Building of CBR's DB using ontology for a collision avoidance system

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ABSTRACT: We have proposed Fuzzy-CBR to find a solution from past knowledge retrieved from the database and adapted to the new situation. However, ontology is needed in identifying concepts, relations and instances that are involved in a situation in order to improve and facilitate the efficient retrieval of similar cases from the CBR database. This paper proposes the way to apply ontology for identifying the concepts involved in a new case, used as inputs, for ship collision avoidance support system and in solving for similarity through document articulation and abstraction levels. These ontologies will be used to build a conceptual model of a manoeuvring situation.

1 INTRODUCTION

Ship manoeuvring is a part of navigation where bridge officers develop their skill through years of experience and knowledge acquisition in able to understand the relation between his ship and ships that are within his sight. This understanding provide him with the necessary idea of what is supposed to be done and of what is not supposed to be done before even deciding what precaution or action he needs to apply to keep his own ship (OS) out of danger of collision (Lee & Rhee 2001; Im & Park 2005; Na et al. 2003; Park & Benedictos 2006)

There has been ship maneuvering systems proposed before but they have failed to capture the expert knowledge in ship maneuvering like the one captured using ontology. We propose to use ontology together with CBR in the acquisition of an expert knowledge in a ship maneuvering system (Watson. 1998; Iwatani etal. 1994; Tano et al. 1995; Fojioka et al. 1995; Aadmont & Plaza 1994). Ontology will be considered as knowledge structures that will identify the concepts, property of concepts and relationships among them to enable share and reuse of knowledge that are needed to acquire knowledge in maneuvering a ship safely in the vicinity of other ships (Nossum et al 2005; Sanches et al. 2005).

In Section 2 we will first discuss the types of maneuvering situation involving a single target ship that are most often used by bridge officers that require basic maneuvering knowledge in order to understand the situation before taking action based on past similar experiences. We will then introduce how ontology can be used to identify the concepts of ship maneuvering and the relations among these concepts (Sanches et al. 2005). In Section 3 we will adapt a new method using ontology for document indexing as discussed by R. Nossum and V. Oleshchuk to find the similarity of a maneuvering situation to any of the ontology describing the concepts of maneuvering (Park & Benedictos 2006). Finally we will be using these ontologies to build a conceptual model of a maneuvering situation involving multiple target ships.of

2 ONTOLOGY IN MANEUVERING SITUATIONS

There are several maneuvering situations that can represent the basic ship maneuvering knowledge of a bridge officer. The knowledge used in this situations are somewhat related to each other though each one is also separated by distinct attributes that can be considered different from the rest. The following are the maneuvering situations in navigation involving a single target ship:

1. Collision Avoidance
2. Altering Course
3. Maintaining Course
4. Overtaking
5. Crossing
6. Non-collision

Though the above maneuvering situations have distinct attributes from each other some of them may share a similar concept or instance to be related to each other. Take for example the first two situations; Collision Avoidance and Altering Course are related with each other when we think about avoiding collision with another ship whose distance is slowly getting near your own ship. On the other hand they are a separate maneuvering situation when you are maintaining a course in order not to be in collision with another ship. This conditional relationship is also present among the other maneuvering situations.

In Figure 1 we can see the five basic maneuvering situations and how they can be related to each other. In the following sections we will be discussing how ontology can be used to represent them as context descriptions together with the algorithm to find the similarity of a given situation.

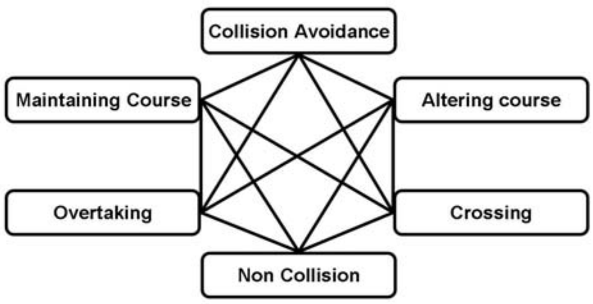

Fig. 1. Basic maneuvering situations and their ontological relations

2.1 *Using ontology in defining concepts*

In this paper we consider ontologies as knowledge structures that identify concepts, properties of concepts and relations among them to enable share and reuse of knowledge. Ontologies. As shown in Figure 2 we will use ontology to collect and organize terms of references presented as graphs that reflect structural and semantic relationships between contexts.

