cognitive map. A *scale* is a subset of concepts of the ontology chosen by the user in order to provide a view for a cognitive map adapted to the user. Each elementary concept, or a concept that generalizes it, must belong to the scale. A view is a cognitive map computed using only the concepts of the scale : the view is then adapted to the user. It usually has fewer concepts than the elementary concepts, ie. the concepts of the cognitive map; we speak of *view for a scale*.

Our second contribution is to automatically provide an adaptation of a cognitive map to a user in the form of an adapted view for him. To do that, a particular scale is associated to a user. We call such a scale a *profile*. When using a cognitive map, the profile associated to the user is used to compute a map, called a *view for a profile*, which is *adapted* to the user. When several users want to work on a single cognitive map, user profiles are combined together so as to construct a new scale composed of *shared concepts*. From the *shared concepts*, a *shared view* adapted to these users is computed.

In practice, to associate an ontology to a cognitive map, we define an *ontological cognitive map* (OCM) as the association of a cognitive map and an ontology whose elementary concepts are the concepts of the map. The *ontological influence* provides a way to compute the influence between any pair of concepts of the ontology. The ontological influence is used to compute the value of the influences in a view. Note that an ontology has already been associated to cognitive maps, for instance in [Jung et al.(2003)Jung, Jung, and Jo] and in [Poignonec(2006)] where it is used to compare or to merge maps.

The second section of this paper presents related works. The third section describes the OCM model and the propagated influence. The fourth section introduces the notion of scale and view for a scale. The fifth section defines what is a profile, a view for a profile and a shared view. The sixth section introduces different ways to compute the propagated influence according to the set of values associated to the map.

2 Related works

In this section we first recall what are the categories of support systems. Second, we show how graphical knowledge models, especially cognitive maps, can be considered in the category of decision support systems. Third, we present three major approaches used by cognitive maps. Fourth, we present an approach mixing different graphical knowledge models, ie. cognitive maps and conceptual graphs. Fifth, we discuss the concept of ambiguities in cognitive maps.

Support systems in business are typically classified in three categories [Turban(1993)]: *EIS* (Executive Information Systems), *ESS* (Executive Support Systems) and *DSS* (Decision Support Systems). EIS focuses on the construction of synthetic data, mostly from databases, highlighting the data that seem most relevant in relation to the chosen objective. For instance, [Paradice(1992)] proposes a hybrid model as the combination of an object model and a causal model. The ESS integrate information from previous systems but operate more by providing a prospective case study or simulation of several scenarios. For instance, [Vasan(2003)] proproses a system of multiple simulations using fuzzy linear programming. The DSS are systems that strongly interact with users: they use different decision models, using data that may be poorly structured, They are used for complex problems and provide mechanisms for cooperative work. For instance, [S. Pinson(1997)] proposes a distributed decision system for strategic planning and [Rommelfanger(2004)] presents a review of fuzzy optimization models for decision support.

Graphical knowledge models, especially cognitive maps, have been defined. Most of these models can be considered as decision support systems. For these models, a decision is often a choice of a user among different alternatives to reach the goal that he fixes. The models help a user to express knowledge about these alternatives, and help him to take his decision. Representation of these alternatives helps the user to take into account the links existing between events or notions: by knowing the consequences of his choice, a user can take his decision. However, to make this help efficient, the user must understand the represented knowledge, he must access easily to the alternatives and he must find and understand their consequences. Several models provide graphical representations of alternatives and links between concepts, some of these models are based on the notion of a map such as mind maps [Buzan and Buzan(2003)], concept maps [Novak and Gowin(1984)] and cognitive maps [Axelrod(1976)]. Among these models, cognitive maps is one of the easiest to use.

Currently, cognitive maps are used primarily in three major approaches. First, cognitive maps are used to assist in the structuring of thought before taking a decision [Huff and Fiol(1992)]. A cognitive map can clarify a confused idea because it models representations and it acts on this representation in the structuring process, the cognitive map metaphor is thus used to model the biological role of the hippocampus [Redish(1999)]. Second, cognitive maps are used as a medium for communication about a decision between individuals [Eden(1988)] or agents [Chaibdraa(2002), Tisseau(2001)] [Parenthoen et al.(2001)Parenthoen, Tisseau, Reignier, and Dory]. The development of a cognitive map facilitates the transmission of ideas between decision makers and becomes a communication tool. Third, cognitive maps are used to make decisions [Huff and Fiol(1992)] [Ronarc'h et al.(2005)Ronarc'h, Rozec, Guillet, Nédélec, Baquedano, and Philippé]. The cognitive map is a model designed to include the path by which an individual will find a solution to a given problem: this path may be computed automatically.

[Genest and Loiseau(2007)] and [Chauvin et al.(2008a)Chauvin, Genest, and Loiseau] proposes an extended model of cognitive maps that mix the cognitive map model with a conceptual graph model. First, concepts are expressed with a conceptual graph [Sowa(1984)]. It provides clear *definitions of concepts*. These definitions are taken into account to provide an efficient search mechanism: a user may build a query using a conceptual graph, and the system can extract the concepts of the map that correspond to the query. So, *sets of concepts* can be automatically built, and this paper proposes some specific inference mechanisms on sets of concepts. Second, a *validity context* is given for each influence of a map in the form of a conceptual graph. The validity context of an influence represents cases in which this influence is relevant. For each category of user, a *use context* is defined using a conceptual graph. Using validity contexts, a *filtering mechanism* extracts concepts and influences that are relevant for one context. So for a user and his use context, the obtained cognitive map is simpler than the initial cognitive map and allows to compute propagated influences that are more adjusted to him. Since conceptual graphs are graphs, conceptual graph model is homogenous with the visual aim of cognitive maps. The conceptual graph model defines operations and has a logical semantics. A conceptual graph is a graph composed of concept nodes representing entities and relation nodes representing relations between entities. A graph is defined on a structure called support that specifies and organizes in a hierarchy the basic vocabulary used for concepts and relations. The support corresponds to a representation of an ontology of the domain. A formal operation, called projection, provides a way to search logical links between graphs and is used as a base of the search mechanism and the filtering mechanism. Some works on conceptual graphs are intended to facilitate the knowledge modelling from several experts. These include for example the model C-Vista [Ribière and Dieng-Kuntz(2002)].

The preceding approaches using cognitive maps and conceptual graphs removes the ambiguous results of the influence propagation by taking into account only the influences relevant to a user profile. Other works address the same problem but solve the ambiguities using different sets of influence values associated to an operation of influence propagation based on logics. [Zhang et al.(1992)Zhang, Chen, Wang, and King] [Zhang(1996)] propose solutions for cognitive maps they describe as vague in defining the opportunity to obtain two different views on influence, for example, one positive and another very negative. The need for such solutions depends on the application, it should be noted that the use of links that are not symbolic elements restrict the use of cognitive maps to expert users. Truck's thesis [Truck(2002)] offers a state of the art solutions to aggregate and make inferences with different operators and is a possible entry point for thinking about the design of extensions of cognitive maps incorporating links or fuzzy data.

3 Ontological cognitive map and inference

An ontological cognitive map (OCM) is the association of a cognitive map and an ontology. The propagated influence between two concepts is a value computed using the influence paths from one concept to the other. The ontological influence is a generalization of the propagated influence to every ordered pair of concepts of the ontology.

A cognitive map is an oriented graph where nodes are labeled by concepts. A concept is a text. An arc is labeled by a value that describes the effect of the influence.

Definition 1 (Cognitive map). Let I be a set of values. Let C be a set of concepts. A *cognitive map* defined on C and I, is an oriented labeled graph $(V, label_V, A, label_A)$ where:

- V is a set of nodes.
- $label_V : V \to C$ is a bijective function labeling a node of V with a concept of C
- $A \subseteq V \times V$ is a set of arcs called *influences*
- $label_A : A \to I$ is a function labeling an influence with a symbol of I.

Example 1. *Map1* (figure 1) concerns a road safety analysis. *Map1* is defined on $I = \{+, -\}$ and represents the influence of different factors on the risk that an accident occurs. For instance, driving in the rain positively influences the risk of the road to being slippery, so there is an arc labeled by a $+$ symbol between the concepts *Rain* and *Slippery road*. On the contrary, *Motorway* negatively influences *Winding road*, so there is an arc labeled by a $-$ symbol.

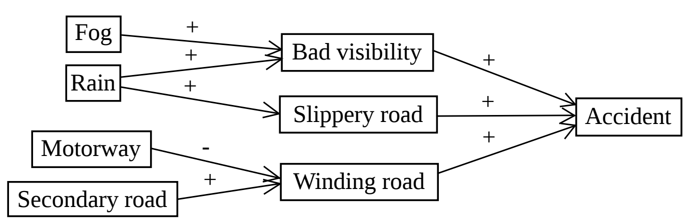

Fig. 1 *Map*1 : a cognitive map about road safety problems

An ontology in an OCM is represented by a set of concepts partially ordered by a specialization relation. For a subset of concepts of an ontology, minimum (resp. maximum) concepts are the concepts for which there are no lesser (resp. greater) concepts than them. An ontological cognitive map is the association of a cognitive map and an ontology. Only the elementary concepts of the ontology are represented in the map because influences are defined only on them.

Definition 2 (Ontology). An *ontology* $(C, \preceq)$ is a set of concepts C partially ordered by a relation $\preceq$. We note $\prec$ the strict order relation associated with $\preceq$.

