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Anchorage Deviation Ship Management and Monitoring Scheme

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Abstract

With the recently rapid development of information technology (IT), new synergies have been created by developing a variety of converged services which integrate information technology environments with a variety of fields. In the proposed method, a vessel's navigation information is received from wide-range sensor systems, and its distance from the anchorage is measured by using spherical trigonometry. When the measured distance is not within the anchorage error threshold defined by the vessel traffic controller, there will be additional voice communications.

Keywords: *Vessel Traffic Service, Vessels Monitoring, Traffic Control, Secure Communication, Group Management*

1. Introduction

There have been sustainable studies on applying various computing services to the infrastructure due to rapid changes in the information technology environments. VTS is essential for marine traffic control to be liberated from the existing management methods simply based on wired/wireless communication and to respond quickly to the potentially dangerous situations. The Vessel Traffic Service is to improve the safety and efficiency of vessel traffic, and its marine traffic control service is very important for safe navigation and departure and arrival as a national backbone network [3, 10].

However, it has been difficult for the existing VTS to respond rapidly to marine emergency situations because it has relied on equipment such as wide-range sensors (LRIT, satellite AIS, HF RADAR, SARSAT), CCTV, VHF, etc. In addition, the controller has been required for passive and intensive monitoring of vessels waiting for departure or arrival in an anchorage. As a result, the controller's fatigue increases and the efficiency decreases. An identical vessel's identical MMSI repetition can cause some drawbacks to be compensated. Therefore, these are considered as hindrances to safe maritime traffic control [4, 11].

The remainder of this paper is organized as follows. In Section 2, a technical overview of the VTS is presented. In Section 3, existing VTS anchorage management methods are analyzed, and then the requirements for the safe and efficient anchorage management are proposed. In Section 4, a management and monitoring method of vessel anchorage deviation is proposed. In Section 5, comparison with existing methods is conducted. Finally, conclusions and possible extensions of this work for future research are drawn in Section 6.

2. Analysis of Existing Schemes

John, *et al.*, [1] proposed an information analysis and design approach to develop an efficient framework for decision-making systems of military vessels in 2005. This approach considered decision-making systems using Karush-Kuhn–Tucker (KKT) conditions. In addition, this approach presented a way to configure the decision-making

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systems of military vessels by applying Multiple Criteria Decision Making (MCDM) methods further.

The complexity and general requirements of WS (Weighted Sum), HWS, AHP and MAU are described in order to apply MCDM. In particular, this approach uses STS-EB(Survivability of Suspected Target Search at the End of Burst) and STS-ES(Survivability of Suspected Target Search at the End of Search) to demonstrate its effectiveness through the analysis and implementation of the objects within the specified area. In 2006, Chaug, *et al.*, [2] proposed a model to determine the optimal route and ships for routing containers by considering shipping costs and inventory costs. To support this model, an optimal decision-making method is proposed for cost-effective analysis and its efficiency.

In particular, this method determines $TC_S = \overline{C^h_{S,t^*}} + C^s_S$, $TC_I = \overline{C^h_{I,t^*}} + C^s_I$depending on ship types andanalyzes the relationship between TC_S and TC_I by calculatingΦ^m_t, Γ^m_t, Λ^m_t, Ψ^m_t in order to determine the most optimal route.

The requirements for the management and monitoring of vessel anchorage deviations are proposed for a decision-making system by using spherical trigonometry.

- Decision making on an activity: When an activity-specific service is to be applied to the decision-making system, it is necessary to provide a separate service for decision making specific to each activity. The drawbacks of the area-based decision making can be compensated in this way. In addition, an assistance service can be provided for the controller‘s decision-making because various activities can be analyzed in detail.
- Group management based on a single object: With the one-to-one management of a single vessel or object, it is possible to manage a small number of vessels in detail. However, it is very difficult to manage a large number of vessels in detail. Thus, group management is essential for decision making on a single vessel.
- Monitoring based on multiple information sources: When a decision-making system is configured, it should be capable of monitoring a variety of information. That is, a vessel which is being traced or not traced is to be monitored on the basis of its properties and navigational information and its multiple information sources are to be considered in the actual decision-making.
- Centralized management: The centralized management is to be available through the centralization of all the information due to the nature of VTS. That is, the control center is to manage and store all the information for the quick and effective management by providing the controller with the monitoring and selected information of vessels.

4. Anchorage Deviation Ship Management and Monitoring Scheme

4.1. System Parameters

- T: Anchor dragging
- R: Anchor dragging error range
- g ∈ G: An Anchorage ground set
- PO: VTS Control center position
- BR, SR: Spherical trigonometry’s great circle/small circle drawn around the center depending on the location of a vessel which has moved from the initial anchorage.
- A: Initial Anchorage position
- B: Moving location of Anchorage vessel
- MR: minimum radius of gyration
- a: Rotate the angle of rotation of the vessel
- L: Length of vessel

- r: Absolute value of anchor length and the distance between the center of the steering handle
- s: Anchoring the vessel's movement speed per minute

4.2. Protocol

(1) A spherical trigonometry-based monitoring technique of anchorage-deviated vessels

If a vessel which has been at anchor for port entry arbitrarily deviates from the anchorage or a vessel deviates from the anchorage due to special emergency situations, the following monitoring process should be performed.

