Conceptual Model for Fuzzy-CBR Support System for Collision Avoidance at Sea Using Ontology

Gyei-Kark Park*, Woong-Gyu Kim** and John Leslie RM Benedictos**

*Faculty of Maritime Transportation System
**Graduate School, Department of Maritime Transportation System
Mokpo National Maritime University
Phone number: +82-61-240-7128
(e-mail: gkpark@mmu.ac.kr)

Abstract

Fuzzy-CBR Collision Avoidance Support Sytem is a system that finds a solution from past knowledge retrieved from the database and adapted to a new situation. Its algorithm has resulted to an adapting a solution for a 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 environment and use them as inputs, for a ship collision avoidance support system., Similarity will be obtained through document articulation and using abstraction levels. A conceptual model of a maneuvering situation will be built using these ontologies..

1. 서 론

Through years of experience and knowledge acquisition, bridge officers develop their skill in ship maneuvering in order to understand the relation between his own ship and ships that are within his sight. This understanding equips him with the necessary idea on what is supposed to be done and what is not supposed to be done before deciding what precaution or action he needs to apply to keep his own ship (OS) out of danger of collision from other ships[1-4].

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[5-9].]. 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[10-11] that are needed to acquire knowledge in maneuvering a ship safely in the vicinity of other ships.

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 [11]. Then, we will adapt a new method using ontology for document indexing as discussed by R. Nossum and V. Oleshchuk[10] to find the similarity of a maneuvering situation to any of the ontology describing the concepts of maneuvering[4]. Finally we will be using these ontologies to build a conceptual model of a maneuvering situation involving multiple target ships and show how they can be related to cases inside the database..

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 Fig.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.
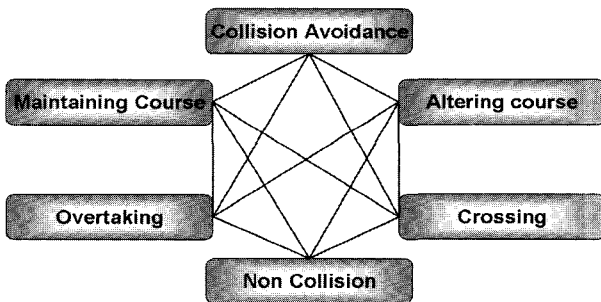

Fig. 1. Basic maneuvering situations and their ontological relations

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 Fig. 2 we will use ontology to collect and organize terms of references presented as graphs that reflect structural and semantic relationships between contexts.

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 ρO and τO to an ontology $O = G(T, R)$.
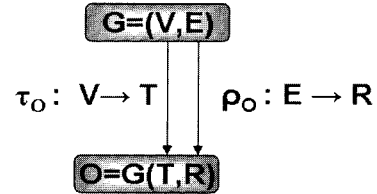

Fig. 2. Mapping of Vertices and Edges

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 Fig. 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 $(a, b) \in R$ it follows that b represents a more general concept than a.

We will define sub-ontology relation $\sqsubseteq$ similar to the subgraph relation.[1]

Let $O_i = G_i(T_i, R_i)$ where $G_i = (T_i, R_i)$, i = 1, 2 be two ontologies. O_1 is a sub-ontology of O_2 denoted $O_1 \sqsubseteq O_2$ if the following properties are satisfied:
- Graph G_1 is a subgraph of G_2;
- $T_1 \sqsubseteq T_2$ and $R_1 \sqsubseteq R_2$;
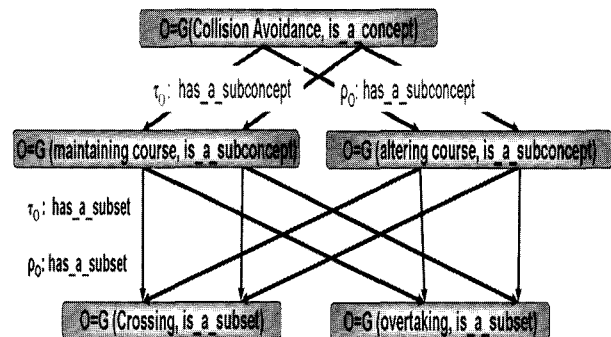- $\tau_{O_1} \sqsubseteq \tau_{O_2}$ and $\rho_{O_1} \sqsubseteq \rho_{O_2}$

