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Collision Risk Analysis in Busan Harbour

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Abstract : *This thesis, concentrates on marine collision risks of the area divided by cells. Using a gas molecular collision calculation model, a collision risk model is proposed. Collision risk is estimated by relative angle, relative speed, and ship's density in the cell. For one week, Automatic Identification System (AIS) data was collected and analyzed on the Busan North Port area. The results indicate a high-risk area at the sea route connection point in Busan North Port .It also shows that twilight is the time of day when most collisions occur .This means that the area is high risk due to the number of collisions and other dangerous factors related to twilight . Although there is still need to consider other risks such as grounding risks, the results of this study are useful to for plotting a risk map for the port.*

Key words : *Workload, Risk analysis, Collision Risks, gas molecular collision calculation model, collision risks of the area divided by cells*

1. Introduction

This research was undertaken to analyze collision risk in, and adjacent to, the port area. Utilization of the risk data would be used for the development of an emergency plan addressing scenarios of personnel rescue and oil spills. Even though huge collisions and accidents rarely occur, a single incident in this area would be disastrous. To minimize risk, it is very important to have plans for accident prevention and emergency preparation. If a high-risk area is identified, cost effective emergency planning would make it possible to have emergency equipment preferentially around this area. For this purpose, area risk needs to be calculated. Also, risk factors such as environmental conditions, vessel size, and speed should be known. There are several types of accident phenomena such as collision, contact/impact, grounding and stranding, foundering and flooding, hull and machinery failure, and fire and explosion. In this paper, the collision is analyzed from the preceding list. For analyzing marine traffic, a systematic approach is required. It should be noted that the scarcity of accident statistics causes limitations, e.g., if no accidents have occurred in a specific highly sensitive area, it does not mean that the probability of an accident in that area would be zero (Yutta, 2010). It also is widely recognized that the human element plays a major role in most accidents involving modern ships. 70% to 80% of accidents are due to human mistakes or other events attributed to the human behavior (P. Trucco etal,2008). Generally, if the human workload increases, the likelihood of human error also increases. There are several studies on the human factors. The Japan Association of Marine Safety (1992), studied the navigational environment by quantitative assessment. They indexed the traffic situation by using a blocking coefficient. Then, they indexed the ship's maneuverability by the controllability and maneuverability coefficient (CMC).

There are some researches in Republic of Korea though, there are few studies about the risk analysis for the divided areas. Hong-Hoo et. al.(2013) studied the evaluation risk at the port of Mokpo including environmental factors. Jong-Sung et. al. (2011) studied the risk on the basis of vessel navigator's risk conscistence. Young-Soo et. al.(2008) studied the risk using the environmental stress model as analyzing relationships among degree of danger, maritime accident, and number of vessel arriving or

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departing in the main ports. Inoue et al.(1998) studied the difficulties of ship handling. Their study proposed a quantitative assessment model, the Environmental Stress (ES) model, to evaluate the stress level burden of mariners under the conditions of traffic congestion and geographical restriction. Seta et al (2006) analyzed safety evaluation in real time at Ise Bay using the ES model. Although this model has been highly effective, it may not be suitable for our current study . Since the models need to correct the navigator's assessment on the situational affordability of risk , it would make the result subjective. Endoh (1982) studied airplane conflict in the same study area using the gas model. This calculation was done for the area based risk analysis and not for the airplane itself. Endoh noted that if the rate of conflicts can be calculated or estimated under some assumptions, the rate may be helpful in estimating the workload of navigators and ship traffic controllers such as the vessel traffic service (VTS). Recently, the Efficient, Safe and Sustainable Traffic at Sea (EfficienSea) published a report for the scope of presenting current knowledge in the field of marine traffic risk modeling, with relation to open water sea areas (2011). The collision risk calculation was also based on the gas model in this report,. Efficiensea provided risk research for the area. They also included the factors that are not matched with previously mentioned this research's intention such as navigators' skills. However, the study area size was much larger than the size needed for this research. Therefore, in this paper, collision risk was modeled based on the gas model but does not include factors that were not possible to get from the outside of the ship. Collision risk was calculated from information including ship's speed, vessel size, and ship's headings. Using this model, it is possible to determine not only the collision risks, but also the human workload, in the area.

2. Collision Risk Analysis Model

The gas model was developed to describe the expected frequency of molecular gas collisions. There are two molecular gas groups, i and j, in the area. A collision is the overlap of these gas molecular circles. Therefore, if the gas molecular group j exists in the area that is calculated by geometrical collision diameter times relative speed, this would be estimated as the collision risk in this area. The image is shown in Figure1.