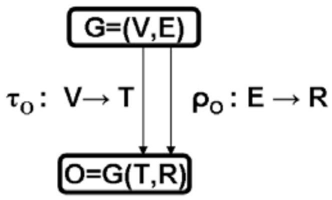

Fig. 2. Mapping of Vertices and Edges

2.2 *Graphical Representation of ontology*

We will assume, that contexts are given in form of ontology. Ontology O is presented as a directed graph $G = (V, E)$ where vertices from V are labeled by elements from T and edges from E are labeled by elements from R. We denote such ontology as $O = G(T, R)$. The mappings of V and edges E are defined by surjective functions $\tau_O : V \rightarrow T$ and $\rho_O : E \rightarrow R$ respectively, that is, $\tau_O(V)=T$ and $\rho_O(E)=R$. In Fig.2, we can see how the relation between graph $G = (V, E)$ is mapped by ρ_O and τ_O to an ontology $O = G(T, R)$.

Using the basic maneuvers, enumerated in the first paragraph of this section, as concepts or terms, we can let T be the set of maneuvers and R be the set of predefined semantic relations among the maneuvers such as *instance_of, subset_of, attribute_of, member-of_group* etc.

Using the ontologies shown in Figures 3 to 8 we can go further to include more transitive and asymmetric relations that will define a hierarchal structure between more specific and more general concepts, where terms inherit all characteristics from their ancestor terms. We take R to represent a hyponymy-like relations, and then from $(a, b) \notin R$ it follows that b represents a more general concept than a.

We will define sub-ontology relation $\subseteq$ similar to the subgraph relation (Nossum et al. 2005).
Let $O_i = G_i(T_i, R_i)$ where $G_i=(T_i, R_i)$, i = 1,2 be two ontologies. O_i is a sub-ontology of O_2 denoted $O_1 \subseteq O_2$ if the following properties are satisfied:

– Graph G_1 is a subgraph of G_2;
– $T_1 \subseteq T_2$ and $R_1 \subseteq R_2$;
– $\tau o_1 \subseteq \tau o_2$ and $\rho o_1 \subseteq \rho o_2$.