①The distance from the A control center to the A vessel in the anchorage is calculated at the control center.

②When a vessel is deviating from the initial anchorage in special circumstances such as bad weather conditions, the latitude and longitude of its current location relative to the control center is to be checked and the great-circle distance and the parallel small-circle distance at the same longitude are to be extracted through spherical trigonometry.

[Proof]

- By applying the law of COS for the plane triangle$\Delta AB'C$,

$$\overline{B'C}^2 = \overline{AB'}^2 + \overline{AC'}^2 - \overline{2AB'}\overline{AC'}\, cos\angle A$$

- By the law of COS for the plane triangle$\Delta OB'C$

$$\overline{B'C'}^2 = \overline{OB'}^2 + \overline{OC'}^2 - \overline{2OB'OC'}\, cos\angle B'OC'$$

$$\therefore \cos\angle B'OC' = \cos\angle a,\ \overline{AB'}^2 + \overline{AC'}^2 - \overline{2AB'AC'}\, cos\angle A = \overline{OB'}^2 + \overline{OC'}^2 - \overline{2OB'OC'}\, cos\angle a$$

$\overleftrightarrow{AB'} \perp \overleftrightarrow{AO}$, $\overleftrightarrow{AC'} \perp \overleftrightarrow{AO}$, where $\overleftrightarrow{AB'}$and$\overleftrightarrow{AC'}$ are tangents to the great sphere atthe point A. Therefore, $\Delta AB'O$ and $\Delta AC'O$ arearight triangle. By applying the Pythagorean theorem to each of the two right triangles, the following can be obtained:$\overline{OB'}^2 = \overline{AB'}^2 + \overline{AO}^2$, $\overline{OC'}^2 = \overline{AC'}^2 + \overline{AO}^2$.

Substituting the previous equation into$\therefore \cos\angle B'OC'$, the following can be obtained, $\overline{AO}^2 + \overline{AB'AC'}cos\angle A = \overline{OB'OC'}cos\angle a$.

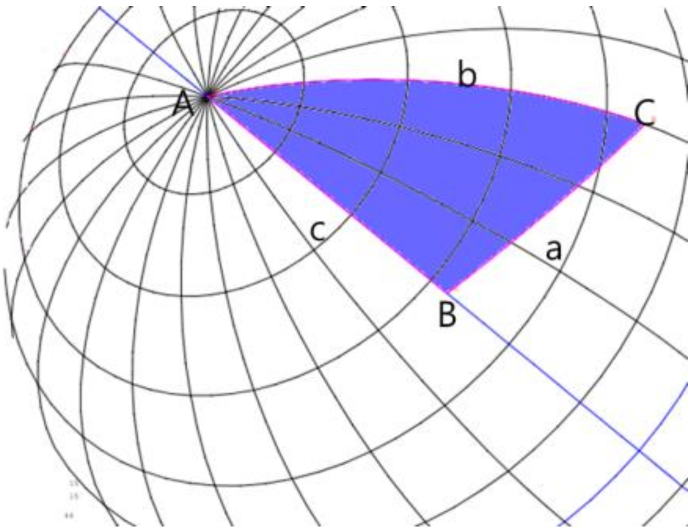

Figure 1. Spherical COS Theoremproof

③The travel distance of the object is compared with its anchorage and the result is checked within the error threshold at the center.

④After the result validity is checked within the error threshold at the center, the anchor dragging status of the object is also checked through the following procedures.

$$\begin{cases} if\ B > BR, & B > SR\ \ then\ T = 1 \\ else\ B \leq BR, & B \leq SR\ then\ T = 0 \end{cases}$$

⑤If the anchor is dragging(T = 1), the Minimum Turning Radius(MR) of the object at anchor is calculated as follows.

$$\mathrm{MR} = (\frac{L}{Sin\ a} + r) \times s$$

⑥At the center, the minimum turning radius(MR) of the vessel at anchor is calculated to determine the distances from the objects around. If the results are outside the minimum turning radius(MR), an alarm message is sent to the controller and the controller informs the corresponding target vessel of its current status and action items via VHF communication.