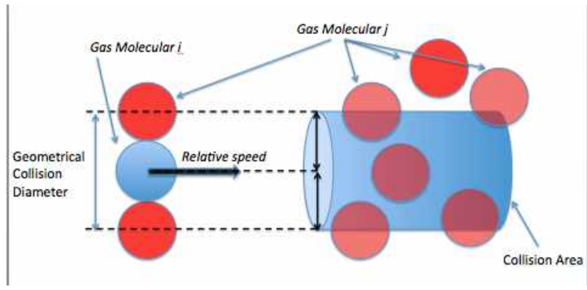

Fig. 1 Gas molecular collision image calculation image

2.1 Model calculation

The magnitude of the relative speed of two ships i and j is calculated as

$$Vr_{ij} = (V_i^2 + V_j^2 - 2V_iV_j\cos\beta)^{\frac{1}{2}} \text{------------}(1)$$

Vr_{ij} (knot): The relative speed of two ships i and j

V_i , V_j (knot): The speed of ship i and j

β (radian): The relative angle of ships i and j

The risk area size is calculated as:

$$R.area = D_{ij}V_{ij}t \text{--------------------------}(2)$$

$R.area$: Risk area

D_{ij} (mile): Geometrical collision diameter of ships i and j

t (hour): Sampling time

The geometrical collision diameter is the diameter of the "no go area" for the target ship.

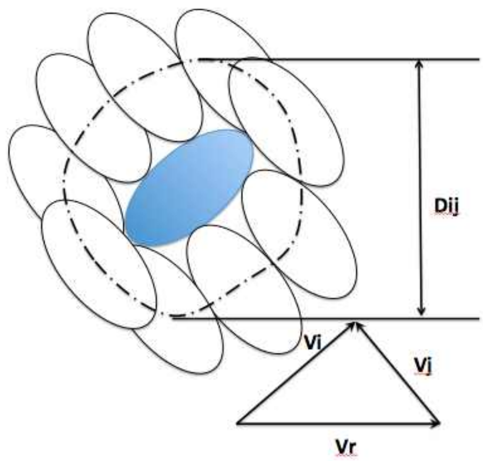

Fig. 2 The geometrical collision diameter

Pedersen's model was used for this research because of its simplicity and well understanding (1995). Recently, Montewka et al.(2010) explained a new approach for determining geometrical collision diameter A collision between two vessels is assumed to become reality when the distance between the vessels is not enough to perform efficient anti-collision maneuverers. Maneuverability is included when the geometrical collision diameter is set. However, in reality, it is difficult to decide the each ship's maneuverability.

Pedersen defines the geometrical collision diameter as:

$$Dij = \frac{LiVj + LjVi}{Vij}\sin\theta + Bj\left\{1-\left(\sin\theta \cdot \frac{Vi}{Vij}\right)\right\}^{1/2} + Bi\left\{1-\left(\sin\theta \cdot \frac{Vj}{Vij}\right)\right\}^{1/2} \quad \text{--(3)}$$

Dij: geometrical collision diameter,
Li , Lj: lengths of vessels in ship classes i and j, respectively
Bi and B:j widths of vessels i and j, respectively
Θ : relative angle between ship i and ship j

Total risk area size is calculated as the summation of all combinations of two ships in the area and the density of the ships in the area:

$$Total\_R.area = \partial_{Cell}\sum_{i=1}\sum_{j\neq i} D_{ij}V_{ij}t \quad \text{---------(4)}$$

∂_{Cell} (area/ship's number): Ship's density in the cell

3. Application of the Collision Risk Analysis Model in Busan Harbor

From 24 July to 31 July, data was collected for one week at the Busan North Port. The AIS antenna was placed at Korea Maritime and Ocean University. The Radar Plus SL161 was connected to the antenna and a laptop computer. The AIS data was decoded by using own program written in MATLAB. Ship size was checked by AIS data and website (MarineTraffic.com, 2013). Using these data, average size was calculated for each ship type. If ship size data was not available, calculated average data was used. Figure 3 shows the ship's track data on 24th July. For analysis, the area was divided into 16x22 cells along latitude and longitude.

