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Grid size optimization for potential field based maritime anomaly detection

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Abstract

This study focuses on improving the potential field based maritime data modeling method, developed to extract traffic patterns and detect anomalies, in a clear, understandable and informative way. The method's novelty lies in employing the concept of a potential field for AIS vessel tracking data abstraction and maritime traffic representation. Unlike the traditional maritime surveillance equipment, such as radar or GPS, the AIS system comprehensively represents the identity and properties of a vessel, as well as its behavior, thus preserving the effects of navigational decisions, based on the skills of experienced seamen.

In the developed data modeling process, every vessel generates potential charges, which value represent the vessel's behavior, and drops the charges at locations it passes. Each AIS report is used to assign a potential charge at the reported vessel positions. The method derives three construction elements, which define, firstly, how charges are accumulated, secondly, how a charge decays over time, and thirdly, in what way the potential is distributed around the source charge.

The collection of potential fields represents a model of normal behavior, and vessels not conforming to it are marked as anomalous. In the anomaly detection prototype system STRAND, the sensitivity of anomaly detection can be modified by setting a geographical coordinate grid precision to more dense or coarse. The objective of this study is to identify the optimal grid size for two different conditions – an open sea and a port area case.

A noticeable shift can be observed between the results for the open sea and the port area. The plotted detection rates converge towards an optimal ratio for smaller grid sizes in the port area (60-200 meters), than in the open sea case (300-1000 meters). The effective outcome of the potential filed based anomaly detection is filtering out all vessels behaving normally and presenting a set of anomalies, for a subsequent incident analysis using STRAND as an information visualization tool.

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1. Introduction

Maritime traffic management decisions were in the past taken on the basis of human experience, and often – a hunch. The operator keeping track of the vessel movements faced a highly sophisticated task to monitor the open sea and harbors in order to detect suspicious behavior and critical situations. Today, expert analysis is informed and augmented by advanced automated systems. However, methods for automated anomaly detection with the aim of supporting the operators in their decision making need to be improved (Department of Homeland Security, 2005). In addition, maritime traffic is continuously increasing, and the importance of using the water as a transportation highway has created a demand for better systems to support agencies responsible for surveillance. The demand for increased security can be satisfied by increasing the surveillance capability and by proactively working to minimize the impact from threats to traffic safety. The maritime domain, being a part of a shared logistic chain, functions as an avenue for a multitude of opportunities and threats (Acciaro & Serra, 2013; Bichou et al., 2013). Much of what occurs in the maritime domain is also difficult to observe and assess, with respect to vessel movements, activities, and intentions. Hence, it is imperative to make the best possible use of all available data in order to detect and visualize out-of-the-ordinary behavior. Just like road traffic, the maritime traffic tends to concentrate locally in certain areas. The distances between ships tend to be smallest in harbors and anchorage zones, and largest on open sea. As a consequence, in some areas the traffic is precisely regulated, while in others it may be less restrained or completely unorganized. In case of an accident, the consequences can be serious both in personnel, environmental and economical terms.

A monitoring system receives information from various sensors based on technologies that are used to quantify location, speed, course, et cetera. In addition, there is a multitude of civil and military maritime traffic surveillance operations that extract data for their own purposes using proprietary management systems. One common system is the AIS (Automatic Identification System) – an automated tracking system used on vessels for identifying and locating ships by electronically communicating with nearby vessels, AIS on-shore base stations and satellites. The information provided by AIS includes a unique vessel identification, position, course and speed. Following the letter of the International Maritime Organization's (2002) International Convention for the Safety of Life at Sea, AIS transponders have to be installed on vessels with a gross tonnage of 300 or more, and on all passenger ships regardless of size. This development of global ship tracking systems in the recent years opens possibilities of advancing maritime safety and security beyond simple collision prevention, e.g., to inform about detected anomalies. Therefore, this study focuses on utilizing the increased surveillance capability, and, more directly, on optimizing a novel method for anomaly detection in maritime traffic by the use of AIS information. The goal is to scale the system settings to accommodate the specificity of traffic in dense port areas, as well as the less regulated open sea. A more specific objective of this study is to identify the optimal grid size for areas with intensive and sparse traffic, by examining the influence of the grid precision on the anomaly detection outcomes. The grid size terminology is further described in section 3. This study uses the concept of potential fields (Osekowska et al., 2013) for data modeling and anomaly detection in maritime traffic. The potential fields are traffic patterns built based on the recorded vessel positions and behaviors history. Anomalies are detected as conflicts between the vessel's current potential, and the local potential fields. Visualizing the potential fields using modern rendering techniques can provide the maritime operators with an automated help in identifying traffic situations that merit further investigation.

2. Background and related work

The detection of anomalies in the maritime domain is a complex process. It can be broken down into several steps including data acquisition, information fusion, situational awareness and anomaly detection. The problem of anomaly detection is also generic, i.e., not tied to the maritime domain, and is present in many other domains. One can view the data acquisition as the first step, providing the raw input material for anomaly detection. Normal behavior models and, consequently, anomalies are then derived from that data. Therefore the success of the