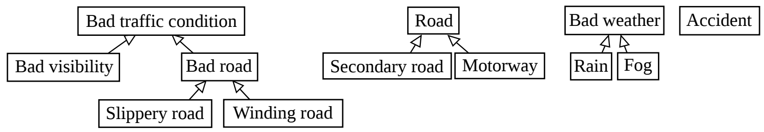

Fig. 2 Ontology1

Definition 3 (Maximum, minimum and elementary concepts). Let $(C, \preceq)$ be an ontology. Let $C' \subseteq C$. We name the set of *maximum concepts* of C': $max(C') = \{c \in C' \mid \nexists\, c' \in C' ,\ c \prec c'\}$. We name the set of *minimum concepts* of C': $min(C') = \{c \in C' \mid \nexists\, c' \in C' ,\ c' \prec c\}$. The concepts of $min(C)$ are called *elementary concepts*.

Definition 4 (OCM). An *ontological cognitive map* defined on an ontology $(C, \preceq)$ and a set of values I is an association of an ontology $(C, \preceq)$ and a cognitive map defined on $min(C)$ and I.

Example 2. *OMAP1* is the OCM built by associating the ontology *Ontology1* (figure 2) and the cognitive map *Map1*. *Motorway* $\preceq$ *Road* means that a motorway is a kind of road. Note that *Map1* only contains the elementary concepts of *Ontology1*. $min(Ontology1) = \{$ Bad visibility, Slippery road, Winding road, Rain, Fog, Secondary road, Motorway, Accident $\}$

The propagated influence of a concept on another is computed according to the influence paths existing between the nodes labeled by these concepts.The propagated influence for an influence path is evaluated by cumulating all values of its influences. Definitions 6,7,9 of operators are made for the set of values $I = \{+, -\}$. Section 5 discusses how to adapt these definitions for other sets of values.

Definition 5 (Influence path). Let $M = (V, label_V, A, label_A)$ be a cognitive map defined on a set of concepts C and a set of values I. Let c_1, c_2 be two concepts of C.

- We name an *influence path* from c_1 to c_2 a sequence (of length k) of influence $(u_i, v_i) \in A$ such that $u_1 = label_V^{-1}(c_1)$ and $v_k = label_V^{-1}(c_2)$ and $\forall i \in [1..k-1], v_i = u_{i+1}$.
- An influence path P from the concept c_1 to c_2 is *minimal* iff an influence path P' from c_1 to c_2 such that P' is a subsequence of P does not exist.
- We note $\mathscr{P}_{c_1,c_2}$ the *set of minimal influence paths* from c_1 to c_2.

Definition 6 (Propagated influence for an influence path). Let $M = (V,\ label_V,\ A,\ label_A)$ be a cognitive map defined on a concept set C and the set of influence values $I = \{+, -\}$.

The *propagated influence for an influence path P* is:

$$\mathscr{I}_P(P) = \bigwedge_{(v,v')\ of\ P} label_A((v, v'))$$

with $\bigwedge$ a function defined on $I \times I \to I$ and represented by the table 1.

$\bigwedge$	+	-
+	+	-
-	-	+

Table 1 $\bigwedge$ operator.

The propagated influence from a concept to another concept can be null (noted by 0) if no path exists between these concepts. It is positive when the influences propagated in all the paths between these concepts are positive (noted by +). It is negative when the influences propagated in all the paths between these concepts are negative (noted by -). When two or more paths have different propagated influences, it is not possible to decide if the propagated influence between these two concepts is positive or negative. It is also not possible to know if the paths compensate each others (in this case it would be null). In such a case, the propagated influence is ambiguous (noted by ?). This mechanism has the drawback to often return ambiguous results.

Definition 7 (Propagated influence). Let $M = (V, label_V, A, label_A)$ be a cognitive map defined on a concept set C and the set of influence values $I = \{+,-\}$.

The *propagated influence* between two concepts is a function $\mathscr{I}$ defined on $C \times C \to \{0,+,-,?\}$ such that:

$$\mathscr{I}(c_1,c_2) = 0 \; if \;\; \mathscr{P}_{c_1,c_2} = \emptyset$$

$$\mathscr{I}(c_1,c_2) = \bigvee_{P \in \mathscr{P}_{c_1,c_2}} \mathscr{I}_P(P) \; if \;\; \mathscr{P}_{c_1,c_2} \neq \emptyset$$

where $\bigvee$ is a function defined on $\{+,-,?\} \times \{+,-,?\} \to \{+,-,?\}$ represented by the table 2.

$\bigvee$	+	-	?
+	+	?	?
-	?	-	?
?	?	?	?

Table 2 $\bigvee$ operator.

Example 3. We want to compute the influence between `Rain` and `Accident`. Two influence paths are presented in $Map1$ between these concepts: p_1 (*Rain* $\to$ *Bad visibility* $\to$ *Accident*) and p_2 (*Rain* $\to$ *Slippery road* $\to$ *Accident*).

$\mathscr{I}(Rain, Accident) = (\mathscr{I}_P(p_1) \vee \mathscr{I}_P(p_2)) = ((+\wedge+) \vee (+\wedge+)) = +$.

The ontological influence provides a mechanism to the user that queries an OCM to determine the influence between any ordered pair of concepts of the ontology. For this, we first determine the two subsets of elementary concepts that specialize the two concepts of the pair. The ontological influence between two concepts c_1 and c_2 is then the aggregation of values of the influences propagated between the elementary concepts of c_1 and those of c_2.