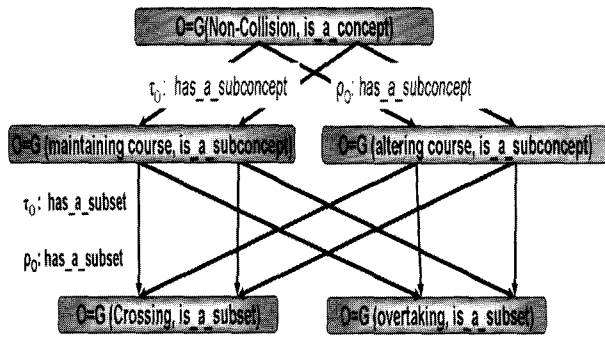Fig. 3. Ontologies under the concept collision avoidance.

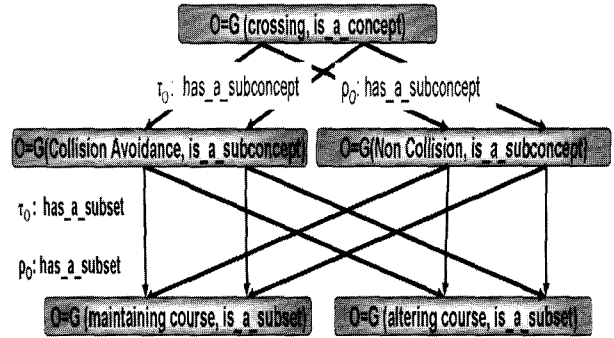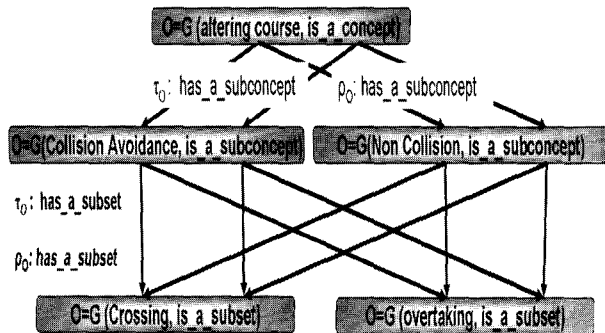Fig. 4. Ontologies under the concept non-collision avoidance.

Fig. 5 Ontologies under the concept altering course.
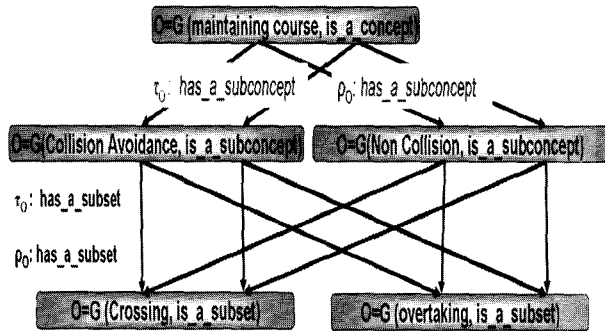

Fig. 6 Ontologies under the concept maintaining course.
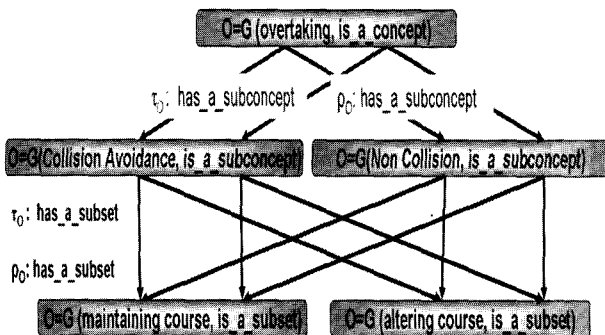

Fig. 7 Ontologies under the concept overtaking.

Fig. 8. Ontologies under the concept crossing.

