Vessel traffic management system (vtms)

Literature Review

The aim of this chapter is to capture the main idea of the research in depth and provide a review on literature related to the study and go through the ideas of various authors towards the relevancy of the study and establish the need for the research.

2. 1 Evolution Vessel Traffic Management System

A vessel traffic management system (VTMS) is a nautical vessel movement observing system established by harbor or port authorities. According to TRANSAS (2014) the VTMS system utilizes information collected by advanced sensors, for example, radar, AIS, closed-circuit television (CCTV), Meteo-Hydro and other electronic object detection systems. The primary purpose of VTMS is to improve the safety and efficiency of navigation, improve features of port services, protection of life at sea and the safeguard marine environment.

In 1946 a demonstration was done in order to identify the helpfulness of coast based radar system in Liverpool. The initial effort in developing harbour controlled radar was done by establishing a system at the end of Victoria Pier, Douglas, Isle of Man in 1948. (Hughes, 2009)

With the rapid growth of marine industry marine safety and efficient navigation has been addressed as one of the issues that have major consideration. Different methods for improving the marine safety have been developed the past few decades. Some of them can be stated as radiocommunications, navigation rules, electronic chart systems and identification systems. (Goralski, Ray, & Gold, 2011)

Goralski et al. (2011) further describes that most recent technological developments in improving vessel traffic management includes radar, electronic charting like Electronic Chart Display Information Systems, (ECDIS), vessel traffic control and management (VTMS) and automatic identification system (AIS) and communication. Several sources of data are combined from sensors such as GPS, radar and AIS in order to improve the vessel traffic monitoring. The final objective of this is offer more precise understanding of the navigational situations.

Many developed countries utilize the services of highly sophisticated VTMS. The Port of London is one of the UK’s busiest ports utilize an exceptionally advanced VTMS. In this VTMS the data from radars are associated with a mass of other data inside a very advanced computer system. This gives an ongoing picture and a thorough record of all developments at Port of London. (Goldman, 2011)

2. 2 Vessel Traffic Management Systems in Commercial Setting

As described by Goralski, Ray, & Gold, (2011) many researchers have presented theories of developing an efficient vessel monitoring systems. The need for diminishing human error and decreasing the number and danger of accidents at sea is a need to be addressed. Developing such system to be used in real-time situations is a challenging task. Not much research has been done in this area.

The world's first three dimensional ECDIS prototype was demonstrated in Brest in 2007. This was a research led by Dr. Rafal Goralski and his team. It's possible to incorporate data from many sensors around a port to produce a real time three dimensional traffic management visualization tool. (Goralski, Ray, & Gold, 2011)

As stated by Goralski, Ray, & Gold, (2011) an interface has been developed and presently being trialed in the Port of Milford Haven. This system is used in real-time for navigation observing and control. The system is considered to be the first commercial operation of a 3D VTS.

Transas Marine Limited and GeoVS Limited offer 3D vessel traffic monitoring solutions. Transas Group is a worldwide pioneer in marine navigation systems. Transas presented its initial 3D vessel activity monitoring system to the business in 2008. This system gives most extreme backing to VTS administrators.

(TRANSAS, 2011).

Sri Lanka's first home-developed vessel movement administration system was the result of investigation led by the modeling and simulation group of University of Colombo, School of Computing. The system includes two dimensional and three dimensional views of the harbor. The three dimensional VTMS was established at the Colombo-South harbor in 5 th August 2013. (UCSC, 2014)

2. 3 Need for more improved Vessel Traffic Management System

The commercial 3D VTMS that were mentioned above are closed proprietary and extremely expensive solutions. This fact raised the need to implement a novel vessel traffic monitoring solution. The modeling and simulation group of University of Colombo, School of Computing developed the Sri Lanka's first home-developed vessel movement administration system. This proposed and developed solution is entirely based on the free and open source structures (Sandaruwan, et al. 2013). There are limitations of the existing solution. In the existing solution, real-time movements of the ships can be visualized. However in the existing solution the path of a moving ship is not continuous.