We propose to add two symbols $\oplus$ and $\ominus$. The first symbol represents the value of an influence that is positive or null. The second symbol represents the value of an influence that is negative or null. These new symbols simplify the reading of the ontological influence.

Definition 8 (Elementary concepts for a concept). Let $(C, \preceq)$ be an ontology. Let c be a concept of C. We name the set of *elementary concepts for a concept* c, the subset of C defined as:

$$elemFor(c) = \left\{c' \in min(C) | c' \preceq c\right\}$$

Definition 9 (Ontological influence). Let OM be an ontological cognitive map defined on an ontology $(C, \preceq)$ and the set of influence values $\{+, -\}$.

The *ontological influence* between two concepts of C is a function $\mathscr{I}_O$ defined on $C \times C \rightarrow \{+, -, 0, ?\}$ such that:

$$\mathscr{I}_O(c_1, c_2) = \bigodot_{\substack{c'_1 \in elemFor(c_1) \\ c'_2 \in elemFor(c_2)}} \mathscr{I}(c'_1, c'_2)$$

where $\bigodot$ is a function defined on $\{+, -, 0, ?\} \times \{+, -, 0, ?\} \rightarrow \{+, -, 0, ?\}$ represented by the table 3.

$\odot$	+	-	0	$\oplus$	$\ominus$	?
+	+	?	$\oplus$	$\oplus$	?	?
-	?	-	$\ominus$	?	$\ominus$	?
0	$\oplus$	$\ominus$	0	$\oplus$	$\ominus$	?
$\oplus$	$\oplus$	?	$\oplus$	$\oplus$	?	?
$\ominus$	?	$\ominus$	$\ominus$	?	$\ominus$	?
?	?	?	?	?	?	?

Table 3 $\odot$ operator.

Example 4. We want to compute the ontological influence between the concept *Bad weather* and the concept *Bad traffic condition*.
First, we determine the elementary concepts for *Bad weather* and for *Bad traffic condition*:

- $elemFor(\textit{Bad weather}) = \{\textit{Fog}, \textit{Rain}\}$
- $elemFor(\textit{Bad traffic condition}) = \{\textit{Bad visibility}, \textit{Slippery road}, \textit{Winding road}\}$

Second, we compute the influence between each possible ordered pair (c_1, c_2) where c_1 is a member of $elemFor(\textit{Bad weather})$ and c_2 is a member of $elemFor(\textit{Bad traffic condition})$:

- $\mathscr{I}(\textit{Fog}, \textit{Bad visibility}) = +$.
- $\mathscr{I}(\textit{Fog}, \textit{Slippery road}) = 0$.
- $\mathscr{I}(\textit{Fog}, \textit{Winding road}) = 0$.
- $\mathscr{I}(\textit{Rain}, \textit{Bad visibility}) = +$.
- $\mathscr{I}(\textit{Rain}, \textit{Slippery road}) = +$.
- $\mathscr{I}(\textit{Rain}, \textit{Winding road}) = 0$.

Third, we agregate the previous propagated influences using the operator $\odot$: $\mathscr{I}_O(\textit{Bad weather}, \textit{Bad traffic condition}) = + \odot 0 \odot 0 \odot + \odot + \odot 0 = \oplus$.
The ontological influence between *Bad weather* and *Bad traffic condition* is positive or null.

4 Scale and View

A scale is a subset of concepts from the ontology, chosen by the user in order to obtain a view. The concepts of the scale will be present in the view.

A scale respects some particular properties : all the concepts must be incomparable and they must be representative of all the concepts of the ontology.

Intuitively, the incomparability avoids taking into account twice the same concept in the scale: once as a concept and once as a concept that generalizes it. Intuitively, the representative ensures that every elementary concept is represented in the scale or a concept that generalizes it.

Definition 10 (Comparable concepts). Let $(C, \preceq)$ be an ontology. Two concepts c and c' of C are *comparable* iff $c \preceq c'$ *or* $c' \preceq c$.

Property 1 (Set of incomparable concepts) *Let $(C, \preceq)$ be an ontology. Let $C' \subseteq C$. C' is a* set of incomparable concepts *iff $\forall c, c' \in C'$ with $c \neq c'$, c and c' are not comparable.*

Definition 11 (Elementary concepts for a set). Let $(C, \preceq)$ be an ontology. Let $C' \subseteq C$. We name the *set of elementary concepts for a set C'*: $elemForSet(C') = \bigcup_{c \in C'} elemFor(c)$.

Property 2 (Representative set of a set) *Let $(C, \preceq)$ be an ontology. Let $C_1, C_2 \subseteq C$. C_1 is* a representive set *of C_2 iff $elemForSet(C_2) \subseteq elemForSet(C_1)$.*

Theorem 1 shows that a set is representative of the ontology if its elementary concepts are the elementary concepts of the ontology.