As shown in Fig.9, let us take the ontologies from the root concept *altering* course having a relation, *is_a_concept*, as an example. It will be mapped by the τ_O and ρ_O, *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.
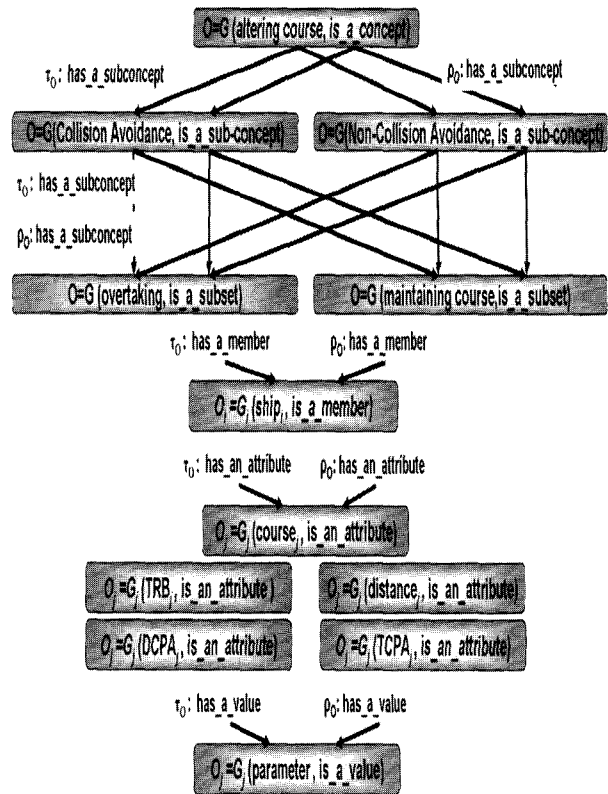

Fig. 9. Ontologies describing the root concept altering course.

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[10].

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 $G = (V, E)$ spanned by V_t

In the articulation of a document, we try to find all

terms from T occurring in t by selecting $V_t \in V$ such that $\tau_0(V_t) = term(t, O)$.

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 $v \in V$ 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 $O_i = G_i(T_i, R_i)$, i = 1,2 denote articulations of t_i 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 $G_{t_i} = (V_{t_i}, E_{t_i})$, 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 sim $(t_1, t_2, O) = \langle s_0 \ldots s_M \rangle$:
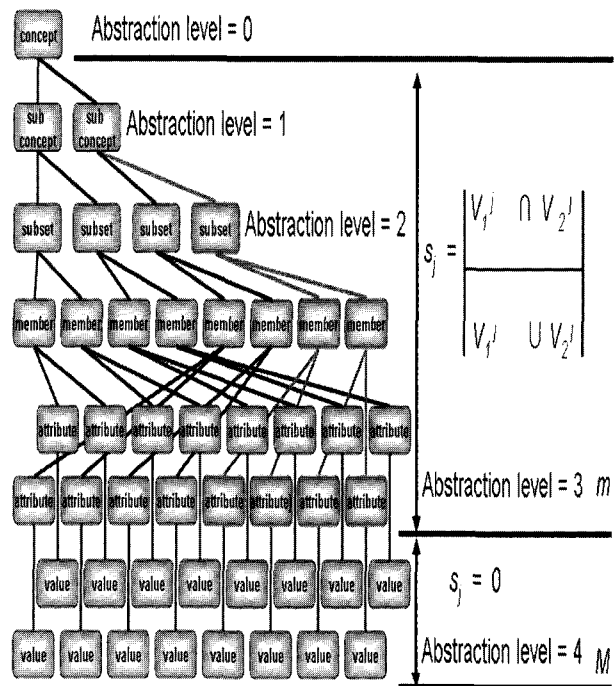

Fig. 10. Solving similarity using abstraction levels.

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

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

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 builda conceptual model[11] 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.

Fig. 11 shows how a set of concepts' relation to a maneuvering situation can be used to buildthe 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.
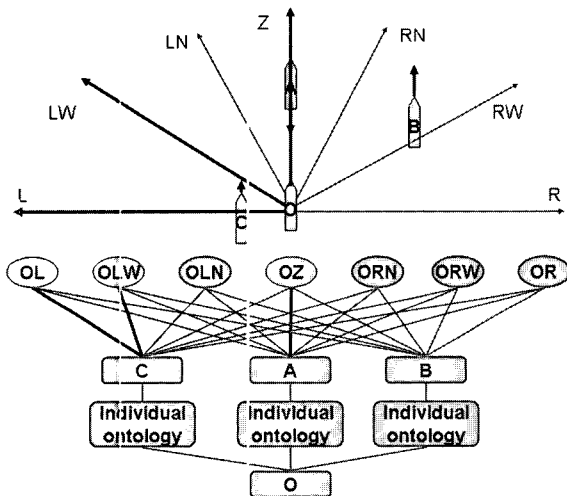

Fig. 11. Constructing a conceptual model of a maneuvering situation using ontology.