Goldman (2011) discussed that one of the major considerations in improving the VTMS is to enhance the use of Automated Identification System (AIS). The objective is to provide more data about the vessel's positions. Furthermore a significant feature of the VTMS upgrading has been to further increase the continuity of the vessel display and resilience.

In a research carried by Popovich, Christophe, Vasily, Cyril, Tianzhen, & Dmitry, (2009) states that some of the important issues to consider in VTMS. The concerns are operability, accuracy and completeness of moving and positioning of vessels. Moreover a key problem in the vessel's location estimation is addressed. That is in the occasions where the estimated location is different with the actual location of the vessel, and then the system should avoid such circumstances.

2. 4 Automatic Identification System (AIS)

The SOLAS (Safety of Life at Sea) Convention by the IMO (International Maritime Organization). According to that the Automatic Identification System (AIS) is an automatic system utilized on ships and other vessels for distinguishing and finding vessels by electronically trading information with other adjacent vessels, AIS base stations, and satellites.

AIS play a vital role in managing vessel traffic and improving maritime security. Vessel engaged in international voyages AIS is required from registered tonnage (RT) of 300. A vessel travelling in national waters AIS is required from registered tonnage (RT) of 500. (SOLAS Chapter v, 2002)

AIS information is classified as 2 types of information static and dynamic. Vessel name, call sign, MMSI number (user ID), IMO number, dimension, type of the ship are static information. Position, course over ground, speed over ground, true heading, rate of turn are dynamic information. (Vesseltracker, n. d.)

AIS transponders naturally transmit information at regular intervals through a VHF radio incorporated with the AIS. The position and speed originate from the ship's GPS or, if that comes up short, from another GPS receiver. Other information is incorporated when AIS transponder is installed on the ship. (Weatherdock, 2014)

The AIS signals are then received by other shore-based facilities like VTMS or nearby vessels. The received information is then used to display ships on two dimensional marine charts. This helps to observe ships activities. This enables ports and coastal states to recognize ships in their waters and regulate the vessel activity. (Weatherdock, n. d.) . In Sri Lanka such receivers located at Colombo and Mirissa, receive AIS signals emitted from vessel at Colombo harbour. This information is used to display the vessel on two dimensional marine charts. The ships are represented by arrow heads.

2. 5 Applications of AIS

There certain usages in AIS data.

- To enhance security nautical activities
- To safeguard the maritime surroundings
- To support collision avoidance.
- To manage vessel traffic in busy harbors.

2. 6 State Estimation Problems

The objective is to estimate the states of a dynamic system sequentially, utilizing set of noisy measurements. Orlande et al. (2012) describes that in state estimation problems, the accessible measured information is utilized together with prior learning of the physical phenomena. This task is undertaken by minimising the error.

There are many applications in state estimations numerous fields. Orlande et al. (2012) describes that the position of an aircraft can be found using estimation. Also it may also be possible to locate the position using GPS system and altimeter. Usually these measurements are not always accurate. In state estimation combines the model predictions and GPS measurements to obtain more accurate estimates of air craft position. This idea can be incorporated in the research since the measurements are available during the course of the ship. It is possible to make estimations for the locations of the ship for the places where measurements are missing. Also it is possible to check whether the estimations are reliable with the measurements.

2. 7 Kalman Filter

The Kalman Filter also known as linear quadratic estimation was developed by Rudolf E. Kalman around 1960. Peter Swerling developed a similar algorithm in 1958. Richard S. Bucy of the University of Southern California backed the theory, making it often being called the Kalman–Bucy filter.

As stated by Madhumitha & Aich (2010) the Kalman Filter is a mathematical system used to correct observed values that contain inaccuracies and other disturbances and produce values with are nearer to true values. In many military and space operations Kalman filter is widely used. The fundamental operation done by the Kalman Filter is to produce estimates of the true and calculated values. Then the uncertainty is calculated along with a weighted average of both the estimated and measured values.

A considerable amount of literature has reported that there exist different variants of the Kalman Filter. Discussions such as that conducted by Madhumitha & Aich (2010) presented that different variants of the Kalman Filter including Extended Kalman Filter (EKF) and Unscented Kalman Filter. The Extended Kalman filter is an extended variant of the original Kalman Filter. The requirement of linear equations for the measurement and state-transition models is relaxed; instead, the models may be nonlinear. The Unscented Kalman filter (UKF) is an improved alternative to the (EKF) for a variety of application. According to Kandepu, Bjarne, & Lars, (2008) the performance of the UKF is better than the EKF in terms of robustness and speed of convergence. However computational effort in both EKF and UKF are almost the same.