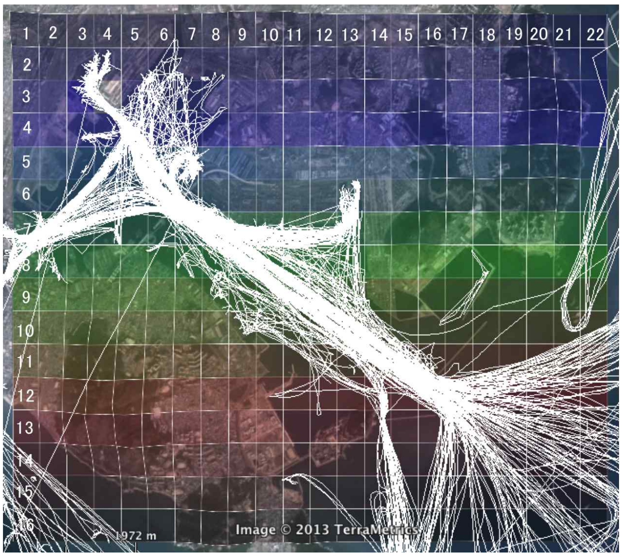

Fig. 3 The analyzed area with ships' track on 24th July

3.1 Collision Risk Level Analysis

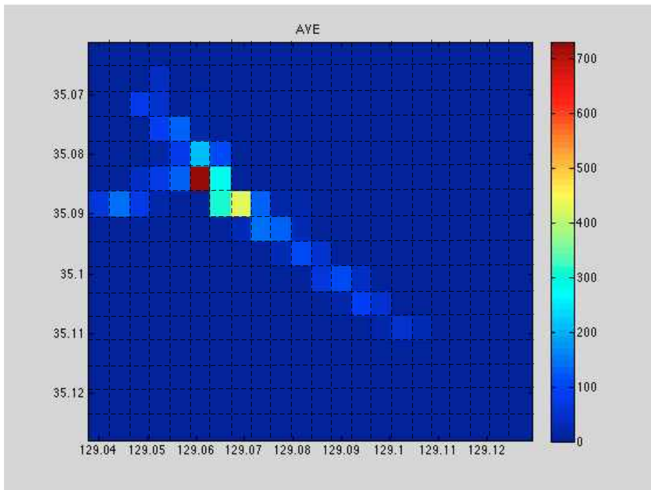

Fig. 4 The average risk level for 1 week

This means that risk was calculated calculation for ships in a given cell during a 30 minute period. Using this information, average risk was calculated for each day. Then, average risk for one week was calculated. The result is shown in Figure 4. From the result, average risk was highest around cell (7,7). The highest risk point was cell (6,6) in Figure 4. The X and Y axes are latitude and longitude respectively. The risk rate is almost double that of the next cell (6,7). The enlarged map of the area around cell (7,7) of Figure 3 is shown in Figure5.

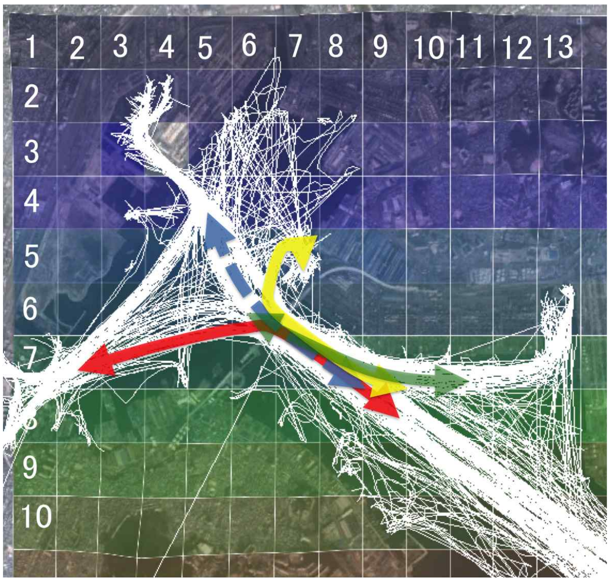

Fig. 5 Enlarged Map around cell (7,7)

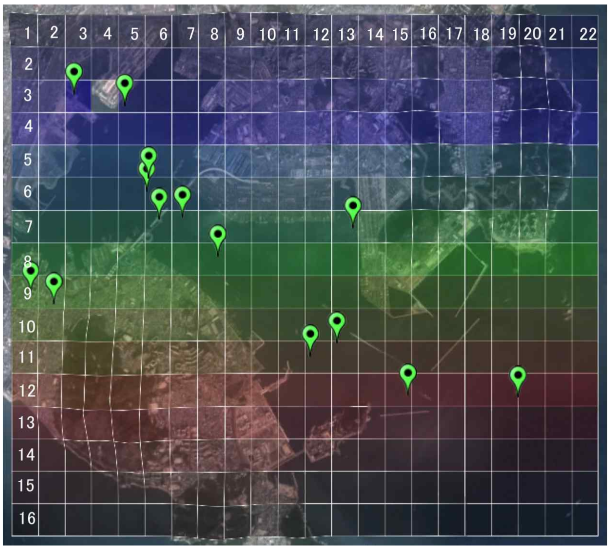

Fig. 6 Collision Map from 2000 till 2012

Ships came and passed around cells (6,6) and (7,7) in four directions as shown in Fig.5. This is a possible explanation for the higher risk rate at this point when compared to other areas. Several collisions have actually occurred in this area. For example, in the study area shown in Figure 3., at least 14 collisions occurred between 2000 and 2012(Korea Maritime Safety Tribunal, 2013). Five or 35%, of the collisions happened only around the areas (6,6) and (7,7) in Figure 6.