In Fig. 11 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.

Similarity of the conceptual model to cases inside the case base can be measured with the same process used in the individual manoeuvering concepts. Fig. 12 shows how the vertices of a conceptual model can be related to a cases inside a database. Fig. 13 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. 14 shows the components and the flow of data using our proposed algorithm of building a conceptual model.
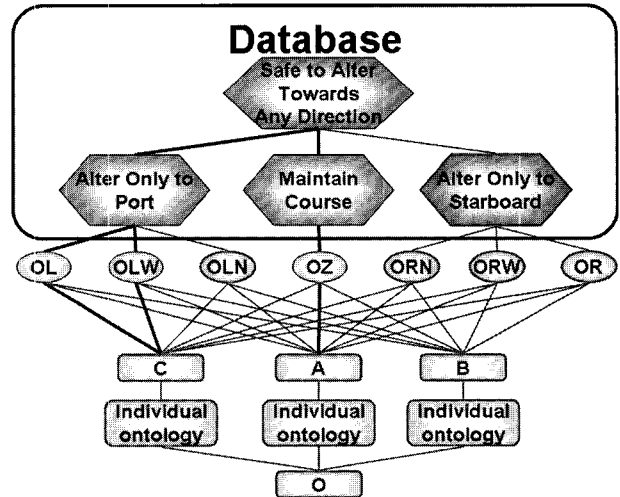

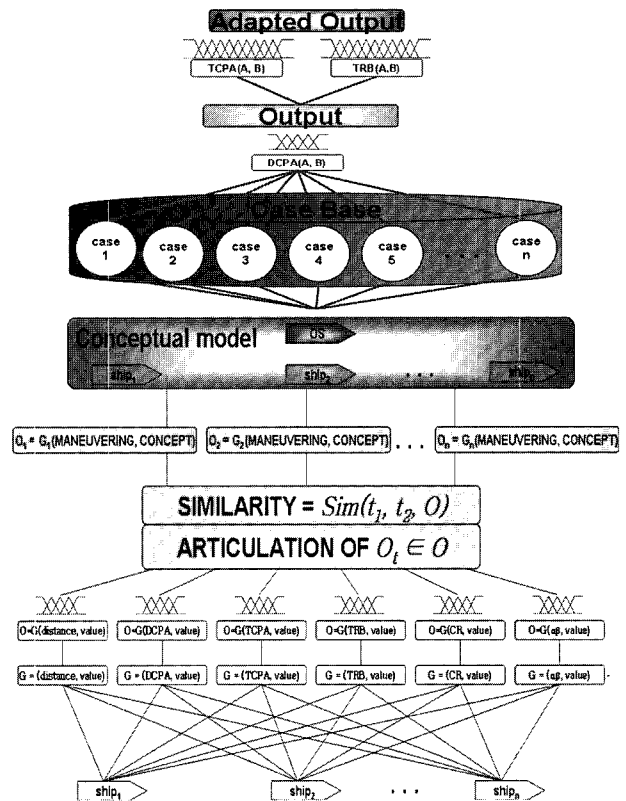Fig. 12. Relation of a conceptual model to cases inside the database.

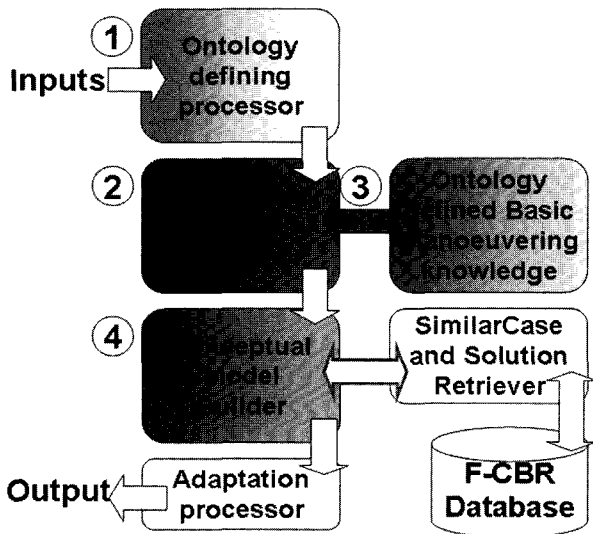Fig. 13. Structure of building a conceptual model.

