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A Study on Probabilistic Stranding Warning for Maritime Safety Control System

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Abstract. Recently, marine accidents of oil tankers and other dangerous cargo vessels are increasing. Especially, stranding of ships due to crash of vessels or crash on fixed structure is causing economic damages to poor grounds and constructions and even environmental problems. Most studies on stranding is about its effects on the hull or the stranded vessel. These previous studies usually researched on the vessel damage models or conducted prediction tests of damages from stranding due to collisions.This study suggests a scheme to predict invisible fixed structures from current location in unpredictable environment when sailing and extract the risk of stranding by calculating DCPA and TCPA of the predicted fixed structure and achieve interaction between vessel and controller about the risk of stranding in the control area by sending the calculated risk to the control center.

Keywords: Vessel Traffic Service, Vessels Monitoring, Traffic Control, Stranding, Warning service

1 Introduction

Recently Korea prepared a base of maritime logistics for export-oriented economic development and has been implementing policies to achieve further advancement. In the west coast, expansion of facilities for maritime logistics system is in progress to support large scale businesses with China [1]. However, problems of social and economic loss are being raised in this maritime logistics due to collision and stranding of vessels. Previous studies focused on prevention of marine pollution for protection of the hull and cargo on board based on the structural design of oil tankers and dangerous cargo vessels, centering on damage simulation and modeling of hull. These studies recognized the collision and stranding as a mechanical problem from outside or inside of the vessel, and research on stranding due to problems in radar detection signal for weather conditions and soft soil is insufficient [2][3]. Studies that provide schemes to check fixed structures that may cause stranding of vessels from current

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location and recognize the risk of collision with fixed structures when reliability of detection equipment is low are needed [5].

This study aims to suggest a scheme to predict the probability of stranding when detection rate is not reliable due to weather conditions or mechanical problems and share this with the control center. In section 2, analysis on existing studies on collision and stranding is provided, and in section 3, requirements for stochastic stranding warning when detection rate of sensor is not reliable are studied. In section 4, stochastic stranding warning scheme for safe vessel traffic control is suggested, then in section 5, the suggested scheme is analyzed through comparison with previous schemes studied in section 2 based on the requirements in section 3. In section 6, conclusion and directions on future study are suggested.

2 Analysis of existing schemes and requirements

2.1 Vessel stranding probability scheme

This paper studied on the stochastic model for stranding accident to develop appropriate risk assessment model for stranding of vessels, and it is suggested for the purpose of application to new traffic system including vessel traffic service.

The analyzed schemes are Fujiischeme, Macduff model, and Pedersen scheme. Fujiischeme considered that the probability of shipbuilding accident causes stranding accident, and to assess the probability P of shipbuilding accident, hypothesis $P_s = N/N_{gg}$ was made based on $\mathrm{N} = \mathrm{P}(\mathrm{D}+\mathrm{B})\rho\mathrm{V}$ (average velocity V, average density $\rho$with $\mathrm{D}+\mathrm{B}$as available width with traffic flow, vessel width B) and the stranding probability $P_s$was calculated. Macduff model used the statistical data on accidents that happened in the Strait of Dover and calculated the geometric probability $P_G (= 4\mathrm{T}/\pi\mathrm{C},$ $\mathrm{T}$is the stopping distance of vessel, $\mathrm{C}$is width of waterway) of stranding on waterway by using Buffon's needle problem. Lastly, Pedersen scheme suggested the stranding accident risk assessment model by using probability and concept of sailing path of vessel. This scheme was suggested based on Fujiischeme in the aspect of trip distribution but it also provides probabilistic implementation of Fault Tree scheme or bayesianscheme as a strong point [4].

2.2 Vessel collision accident risk control scheme

This study presents the scheme suggested by Wonjae Yang et al. in 2003, which analyzed the risk of vessel collision accident and accident rate by using FSA assessment system and proposed a control scheme to prevent these accidents [6]. FSA system is applied in the fields that study about cases on current risk and risk control based on risk of people, property, and environment, and in the scheme introduced in this study, FSA is applied to accident status of Korea (Fujii chain matrix and composition of sets)and structured graph is made. Based on this, data on collision is divided in factors of administration, operation, work environment, knowledge, and decision making, and were presented as risk statistical data. Therefore, the schemesuggested in this study conducted structural analysis by studying the factors of vessel collision accidents in a hierarchical way and arranging their relations, and direct or indirect effects were presented through it. Based on the model outcome, accident control scheme was proposed.

3 Requirements analysis

In this section, requirements for stochastic stranding warning for maritime safety control system are studied.

- Verification of stranding from unidentified fixed structures: Bottom area of vessel can be damaged from collision with rocks or structures that cannot be identified due to bad weather. To resolve this, fixed objects in the sea that are marked in the chart of current location must be speculated and safe traffic service must be provided through real time communication about stranding risk of vessel with vessel traffic control center based on this.
- Prediction service for risk of collision with fixed structure: Previous studies extracted power-time record based on kinetic energy of random position in random direction of vessels but collision risk with fixed target must be predicted and a service that gives warning messages of collision risk by level to both controller and sailor and have them shared and recognized should be provided.
- Domain-based decision support: Generally studies on collision are about collisions between vessels. In cases of stranding, service for stranding alert based on domain should be available by providing data based on zones with domain data relying on charts. Especially, to prevent accidents from objects that are in aware of and changes of environment such as deteriorating weather conditions, domain service is essentially required.