Theorem 1 *Let $(C, \preceq)$ be an ontology. Let $C' \subseteq C$. C' is a representative set of C iff $elemForSet(C') = min(C)$.*

Definition 12 (Scale). Let $(C, \preceq)$ be an ontology. Let $C' \subseteq C$. C' is a *scale* iff C' **1)** is a set of incomparable concepts (Property 1) and **2)** is representative of C (Property 2).

Example 5. Let $A = \{\textit{Bad traffic condition}, \textit{Bad weather}, \textit{Road}, \textit{Accident}\}$. A respects property 1 because *Bad traffic condition*, *Bad weather*, *Road*, *Accident* are not comparable. A respects property 2 because $elemForSet(A) = \{\textit{Bad visibility}, \textit{Slippery road}, \textit{Winding road}, \textit{Rain}, \textit{Fog}, \textit{Secondary road}, \textit{Motorway}, \textit{Accident}\} = min(Ontology1)$. So, A is a scale.

A view of an OCM is a cognitive map in which concepts are those of a scale. Two concepts of a view are connected if there is one elementary concept for each of them so that those two elementary concepts are connected in the OCM. An arc between two elementary concepts of the view is labeled in the same way as the corresponding arc of the OCM. In other cases, the value of an arc in the view is computed using the ontological influence.

Definition 13 (Connection between two concepts).
Let $OM = (V, label_V, A, label_A)$ be an OCM defined on an ontology $(C, \preceq)$ and a set of values I. Two concepts c_1 and c_2 of C are *connected* iff $\exists c'_1 \in elemFor(c_1)$, $\exists c'_2 \in elemFor(c_2) \mid (label_V^{-1}(c_1), label_V^{-1}(c_2)) \in A$.

Definition 14 (Value of an influence between two connected concepts). Let $OM = (V, label_V, A, label_A)$ be an OCM defined on an ontology $(C, \preceq)$ and a set of values I. $\forall c_1, c_2 \in C$ that are connected:

$$Value(c_1, c_2) = \begin{cases} label_A(label_V^{-1}(c_1),\ label_V^{-1}(c_2))\ if \\ c_1\ and\ c_2\ are\ elementary\ concepts. \\ \mathscr{I}_O(c_1, c_2)\ otherwise. \end{cases}$$

Definition 15 (View for a scale). Let $OM = (V, label_V, A, label_A)$ be an OCM defined on an ontology $(C, \preceq)$ and a set of values I. Let C' be a scale. A *view for C'* of OM is a cognitive map $(V_s, label_{V_s}, A_s, label_{A_s})$ defined on C' and I such that:

- V_s is a set of node whose cardinality is equal to the cardinality of C'.
- $label_{Vs} : V_s \rightarrow C'$ is a bijective function labeling each node of V_s with a concept of C'.
- $A_s \subseteq V_s \times V_s$ is the set of influences $(label_{Vs}^{-1}(c_1), label_{Vs}^{-1}(c_2))$ such that c_1 and c_2 are connected.
- $label_{A_s} : A_s \rightarrow I \cup I \times I$ is a labeling function such that $label_{A_s}((v_1, v_2)) = Value(label_{V_s}(v_1), label_{V_s}(v_2))$

Example 6. Figure 3 is the view of *OMAP1* for the scale $\{$ *Bad traffic condition*, *Road*, *Bad weather*, *Accident* $\}$. The color gray of boxes are the maximum concepts introduced by the scale. We note that the influence between *Bad weather* and *Bad traffic condition* is labeled by $\oplus$ as seen in the example 4. The influence between *Road* and *Bad traffic condition* is labeled by ? because, in *Map1*, there is a positive influence between *Motorway* and *Winding road* and there is a negative influence between *Secondary road* and *Winding road*. The influence between *Bad traffic condition* and *Accident* is labeled by $+$ because all influences from an element of $elemFor($*Bad traffic condition*$)$ to *Accident* in *Map1* are positive.

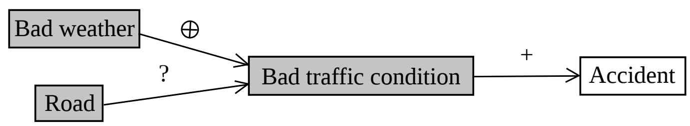

Fig. 3 View of $OMAP1$

5 Specific View

To a user is associated a profile that defins a scale that fits to him. This profile provides a solution to obtain a view well adapted to the user: it is the *view for the profile*.

Definition 16 (User profile). Let $(C, \preceq)$ be an ontology. A *user profile* is a scale for C.

Definition 17 (View for a profile). Let OM be an OCM defined on $(C, \preceq)$ and I. Let P be a user profile. The *view for a profile* P is the view for P of OM.

Example 7. Figure 4 presents the view for the profile $P_m = \{$*Fog*, *Rain*, *Road*, *Bad traffic condition*, *Accident*$\}$ built for the user “meteorologist”. Another view for the profile $P_r = \{$*Motorway*, *Secondary road*, *Bad weather*, *Bad traffic condition*, *Accident* $\}$ can be computed for the user “road constructor”.