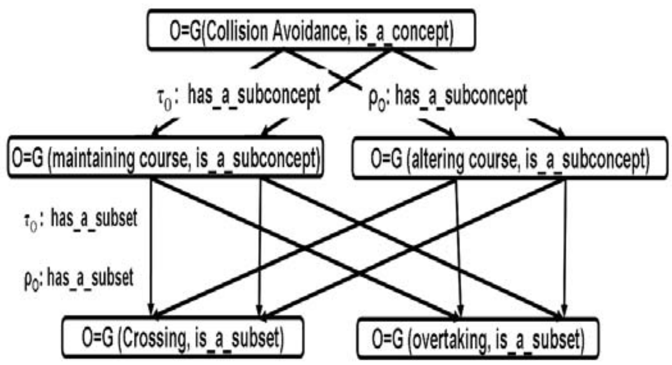

Fig. 3. Ontologies under the concept collision avoidance

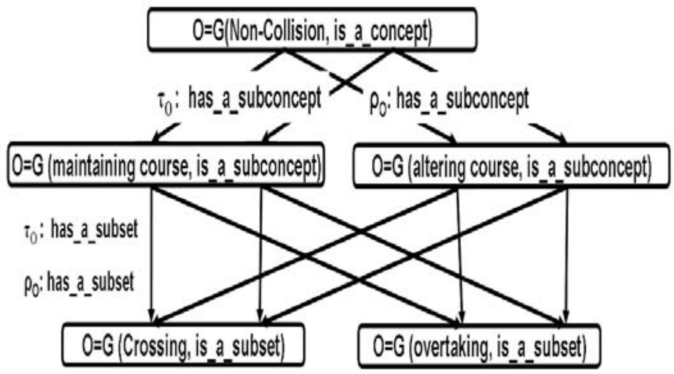

Fig. 4. Ontologies under the concept non-collision avoidance

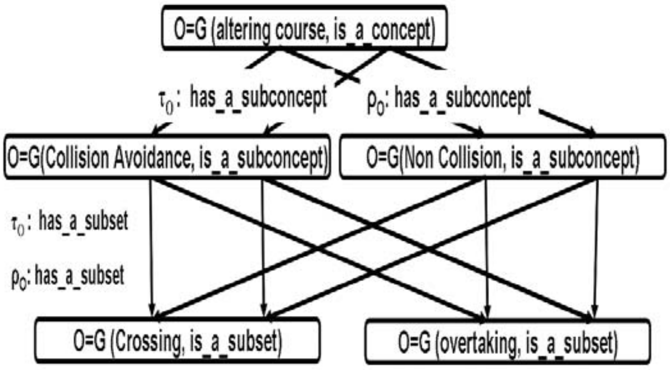

Fig. 5. Ontologies under the concept altering course

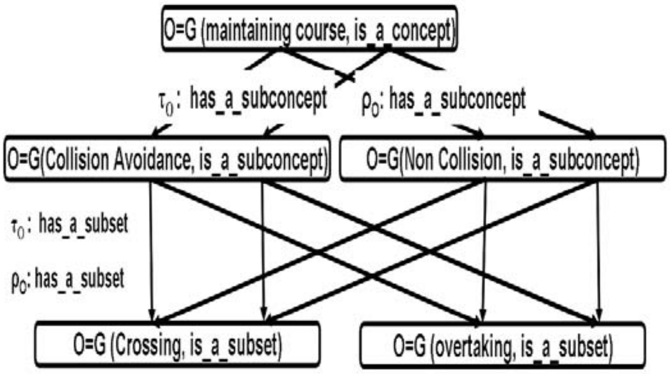

Fig. 6. Ontologies under the concept maintaining course

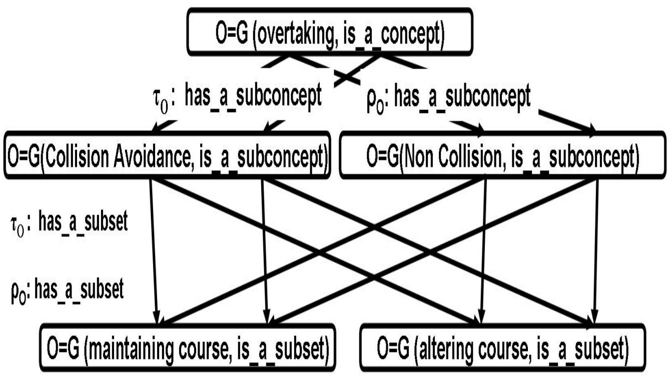

Fig. 7. Ontologies under the concept overtaking

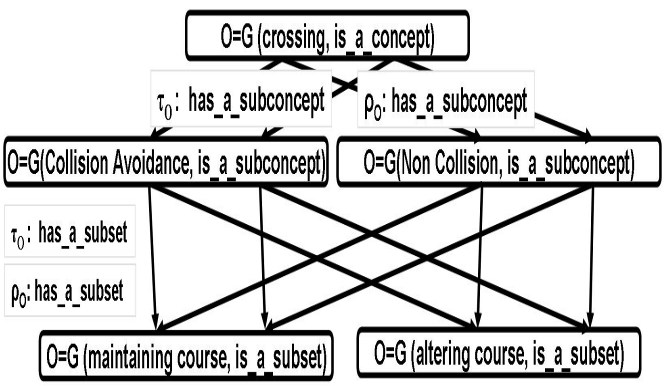

Fig. 8. Ontologies under the concept crossing

As shown in Figure 9, let us take the ontologies from the root *altering course* having a relation, *is_a_concept*, as an example. It will be mapped by the *τo* and *po*, *has_a_subconcept*, to *collision avoidance* which has a relation *is_a_sub-concept.* The sub-concept will have a mapping *has_a_subset* to *Altering course* having a relation *is_a-subset*. The sub-set will have a mapping *has_a_member* to *ship* having a relation *is_a_member*. The member will also have a mapping *has_an_attribute* to the attributes *course*, *distance*, *relative* bearing, *TCPA*, *DCPA*, and *αβ* having a common relation *is_an_attribute*. These will have a common mapping *has_a_value* to their respective parameters having a relation *is_a_value* that could describe a maneuver that calls for an alteration of course.

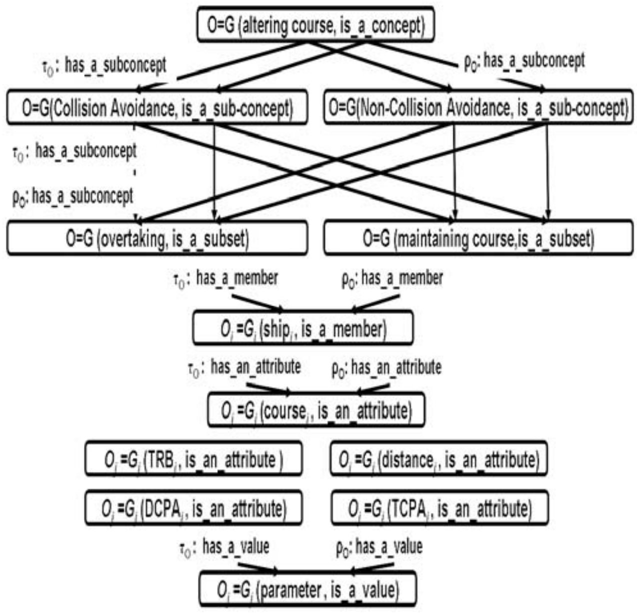

Fig. 9. Ontologies describing the concept altering course

3 DOCUMENT ARTICULATION AND SOLVING FOR SIMILARITY

We will give a formal definition of semantic similarity and explain how to calculate similarity between two maneuvering situation using *abstraction levels* and based on context defined in the form of ontology (Nossum et al. 2005).

3.1 *Document articulation*

Parameters used in this articulation will be defined as the following:

Distance - Distance between the ship in the vicinity from (OS).

TRB – Target ship's relative bearing will help determine the type of approach of the dangerous ships as well as in adjusting the solution to be adapted by its similarity from the that in the case base.

TCPA – Time of CPA will be used to determine the CR of each vessel within the dangerous area. It is also used to adjust the solution to be adapted by finding its similarity from that in the case base.

DCPA – Distance at CPA will be used as a fuzzified input implicated by the rules in the case base to produce an adjusted output of new heading.

CR – Collision Risk is the result of implicating the TCPA and TRB rules. I will indicate the degree of danger that an approaching ship poses to OS.

αβ – The angle of approach of a ship in the vicinity in relation to OS heading measured from the direction of OS's heading for ships forward of OS's beam and measured from the direction of OS's stern for ships abaft OS's beam.

We take maneuvering situation *t* as document containing the set of *values* of the *attributes distance, TRB, DCPA, TCPA, CR and αβ* as the input. The input *t* is to be articulated with respect to an ontology $O = G(T,R)$, where $G = (V,E)$. O will represent the ontology representing our maneuvering situations above.

The articulation of *t* with respect to *O* is a sub-ontology *O* denoted as O_t such that $O_t \subseteq O$, let *term* (t,O) denote the set of terms from *T* that occur in *t* that is, $term(t,O) \subseteq T$.

We can define O_t *as* $G_t(T_t, R_t)$, where $G_t = (V_t, E_t)$, and let $G_t = (V_t, E_t)$ be the subgraph of $G = (V, T)$ spanned by V_t

In the articulation of a document, we try to find all terms from *T* occurring in *t* by selecting $V_t \subseteq V$ *such that* $\tau_O(V_t) = term(t, O)$.

3.2 *Similarity using Abstraction Levels*

The articulation of our document *t,* containing a set of *attribute values,* relative to an ontology *O* that defines a *maneuvering situation* is in general a forest of trees or *sub-ontology* of *O* where parent vertices represent more abstract concepts than their children and root vertices are the most abstract concepts. Root vertices have abstraction level 0 and non root vertices have abstraction level 1 more than its parent. We will denote abstraction level of a vertex $v \notin V$ as *level(v)* expressed as:

$level: V \rightarrow \{0,1,2,\ldots\}$

Defining the similarity of a set of input t_1 to a set of *ontology* t_2 relative to an on ontology $O = G(T, R)$ where $G = (V, E)$. Let $Ot_i = Gt_i(Tt_i, Rt_i)$, $i = 1,2$ denote articulations of t_1 and t_2 with respect to *O*. Similarity is measured as a number between 0 and 1 which is a ratio of the number of common terms at the relevant abstraction level shown in Fig. 10.