4 Probabilistic stranding warning Scheme for maritime safety control system

Stranding of vessel during sailing may occur in an unpredictable situation. Especially, when visibility and weather conditions are bad and it is difficult to rely on existing hardware, the risk of stranding increases. Therefore, in this section, a scheme that is possible of safe vessel operation in the control domain by predicting objects of stranding risks near the vessel in probabilistic way from the location of the vessel and creating warnings on stranding risk is suggested.

4.1Assumptions

- Multi Sensor Integration System (MSIS) sends data at regular intervals. The format of MSIS is as follows. MSIS data format = {vessel ID, longitude and latitude, time stamp, type of network, status data}

- Control system sets the stranding domain and sends this data to decision support system.
- Threshold value of stranding domain is set by the controller.
- Each vessel has separate H/W for the provision of decision support service related to stranding, and continuous voice service between controller and vessel is provided.
- Decision support system between control center and vessel shares the domain threshold value for stranding risk in the same form.

4.2 System parameters

System coefficient on stochastic stranding warning for maritime safety control system is explained in this section.

- V: a set with n zeniths (a, b ∈ V)
- ρ: Density of object
- r_0: Randomly selected object
- V_{ry}, V_{rx}: Velocity of the target transferred from MSIS
- V_{wx}, V_{wy}: Related velocity

4.3 Protocol

Probabilistic stranding warning scheme for maritime safety control system is comprised of the protocols explained below.

A) Stochastic stranding warning

①Current control data of vessel is transferred from Multi Sensor Integration System (MSIS).

MSIS data format = {Ship ID, Latitude / longitude, Time-stamp, Communication type, state_info}

②The probability of an object to exist near $n_0$when objects in the control domain are randomly distributed from current target and the object that ins located near the target is $n_0$is as follows.

$$\mathrm{P}(\mathrm{d} = n_0) = \frac{(e^{-\rho\pi {r_0}^2})^{n_0}}{n_0!} \cdot e^{-\rho\pi {r_0}^2}$$

Therefore, there are two cases depending on the existence of the object nearby.

[Theory 1] Graph Theory $G(V.E)$

When assuming V is a set with n zeniths, complete graph with V as its zenith refers to a graph without loop that have the corner (a,b) at a, b ∈ Vwhich a ≠ b, and it is called K_n.

$d_{min}(G) = \min d(x)$, ∀x ∈ G

③-1 When there is no object nearby n is 0 so probability is $e^{-\rho\pi {r_0}^2}$ and average degree E(d) is as follows.

$$E(d) = d_{avg} = \rho\pi r_0^2 - 1$$

③-2 When there are more than 1 object in the relevant domain, r_0 is as follows because $n \gg 1$.

$$r_0 \geq \sqrt{\frac{-\ln(1 - p^{\frac{1}{n}})}{\rho\pi}}$$

④When object exist in the control domain area of relevant vessel (target), TCPA, DCPA of transferred data from MSIS are calculated.

$$T_{D_{min}} = -[\frac{XV_{wx} + YV_{wy}}{V_w^2}], \; D_{min} = |\frac{XV_{wy} - YV_{wx}}{V_w}|$$

Based on each calculation of TCPA, DCPA, stranding risk of one or more objects is extracted and this is sent to control system through decision support.

5 Analysis of proposed scheme

In this section, the stochastic stranding warning scheme for maritime safety control system is analyzed based on the requirements.

- Verification of stranding from unidentified fixed structures: This scheme recognizes that stranding can occur due to collision with unidentified fixed structures in bad weather and infers to find fixed structures in a probabilistic way according to current location of the vessel other than fixed structures marked on the chart, and DCPA and TCPA of collision are calculated based on this. This is noticed to the controller and security against unidentified stranding risk can be acquired.
- Prediction service for risk of collision with fixed structure: This scheme is different from the existing studies that focused on collisions with other vessels and internal mechanical problems of stranding, and it predicts the risk of collision with fixed structures. Especially,
- Domain-based decision support: Most of the existing studies suggested the risk of collisions with vessels based on time and velocity in external mechanical aspects. However, when this is applied to stranding, there may be difficulty in control for one vessel and weather deterioration so fixed domain was set for relevant vessel and unidentified structures in the domain was confirmed, then consistent stranding warning service to vessel and controller was made available.

6 Conclusions

Recent maritime accidents are weighting the pollution of marine environment due to oil spills and its damages on people and property are being raised as a social problem. To prevent this kind of maritime accidents studies on vessel collisions or stranding from fixed structures must be conducted and actual accidents can be kept from happening beforehand. However, most studies are focused on internal mechanical issues of the vessel and the studies about collisions are mainly about maintaining internal strength of vessels.Therefore, this study searched for fixed structures that are not identified because of bad weather and confirmed the stranding risk based on this to prevent accidents from bad weather. Then an automatic decision making between vessel and control tower through real time voice communication with controller in control domain was made available.

Future study aims to research on provision of automatic service for various decision support other than stranding (anchorage management, restricted area, sail route deviation, etc.).

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