When two users share the same map and want to use it together, a shared view, adapted to the two users, will be built from a scale compound of all the concepts shared by two users. This set of shared concepts is the union of the two user profiles to which a min is applied for two reasons. First to provide the most specialized concepts relevant to both users. Second to ensure that all shared concepts is a scale.

Definition 18 (Shared concepts). Let OM be an OCM defined on $(C, \preceq)$ and I. Let P_1 and P_2 be two profiles. $SharedConcepts(P_1, P_2) = min(P_1 \cup P_2)$.

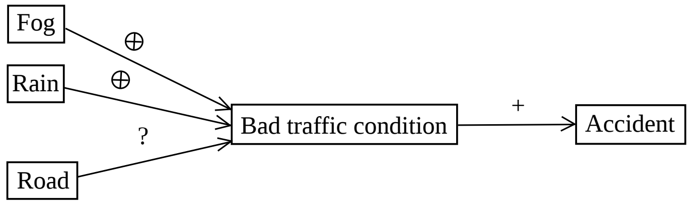

Fig. 4 View for the user “meteorologist”

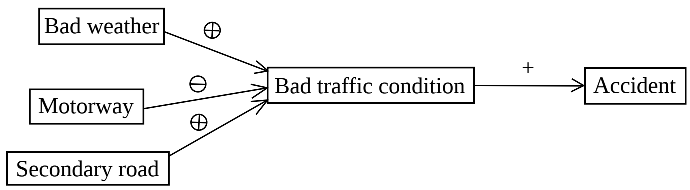

Fig. 5 View for the user “road constructor”

Property 3 enables to use the shared concepts in order to compute a view.

Property 3 *Let OM be an OCM defined on* $(C, \preceq)$ *and I. Let* P_1 *and* P_2 *be two profiles.* $SharedConcepts(P_1, P_2)$ *is a scale for C.*

Definition 19 (Shared view). Let OM be an OCM defined on $(C, \preceq)$ and I. Let P_1 and P_2 be two profiles. The *shared view* for P_1 and P_2 is the view for $SharedConcepts(P_1, P_2)$ of OM.

Example 8. Figure 6 presents the shared view for the two profiles P_r and P_m. For a better presentation, the concepts which are in P_r are represented by boxes whose borders are small dashes ; the concepts of P_m are represented in gray boxes.

The user “meteorologist” finds in this view the concepts that interest him particularly: *Fog* and *Rain*. The user “road constructor” finds in this view the concepts that interest him particularly: *Motorway* and *Secondary road*. Using this view they can talk about the influence of their particular interest on the *Bad traffic condition* or *Accident*.

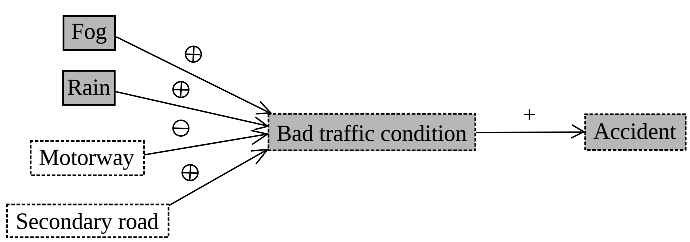

Fig. 6 Shared view for P_r and P_m

Shared view can be trivially generalized to more than two users.

6 Parameters

In the previous sections, the cognitive maps have been defined on the set of values $I = \{+,-\}$, and operators have been defined for this set. It is possible to change the operators used in the definitions 6,7,9 for a new set of values.

For $I = [-1,+1]$ the propagated influence for an influence path and the propagated influence between two concepts are given in definition 20, in conformity with [Kosko(1986)]. The ontological influence is given in definition 20 in conformity with [Chauvin et al.(2008b)Chauvin, Genest, and Loiseau].

Definition 20 (Propagated influence ($I = [-1,+1]$)). Let $(V, label_V, A, label_A)$ an ontological cognitive map defined on the ontology $(C, \preceq)$ and on the set of values $I = [-1,+1]$.

- The *propagated influence for an influence path P* is:

$$\mathscr{I}_P(P) = \prod_{(v,v')\ of\ P} label_A((v,v'))$$

- The *propagated influence between two concepts* is a function $\mathscr{I}$ defined on $C \times C \to I$ such that:

$$\mathscr{I}(c_1,c_2) = \begin{cases} \frac{\sum_{P \in \mathscr{P}_{c_1,c_2}} \mathscr{I}_P(P)}{card(\mathscr{P}_{c_1,c_2})} & if\ \mathscr{P}_{c_1,c_2} \neq \emptyset \\ 0 & otherwise. \end{cases}$$

- The *ontological influence between two concepts* c_1, c_2 *of* C is a function $\mathscr{I}_O$ defined on $C \times C \to I \times I$ such that:

$$\mathscr{I}_O(c_1,c_2) = [\min_{\substack{c'_1 \in elemFor(c_1) \\ c'_2 \in elemFor(c_2)}} \mathscr{I}(c'_1,c'_2), \max_{\substack{c'_1 \in elemFor(c_1) \\ c'_2 \in elemFor(c_2)}} \mathscr{I}(c'_1,c'_2)]$$

Example 9. Let *OCM2* be an ontological cognitive map based on *OCM1* but labeled by the set of values $I = [-1,+1]$. The figure 7 represents *OCM2* and the view of *OCM2* for the profile “meteorologist”.