Assuming that $Gt_i = (Vt_i, Et_i)$, and V_i^j is the set of vertices at abstraction level *j* in the articulation of t_i relative to *O*. let m_i be the highest value of *j* such that $V_i^j \neq 0$, $i = 1,2$ and let $m = min(m_1, m_2)$, $M = \max(m_1, m_2)$

The similarity of t_1 and t_2 relative to *O* is a vector $\text{Sim}(t_1, t_2, O) = (s_0 \ldots, s_M)$:

$$s_j = \left| \frac{V_1^j \cap V_2^j}{V_1^j \cup V_2^j} \right| \quad \text{for } 0 \leq j \leq m$$

$$s_j = 0 \quad \text{for } m < j \leq M$$

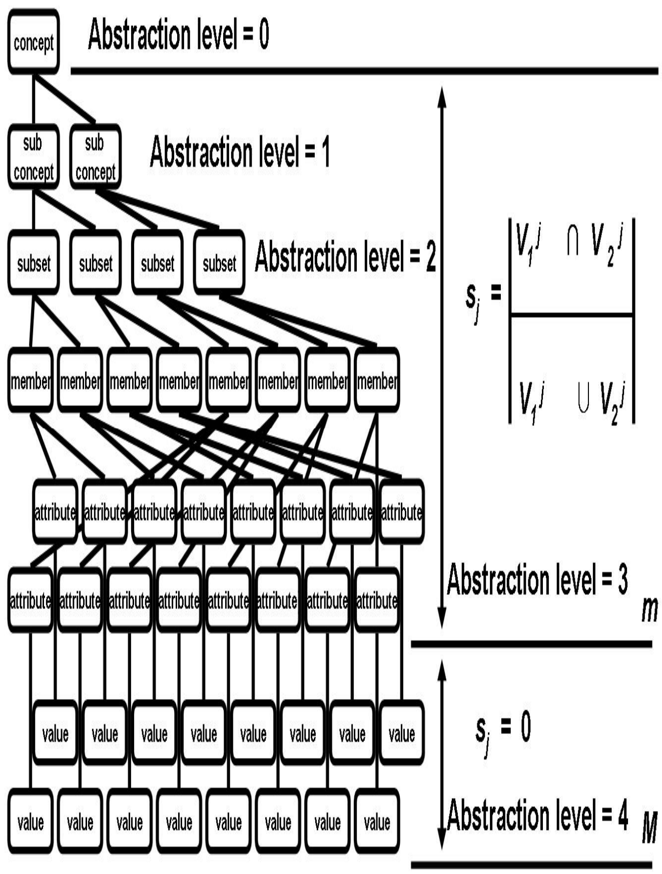

Fig. 10. Solving similarity using abstraction levels

Similarity will be measured by the total number of related terms in every abstraction level divided by the number of vertices.

3.3 *Conceptual Model*

After solving for the individual similarity of a maneuvering situation involving a single target ship in a maneuvering situation, in the preceding sections, we can further apply ontology to build a conceptual model (Sanches etal.2005) of a new maneuvering situation involving multiple target ships in order to find a similar case from the CBR database where a solution can be adapted to obtain an optimum output to avoid collision.

Figure 11 shows how a set of concepts' relation to a maneuvering situation can be used to build the conceptual model of a maneuvering situation by defining the allowed parameter for alteration of heading depending to each target ship's relation to the concepts of maneuvering situations.

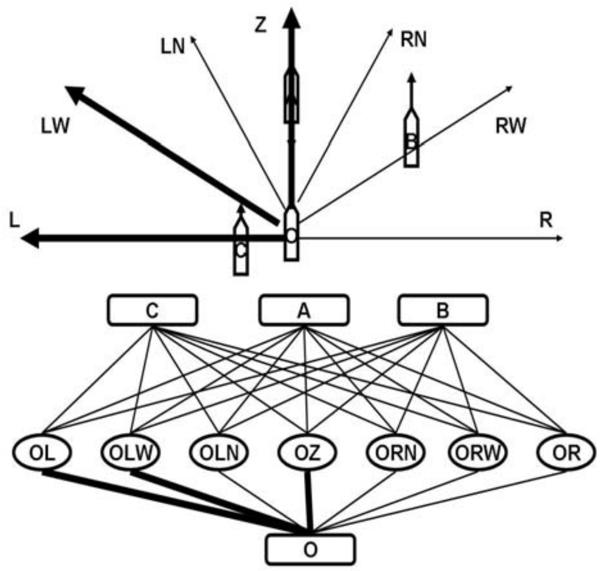

Fig. 11. Constructing a conceptual model of a maneuvering situation using ontology

Looking at the figure above, The vertices *OL, OLW, OLN, OZ, ORN, ORW, OR* are *ontologies* having relations mapped to the concepts *A, B, C.* They define the allowed alteration in relation to the respective concepts. The bold lines denote maneuvers that have no relation to the ontology and the narrow lines denote the maneuvers that have a relation to the ontology. Vertices having no relation to the ontology denote that the alterations are not allowed.

This conceptual model can be used to find a similar case in the CBR database that would give the optimum solution to obtain an output for avoiding collision. Figure 12 shows the structure of building a conceptual model of a maneuvering situation using a set of ontology to be used as a tool in finding a similar case from the CBR database.

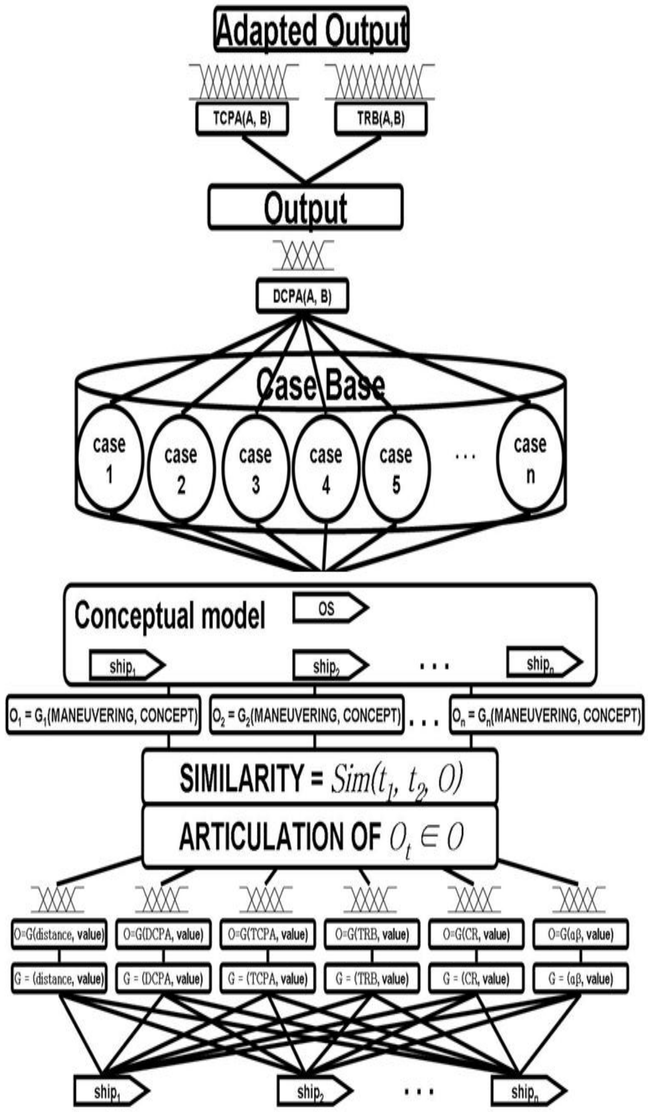

Fig. 12. Structure of building a conceptual model.

4 CONCLUSION

We have adapted an algorithm using ontology to define the basic concepts that can represent an acquired expert knowledge in maneuvering a ship. We have also used a set of ontologies to build a conceptual model that can represent a new maneuvering situation involving multiple target ships. The conceptual model can be used as a tool in improving the algorithm for finding similar cases from the CBR database.

Future research will focus on finding similar cases from the CBR database using conceptual model as a tool. The effect on the efficiency of obtaining an optimal output from the Fuzzy-CBR database would be validated by further tests in more complicated maneuvering environmenst.

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