



A spatial–temporal forensic analysis for inland–water ship collisions using AIS data

Yang Wang, Jinfen Zhang*, Xianqiao Chen, Xiumin Chu, Xinping Yan

Intelligent Transportation System Research Center, Wuhan University of Technology, Wuhan, China

Engineering Research Center for Transportation Safety (Ministry of Education), Wuhan University of Technology, Wuhan, China

ARTICLE INFO

Article history:

Received 9 June 2012

Received in revised form 29 January 2013

Accepted 4 February 2013

Available online 23 March 2013

Keywords:

Collision accident

Forensic analysis

Dempster–Shafer theory

Spatial-temporal fusion

AIS data

ABSTRACT

Ship collision is a major type of accident in waterway transportation, with considerable annual occurrence that always causes serious casualty. Among the evidences that can facilitate the investigation, AIS data recorded during the context of the collision are highly informative. This paper exploits the contextual AIS data in a coupled spatial–temporal perspective. With the discrete waypoints specified by the AIS data, the trajectories of the colliding ships are regenerated with three reasoning respects: (1) the conflict-resolution envisioned by each ship in the collision-inducing scenario when the two ships are drawing near; (2) to what extent the two ships can make situation assessment and the *de facto* maneuvers exerted to steer the ships; (3) how to evaluate the decision quality of the steering process and how to measure the consistency between the subjective endeavors and the objective results in the context of bilateral anti-collision maneuvers. According to the periodical nature of the AIS data, time is slotted into slices to make temporal analysis and to sketch out the decision sequences made by both ships. Fuzzy set method is adopted to estimate the quality of the decisions, and a Dempster–Shafer Theory (DST) based method is employed to fuse the discernment in time domain and in spatial domain, so that an overall impact of the behavior of both ships can be calculated. The current paper presents a microscopic analytical scheme for a two-vessel collision accident investigation, and the proposed scheme may be heuristic to yield a generalized result for a multi-vessel case.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Maritime transportation has been a major mode of transportation for domestic and international trade due to its large capacity and environment-friendly nature. It is estimated that around 90% of world trade is carried by water (IMO, 2008). Many countries with large rivers/canals promote waterway transportation to take a greater share in their total interior transportation market to reduce carbon emission. Nevertheless, maritime accidents have been a problem of maritime transportation all along, despite all the efforts man has made to eliminate it (Mullai and Paulsson, 2011).

Maritime accidents often result in catastrophic consequences, such as deaths, loss of hazardous material and pollution of water resources. Collision is a type of maritime accident in which striking between ships causes damages to one or both of the ships (Soares and Teixeira, 2001; Wang et al., 2002). Some statistics of maritime accidents show that collisions account for a heavy portion of all the maritime accidents. For example, according to Yip's survey of the accidents in Hong Kong waters during the year 2001–2005, the occurrence percentage of collisions reaches as high as 54% of all

accidents (Yip, 2008). Another statistic drawn from the Gulf of Finland shows the collision occurrence constitutes 20% of the overall accidents (Goerlandt and Kujala, 2011). Another feature for maritime accident is that the majority of accident happens in restricted waters such as ports, inland waterways, straits (Tzannatos and Kokotos, 2009).

Because the consequence and the occurrence frequency of ship collisions are both highly undesirable, research of ship collision and anti-collision strategy has been an important topic of maritime transportation study for long. The most significant formal international regulation of anti-collision dated back to 1972, when *Convention on the International Regulations for Preventing Collisions at Sea* (COLREGS) was approved by International Maritime Organization (IMO). The convention defines a set of rules or specifications for anti-collision practice, and is observed by most countries. However, the regulations alone cannot guarantee a collision-free navigation, and a deeper probing and insight of the mechanism of collision should be acquired by theoretical modeling and empirical studies.

In the literature, general research on pre-accident and post-accident has been reported extensively, the specific research related to collision accident investigation remains very sparse. Of the few research articles specialized in collision investigation, Martins and Maturana (2010) presented a quantitative analysis of the

* Corresponding author.

E-mail address: zhangjinfen2000@126.com (J. Zhang).

human failure contribution to the collision. In 2008, IMO issued the *Code of International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident* ("Casualty Investigation Code") by resolution MSC.255(84), and the code has taken effect since 2010. However, the Code was compiled in a legislative or administrative sense rather than a technical sense. Thus there is a strong requirement that technical investigation into collision accident should be fully studied.

The maritime accident database of Yangtze River (Changjiang) can give some insight into inland water ship collisions. Firstly, the collision occurrence rate is high. According to the database, over 700 collisions are recorded out of a total of 1613 accidents during 2006–2010, thus the percentage is around 44%. Comparing to the navigation near shore or at sea, navigation in a river is confined to a relatively narrow waterway, often with strong current. The growing density of vessels also intensifies the problem. Secondly, there is some inconsistency among regulations issued by different administrations. The Ministry Of Transport (MOT) of China issued in 1991 the *Inland River Collision Avoidance Regulations In China*, and later in 2003, Jiangsu Maritime Safety Administration, a subordinate body of MOT, also issued the Regulations on the Ship's Routing System in Jiangsu Section of Yangtze River (RSRS). Some discrepancy arises between the two regulations, which will cause confusing situations for a ship entering or leaving the waters of Jiangsu along Yangtze River. Thirdly, the crew competence and equipment availability in the inland river are sometimes below the required standards.