Fig. 14. Components and the flow of data in building a conceptual model for F-CBR.

4. CONCLUSION

We have used ontology in adapting an algorithm 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. We have shown how a conceptual model can be used as a tool to obtain similar cases from the F-CBR database by finding its similarity in relation to a case inside the database and help to improve the accuracy of the resulting output.

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

REFERENCES

[1] H. J. Lee and K. P. Rhee, Development of Collision Avoidance System by Using Expertand Search Algorithm, Int'l. Ship Building System, Vol.48, No. 3, pp.197-210, 2001.

[2] N. K. Im and G. K. Park, Simulation Study on Auto Navigation System. pp. 572-576, Proc. of the 6thSymposium on Advanced Intelligent Systems, 2005.

[3] Y. N. Na, W. G. Choi and S. J. Lee, Self Organizing Fuzzy Controller Using Command Fusion Method and Genetic Algorithm, International Journal for Fuzzy Logic and Intelligent Systems, 2003.

[4] G. K. Park, J. L. R. M. Benedictos, Ship's Collision Avoidance System Using Fuzzy-CBR, Vol.16, No. 2, pp. 39-44,Proc. of KFIS Autumn Conference, 2006

[5] I. Watson, CBR is a methodology not a technology, In, Research and Development in Expert Systems XV, 1998.

[6] T. Iwatani, S. Tano and W. Okamoto, Fuzzy Case Base Reasoning in FLINS (Fuzzy Lingual Reasoning), LIFE Technical Report, TR-4N020, 1994.

[7] S. Tano, T. Iwatani, W. Okamoto, A. Inoue and R. Fojioka, Natural Language Communication System -Concept and Conversation Examples,pp. 1039-1044, 1995.

[8] R. Fojioka, S. Tano, W. Okamoto, A. Inoue and T. Iwatani, Treatment of fuzziness in natural language by Fuzzy Lingual Sytem -FLINS, FUZZ-IEEE'95. pp.1045-1050, 1995.

[9] A. Aadmont and E. Plaza, Case-Based Reasoning: Foundational Issues, Methodological Variations, and system approaches,AI Communications, 7(1):39-59, 1994.

[10] R. Nossum and V. Oleschuk, Dynamic Documents Indexing in Evolving Contexts, CiteSeer.IST Scientific Literature and Digital Library, Microsoft research, National Science Foundation, Nasa, <http://citeseer.ist.psu.edu/733761.html>.

[11] D. M. Sanches, J. M. Cavero and E. Marcos, On Models and Ontologies, 1st Workshp on Philosophical Foundations of Information systems Engineering , PHISE05, <http://kybele.escet.uric.es/PHISE/index.php?page-Program>

저 자 소 개

Gyei-Kark Park
1982 Graduated from Dept. of Nautical Science, Korea Maritime University
1993 Received the degree of Doctor of Engineering from Tokyo Institute of Technology
1993-94 Senior Researcher, LIFE(Laboratory for International Fuzzy Engineering)
2001-02 Visiting Professor, University of Cincinnati
2006 Professor, Faculty of Maritime Transportation system, Mokpo National Maritime University
Awards:
1994 Outstanding Paper Award in Japan Society for Fuzzy Theory and Systems

Research Interest:
- Intelligent system in marine industry
- Intelligent navigation control system
- Machine Learning based on linguistic instruction

Phone : +82-61-240-7128
E-mail : gkpark@mmu.ac.kr

Feb. 1982 Graduated from Korea Maritime University
Jul. 1996 Masters Degree of Business and Administration from Helsinki School of Economics, Finland
Feb. 2007 : Completed Doctorial Course of Maritime Information System in Mokpo Maritime University

At Present CEO&Vice Chairman of GMT e-MLX, Korea Major interest in Strategic Business Management, Logistics Systems, Electronic Navigational Charts, Marine GIS, Maritime Intelligent Transportation System, Integrated Navigational Systems, Vessel Traffic System.

Phone : +82-42-865-1880
E-mail : ceo@ecdis.co.kr

John Leslie RM. Benedictos
1989 Graduated Bachelor of Science Major in Marine Transportation, Philippine Merchant Marine Academy.
2003 Assistant Professor, Faculty of College of Marine Transportation, Philippine Merchant Marine Academy
2005-2006 Graduate School, Division of Marine Transportation System, Mokpo National Maritime University

E-mail : jlrmb66@gmail.com