3.2 Collision Risk Time Series Analysis

From the previous risk calculation result, cells, including high-risk areas, along the navigational routes were chosen and analyzed over time. Over a one week period, data was averaged every 30 minutes starting from midnight until the next midnight. High-risk rate areas including (6,6), (6,7), (7,7) and (7,8) are shown in Fig7. The X and Y axes are calculated risk level and time respectively in the figure from 7 to 9.

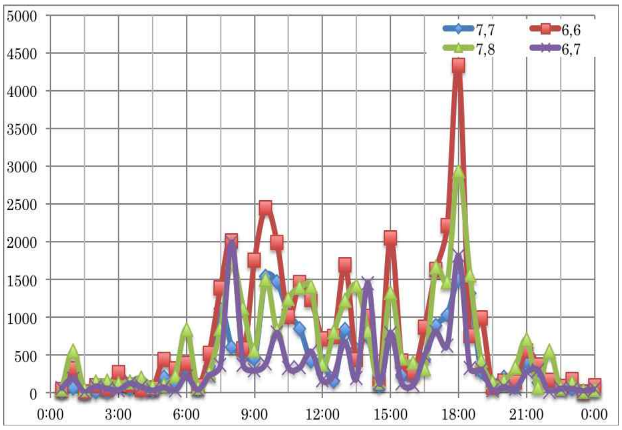

Fig. 7 Risk rate change by time at high-risk cell

Risk rates increased from 0600 hours and kept changing until 2230 hours . The rate gets highest around 1800 hours. This time is approximately twilight time at Busan Harbor in August. Twilight is known as a dangerous time for navigators because of fatigue, decreased visibility and changing the environmental things according to the sun set (The Japan Association of Marine Safety, 2012).

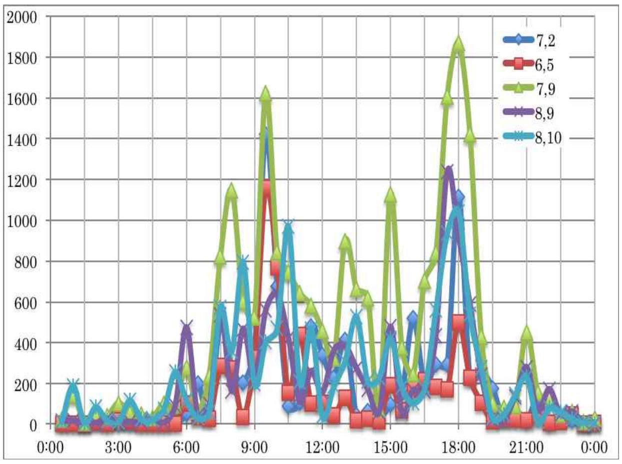

Fig. 8 Risk rate change over time in the cell

Figure 8 shows the risk change by time in other cells, (6,5), (7,2), (7,9),(8,9) and (8,10),. Although risk is lower than the aforementioned areas, there is also high-risk time at 1800 hours.

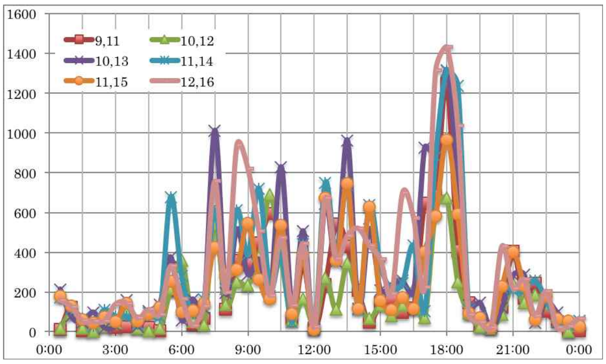

Fig. 9 Risk rate change over time in the cell

Other cells that indicate risk along the navigational route, (9,11), (10,12), (10,13), (11,14), (11,15) and (12,16), are shown in Fig.9. Although the trend is not obvious when compared with Figures 7 and 8 , it is also evident that the high-risk time is around the 1800 hours in each cell.

A year long study should be undertaken to validate the initial results.

4. Conclusions

In this study, a model based on a gas model is proposed for analyzing collision risk in the area divided by cells. Although the result only shows the risk rate as high or low, the model is able to determine the level of risk in each cell.. In addition, it is also possible to know how the risk rate changes over time. The most high risk time might be analyzed along with other factors such as visibility, current, time of day, obstacles, and constructions in the area. This time averaged causation probability is used. For more precise study, the causation probability might be needed to calculate for each cell. The grounding risk needs to be considered in the future studies. The traffic density is included in this time because it should be affected collisions. In future study, the risk level for per vessels would be studied to compare the result including the ship's density.

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