Webb, Prazenica, Kurdila & Lind (2007) addresses a problem of obtaining a robust, real-time estimation of aircraft states from a set of measurements. The solution is gotten through by implementing implicit extended Kalman filter, a variation of the classical Kalman filter. The approach taken in this paper is to use the Kalman Filter to provide reliable state estimation. The resulting estimates are implicit functions of the aircraft states, the tracked feature points, and the camera parameters.

In a research carried out by Freeston (2002) the Kalman Filter has been implemented for robot localization. Robot localization means the method whereby a robot locates its own position in the world in which it functions. The measurements of the robots x and y components of the position and the orientation is available. The information can be represented by a state vector. In order to find out its position, the robot uses beacon distance and angle measurements and kinetic data. This data consists of error. The Kalman Filter is one of the better methods to incorporate measurements into estimates. The Kalman Filter identifies that the measurements are noisy and that occasionally they are discarded. Furthermore the Kalman Filter identifies measurements that have only a small effect on the state estimate. The Kalman filter smooth out the uneven effects of noise in the state variable being estimated by add in more information from trustworthy data than from untrustworthy data. The user is able to provide the value of the error in the data and the system as an input in the filter. The Kalman filter computes an estimate of the position by considering the noise in the data and the system.

The Kalman Filter algorithm can be used to combine measurements from different sources such as vision measurements and kinetic information and different times updates as a robot is moving. In addition the algorithm provides an estimate of the state variable vector uncertainty which is a measure of how accurate the estimate. This situation is somewhat similar to the situation discussed in the research. This idea can be utilized in the research to obtaining better estimates of the state variables by minimizing the effect of the noisy measurements. (Freeston, 2002)

2. 8 Particle Filter

The Kalman filter (KF) has revealed tremendously useful, however has stern assumptions about linearity and Gaussian noise. This is not always satisfied in real world applications. In such situations Particle Filter can be used to obtain solutions. (Orlande, et al., 2012)

The Particle Filter Method is a Monte Carlo technique that can be utilized to obtain the outcome of state estimation. Particle filtering methods can be used in situations which are non-linear and/or non-Gaussian. Particle Filter otherwise called as bootstrap filter, condensation algorithm, interacting particle approximations and survival of the fittest. (Orlande, et al., 2012)

In Karlsson (2005) the Particle Filter is adapted to some positioning and tracking applications. Particle Filter is constructed on a model which is linearized and a Gaussian noise assumption. A method for estimating position of industrial equipment that works underwater is developed. The data is collected from sonar sensor and surface direction finding system using radar readings and sea chart data. The problem is approached by using Bayesian methods and data collected from maps are used to improve the estimation performance. A real-time application of the Particle Filter as well as hypothesis testing is presented for a collision prevention application.

A situation is somewhat similar to the condition talked about in the research is discussed by Ceranka & Niedzwiecki (2003). A navigation system for the estimation of the pedestrian position, based on evidence from sources like GPS, is created using the Particle Filter approach. Although the GPS provide accurate information obstacles such as high buildings, trees, bridges may weaken or reflect the signals. This leads to significant growth of errors or even creates loss of GPS signals completely. The Particle Filtering approach is suggested to be suitable in this situation in order to estimate the missing locations and make sure the estimates comply with the constraints of the digital map.

2. 9 Chapter Summary

In this chapter the past studies and discoveries presented by various researchers related to the research is discussed. The details about the development of vessel traffic management systems (VTMS) up to the present day commercial vessel traffic management systems are presented. The problems associated with the VTMS are addressed. Then the facts about the AIS data are presented. Then the chapter addressed the solutions to improve the VTMS such as state estimation. The theoretical background of the Kalman Filter is presented as a solution to the state estimation problem. In the instances the Kalman Filter is not applicable the Particle Filter is presented as a better approach.