5. Analysis of the Anchorage Deviation Ship Management and Monitoring Scheme

5.1. Analysis of Proposed Scheme

- Decision making on each activity: The decision-making system proposed for anchorage management assists the controller as one of the various decision-making processes and compensates the drawbacks of one area-based decision-making system which makes the detailed management difficult. Therefore, the proposed method enables the anchorage analysis and offers the more specific services based on the analysis result.
- Group management based on a single object: In this method, an anchorage is defined as a group and an anchored vessel is defined as a static group member whose registration and withdrawal is not easy. The vessel ID is generated on the basis of MMSI, thereby a secure session key is constructed, and a pair of temporary public keys$(\mathrm{P}_1, \mathrm{Q}_1)$is distributed for anchoring. As a result,it is possible to improve the efficiency and safety of the anchorage management by controlling all the anchored vessels as well as a single anchored vessel.
- Multiple information-based monitoring: This proposed method uses navigational information as well as vessel-specific information to propose decision-making services for the anchorage management. This method enables the more detailed monitoring of all the vessels associated with an anchorage regardless of their tracking information through the required process.

5.2. Implementation

This proposed method is applied to the system for the development of next-generation VTS technology

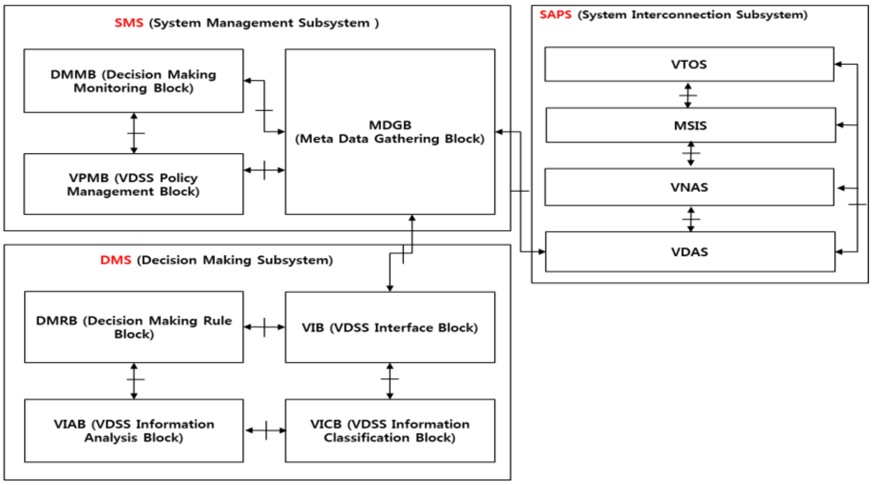

Figure 2. System Architecture

6. Conclusions

In this paper, a method of vessel deviation management and monitoring using spherical trigonometry is proposed, depending on the information collected from wide-range sensors. The proposed method compensates the drawbacks of existing area-based decision-making systems to enable the management and decision-making of a specific object. The method also presents a secure communication and management method which identifies and recognizes an actual target vessel having the same MMSI. In particular, this method is applied to the theoretical and practical suggestions for the next-generation VTS system in order to improve its practical applicability.

References

[1] J. C. Hootman and C. Whitcomb, “A Military Effectiveness Analysis and Decision Making Framework for Naval Ship Design and Acquisition,” Naval Engineers Journal, **(2005)**, pp. 43-61.
[2] C.-I. Hsu and Y.-P. Hsieh, “Routing, ship size, and sailing frequency decision-making for a maritime hub-and-spoke container network,” Mathematical and Computer modeling, vol. 45, **(2007)**, pp.899-916.
[3] T.-P. Hsu, C.-L. Chen and J.-R. Chang, “New Computational Methods for Solving Problems of the Astronomical Vessel Position,” Journal of Navigation, vol. 58, no. 2, **(2005)**, pp. 315-335.
[4] J.-H. Kim and S.-G. Gug, “Analysis on the Marine Traffic Flow Characteristics for Gamchen harbor,” Conference on Korean Institute of Navigation and Port Research, **(2006)**, pp. 137-146.
[5] A. Tversky and D. Kahneman, “The Framing of Decisions and the Psychology,” Science, vol. 211, issue 4481, **(1981)**, pp. 453-458.
[6] G. Bobovnika, N. Mole, J. Kutina, B. Stokb and I. Bajsic, “Coupled finite-volume/finite-element modeling of the straight-tube Coriolisflowmeter,” Comput. Mech., vol. 43, **(2008)**, pp. 103-113.
[7] J. M. Green and B. W. Johnson, “Towards a theory of measures of effectiveness,” NAVAL POSTGRADUATE SCHOOL MONTEREY CA, **(2002)**.
[8] H. Song and K. Kim, “A Study on Accessing Distributed Marine Database for Upgrading Marine Resources Information System,” Conference on GIS, **(2009)**, pp. 132-137.
[9] C.-I. Hsu and Yu-Ping Hsieh, “Direct versus terminal routing on a maritime hub-and-spoke container network,” Journal of Marine Science and Technology, vol. 13, no. 3, **(2005)**, pp. 209-217.
[10] M. Hussain and M. Hussain, “A Survey of Image Steganography Techniques”, International Journal of Advanced Science and Technology, vol. 54, **(2013)**, pp. 113-124.
[11] T. Altameem, “Delivering E-Learner Satisfaction: A Study of the Technical Dimensions,” International Journal of Advanced Science and Technology, vol. 53, **(2013)**, pp. 127-134.

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