For $I = \{null, some, much, a\ lot\}$, the propagated influence for an influence path and the propagated influence between two concepts are given in definition 21, in conformity with [Zhou et al.(2003)Zhou, Zhang, and Liu].

The ontological influence is the same as the one of the definition 20. It returns an interval between two values of I.

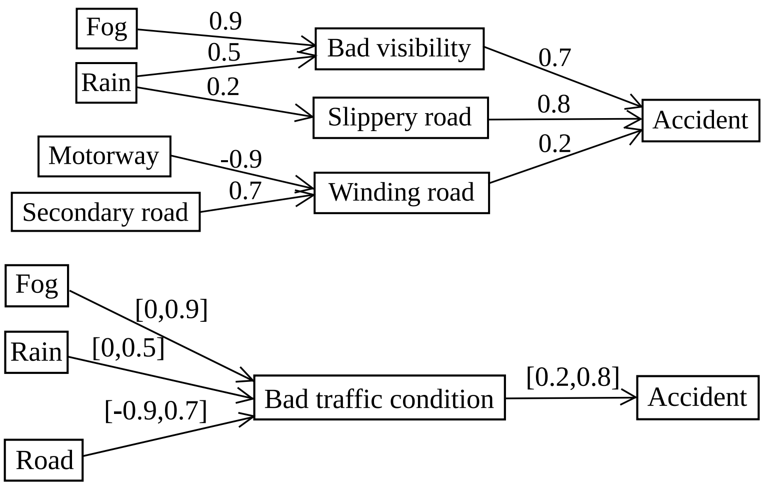

Fig. 7 *OCM2* and the view of *OCM2* for the profile “meteorologist”.

Definition 21 (Propagated influence ($I = \{$*null* $\preceq$ *some* $\preceq$ *much* $\preceq$ *a lot*$\}$)). Let $(V, label_V, A, label_A)$ an ontological cognitive map defined on the ontology $(C, \preceq)$ and on the partial ordered set $I = \{null \preceq some \preceq much \preceq a\ lot\}$.

- The *propagated influence in a path P* is defined such as:

$$\mathscr{I}_P(P) = \min_{(v,v') \text{ of } P} label_A((v,v'))$$

- The *propagated influence between two concepts* c_1 and c_2 is defined such as:

$$\mathscr{I}(c_1,c_2) = \begin{cases} null & \text{if } \mathscr{P}_{c_1,c_2} = \emptyset \\ \max\limits_{P \in \mathscr{P}_{c_1,c_2}} \mathscr{I}_P(P) & \text{if } \mathscr{P}_{c_1,c_2} \neq \emptyset \end{cases}$$

- The ontological influence between two concepts is defined in one of definition 20.

Example 10. Let *OCM3* be an ontological cognitive map based on *OCM1* but labeled by the set of values $I = \{null \preceq some \preceq much \preceq a\ lot\}$. The figure 8 represents *OCM3* and the view for the profile ”meteorologist”.

Notice that other sets of values and operators can be proposed.

7 Conclusion

This work extends the model of cognitive maps and its associated reasoning mechanisms in order to organize the concepts. It provides synthetic views of a cognitive

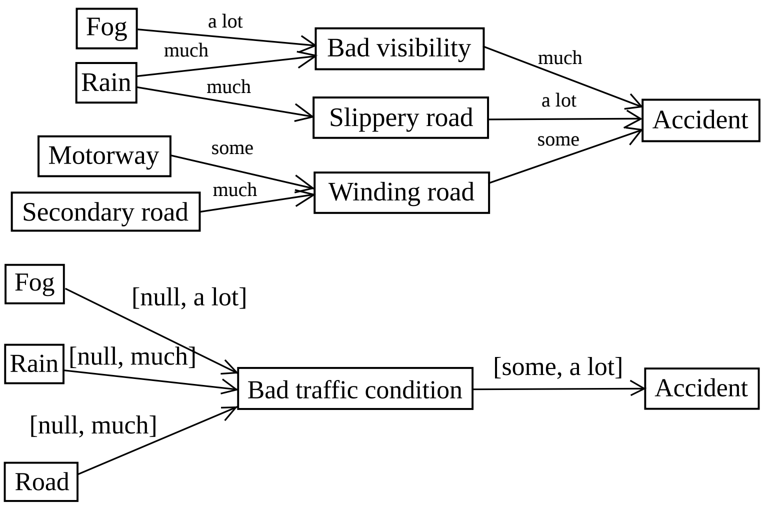

Fig. 8 *OCM3* and the view of *OCM3* for the profile ”meteorologist”.

map, using scales to see maps of different conceptual levels. It also proposes to take into account the user to adapt maps to him or her. The idea behind these extensions is that both during its edition and during its use, it is important to “navigate” in the map space so as to have different points of view; information considered important from a certain point of view is not the same as those that considered important from another. This idea of navigation in a cognitive map is new: previous work on cognitive maps are usually interested in the edition of maps, in the computation of propagation between concepts, or the comparison of maps.

SCCO (figure 9)[1] is a prototype that implements the ideas of this article. SCCO is able to add an ontology to cognitive maps ; it provides mechanisms to compute the ontological influence of a concept of the ontology to another concept; it defines a scale as a subset of an ontology checking representability and incomparability properties; it uses a scale to produce a suitable view; it also proposes a profile and a shared view. Ontological cognitive maps containing about fifty concepts have been built with this program. It shows the interest of our approach.

[1] `http://forge.info.univ-angers.fr/~lionelc/CCdeGCjava/`

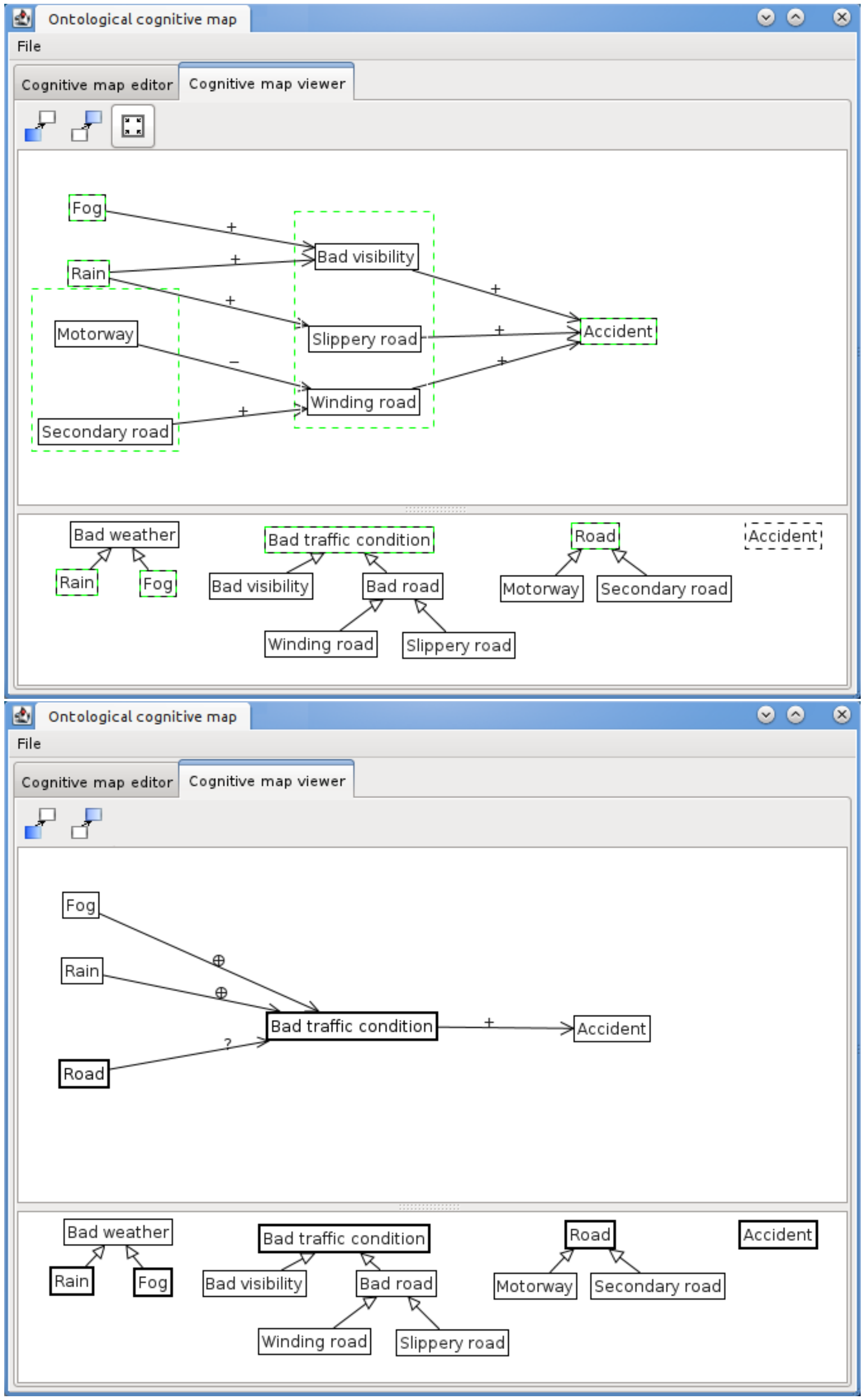

Fig. 9 Prototype: selection of a scale and a view of a cognitive map.

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