This paper deals with the post-accident investigation of inland water ship collisions by Automatic Identification System (AIS) data. The reason that AIS data are chosen as the source of analysis can be ascribed to the two aspects: (1) The good reliability and availability: Although other evidence source such as VTS (Vessel Traffic Services), VDR (Voyage Data Recorder) can also be useful, the coverage of VTS or the installation of VDR are always very limited in inland waters/shipping, whereas AIS is widely configured both in ship-borne devices and the shore-based stations. (2) AIS data are neutral and carry little subjective distortion if liability inspection is to carry out. Furthermore, AIS data are always well retained by the local maritime safety administrations, which usually act as an authority in post-accident investigation.

The difficulties of collision accident investigations involve some key points as follows. First, the AIS data are broadcasted at discrete points in varying intervals. Thus trajectory fitting and status estimation between two successive records have to be made. Second, the collision is a result of a sequence of bilateral interactions conducted by both sides. For each vessel, any action it takes at one moment is not only a real time response to the current situation, but also a precursor that will lead to the response from the other vessel. Finally, when the situation is approaching collision, urgent maneuvers can be made by both sides, which may make it deteriorate until collision finally occurs. Hence the liability of collision is often tightly interwoven so that definition of human error or causation is sometimes intractable.

The paper proposes a data mining method basing on AIS data, to yield a more sophisticated collision accident analysis. The proposed method lays emphasis on steering intentions, liability discrimination and how to measure the deviation of situation assessment. The paper is organized as follows: in Section 2, a brief review of the literature is given to illustrate the state of the research; Section 3 introduces the preliminaries of the theoretical tools; Section 4 delineates the methods and the detailed calculation; in Section 5, simulation study is given for elaboration; and finally in Section 6, the whole results, innovations and contributions are summarized, with prospected future research concisely described.

2. Literature review

One important line of collision research aims to obtain a quantitative approach to evaluate or predict the potential collision occurrence. Collision probability model is a straight forward way to assess the likelihood of a collision risk. This approach, presented by Fujii and Shiobara (1971) and MacDuff (1974), has been adopted by many researchers for its simplicity and robustness. As the model puts it, the estimated collision probability is the product of ship encounter chances and the possibility of failing to avoid a collision. To strengthen the concept of ship encounter, collision diameter is defined to be the threshold of the distances between pairwise vessels that can be recognized as collisions. Analogous to the idea of collision diameter, ship domain theory was put forward to describe the collision avoidance behavior of vessels (Fujii and Tanaka, 1971; Goodwin, 1975). The collision probability based work helps to form a diagnostic view of the courses and indication of the risk level.

Prior-study on the maritime safety issue has revealed that human error can account for a considerable percentage of all the maritime accidents, thus human error has drawn keen attention from researchers (Martins and Maturana, 2010; Harati-Mokhtari et al., 2007). In 1998, IMO enforced the International Safety Management Code (ISM Code) (Tzannatos and Kokotos, 2009; Kokotos and Linardatos, 2011) to provide an international standard for ship safety management and prevention of pollution. Although the implementation of ISM Code led to an overall reduction of human-induced accidents, human error is still a dominant factor for accidents, especially in restricted waters. Hsu (2012) studied the influence of ports service attributes on safety with AHP method. His research shows that marine pilot's professional skills and communication abilities are essential for maintaining navigational safety. Knudsen and Hassler (2011) studied the IMO convention and its implementation, and shows that a strengthened tie has to be built among IMO and the flag/port states to reach a safer shipping industry. These studies provide a management and administration perspective about the maritime accident reduction.

Another body of ship collision study is the anti-collision strategy and techniques. Generally, the anti-collision research can be categorized into two classes: course design and decision making for maneuvering. Many methods from intelligent computing have been utilized on the above problems. Tsou et al. proposed a course planning method using ant colony algorithm (Tsou and Hsueh, 2010), and he also delineated a genetic algorithm based course design (Tsou et al., 2010). Evolutionary algorithm is applied to calculate anti-collision trajectory by Smierzchalski and Michalewicz (2000). In their work, a safe trajectory can be realized in two stages: offline stage and online stage. A course is presented by an individual, i.e. a chromosome, which is further composed of a sequence of genes indicating positions of the waypoints. Evolutionary algorithm is imposed on a set of initial randomly generated individuals with the same start point and end point. Offline planning and online planning is combined to compose a dynamical decision process for collision prevention. Recently, Perera et al. (2011) proposed a fuzzy logic based decision support system for collision avoidance, with special respect to the accordance with COLREGS.

The aforementioned research is mainly targeted to the prevention of collisions. The research on post-accident analysis has also attracted much attention. The analytical methods mainly involve statistical tools, data mining techniques and some general models such as fault trees or event trees (Fowler and Sørgård, 2000). Researchers tend to undertake their accident-centered research depending on some data sets. Hassel et al. (2011) studied several data bases covering the period 2005–2009, to find the underreport-

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات