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ANCHOR: Navigation, Routing and Collision Warning during Operations in Harbors ⋆

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Abstract: The traffic density in and around harbors is rising continuously and it is challenging to maneuver a ship through the port to or from its assigned mooring dock. Thus, the ANCHOR project aims at assisting pilots and port operators during piloting large vessels safe and economically in time within harbor areas. This work focuses on the highly accurate, portable, and reliable navigation system developed within the project ANCHOR.The system suggests routes and has a built-in collision warning system to enhance safety. To be able to provide the mentioned functionality portabledevices are handed out to the pilots. The devices can be used ship independent and therefore shipowners do not need to equip their vessels with extra technology. The navigation units measure ship position, and attitude. Furthermore, they are connected to a server via a communication link to share their information, and measurements. The server additional receives environmental data like wind, and current from the projects sensor network as well as AIS data from an integrated AIS receiver. Combining all the data, the server delivers optimized routing information, and collision warnings to the pilots. Achieved results showing the potential of the system as well as further planned tests and demonstrations are introduced in this paper.

Keywords: guidance systems, navigation systems, communication systems, sensor systems, ship control, GNSS

1. INTRODUCTION

Due to the rising traffic density, especially in and around harbors, it is challenging to maneuver a ship through the harbor to or from the mooring dock. Therefore, an accurate and flexible assisting system for pilots is needed.

Nowadays ship navigation in the harbor area is based on the same technology as normal route navigation in the open water. In most cases this technology consists of common GPS receiver, sometimes combined with digital map. However the harbor is a very specific region, with a lot of traffic, where accurate and reliable localization and therewith effective, and safety navigation is crucial. There have been numerous initiatives aiming at developing a automatic docking system. However, their use refers only to the final phase of approaching the ship to the wharf. One example is given by Zalewski [2012] where laser scanners improve the position accuracy. ANCHOR does not aim at automating the docking process but on improving the whole harbor approach.

In Engler et al. [2012] the author summarizes a study showing that about 50% of all accidents during maritime processes have navigational causes. This means, in consequence, the number of maritime hazards can be reduced with improved navigation. The areas around and in harbors are particularly dangerous. On the one hand, space is limited and further restrictions and constraints are present as well. On the other hand, there is heavy traffic in harbors. So the harbor operators aim consist in running an efficient and productive harbor. At the same time the procedures in a harbor need to be safe, to minimize potential damages, threats, and hazards. A navigation assistant system particularly for the area in and around harbors, such as ANCHOR, can help to increase maritime safety and boost the effectiveness of ship operations, simultaneously.

A key enabler for such applications is communication, as shown by Challamel et al. [2012]. The article presents the advantages of satellite-based communication. In the considered area in and close to harbors, additional communication channels can be used to improve assistance systems. Jiang et al. [2013] addressed this approach by presenting a docking assistant based DGPS getting correction data via communication, namely WiMAX. WiMAX provides high data rates of multiple Mb/s, thus, it is capable to provide latest DGPS correction data. It also complies with the request for good coverage. A single base station covers an area with a radius of multiple kilometers. Since more and

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more WiMAX services are about to be powered down, for example the united states biggest WiMAX network hosted by Sprint, as indicated by the United States Securities and Exchange Commission [2013], different approaches need to be used in order to maintain an equal quality. This leads to the second important enabler: Global Navigation Satellite Systems (GNSS) such as the Global Positioning System (GPS), Galileo, GLONASS and others. But not only the position is important, a reliable heading information is at least equally important. As shown in Giorgi [2010], Giorgi et al. [2012], Dai et al. [2012], and Daneshmand et al. [2014], GNSS using multi antenna constellations enables precise heading information. In order to deliver reliable position, and attitude information in ANCHOR localization is based on a sophisticated two antennas GNSS receiver integrated with a inertial navigation system (INS) module. The proposed solution will be able to obtain an accuracy in the level of one meter in almost every condition and the ship orientation with one degree accuracy without the need of transmitting correction data over the ANCHOR communication channel. Combined with high resolution and accurate digital maps and advanced algorithms, the system will be able to calculate a high level navigation solution. The third mayor feature is the portability of the ANCHOR system. Due to the fact that the system is portable every vessel can be equipped with it. So the number of needed systems is smaller what helps keeping cost low. After temporarily mounting the portable receiver on the ship the pilots are able receive information provided by ANCHOR. These information consists of the own position, positions of neighboring ships, a suggested route to the desired docking position, and collision warnings based on the ships predicted movements.

Besides the navigational approaches presented in this paper, ANCHOR also addresses other aspects. Today, there are a lot of different environment monitoring sensors and also internet platforms, where the public has access to the data. But in most cases the services only provide one kind of observations (weather, water currents, pollution, etc.). The Anchor system will create a special internet platform where all important data will be centrally available. This data comes from self-developed sources as well as from different available sources such as AIS and other global environment monitoring services.

The whole ANCHOR system can be summarized by its mayor features. It addresses the users request to improve the *localization and navigation* of ships in harbor area. Therefore, a *portable solution* is developed, that brings its own sensor network for *data acquisition*. Furthermore, it delivers an open internet platform with *environment monitoring* data which due to its *open architecture platform* can also be enhanced with new types of sensors.

This paper introduces the ANCHOR software components used to realize navigation, routing, and collision warning. Therefore, a project overview is given followed by the technical system description. Herein, the implementation of the desired software components is discussed. The paper closes with validation tests performed in the project and ends up with a conclusion.

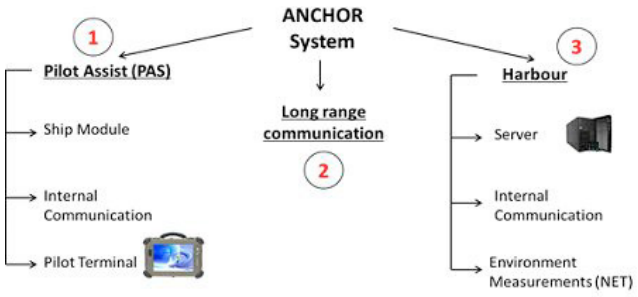

Figure 1. ANCHOR system components

2. ANCHOR PROJECT OVERVIEW

The ANCHOR system improves the harbor safety and the piloting of large vessels by a GNSS-based assistance and navigation system aiming at the ship approaching its determined docking position in the harbor. Therefore its objective is to develop a system including the following modules:

- An *Internet Platform* for sharing and exchanging GIS, GMES and local measurement data.
- The Harbor Server for the analysis and graphical visualization of all data. Data will also be archived there.
- An *Environment Measurement Network (NET)* to assure accurate weather and water conditions data.
- The *Ship Module*, which ensures a precise localization and orientation solution.
- The *Pilot Software* for the visualization and analysis of all relevant data.
- A *Wireless Communication Link* for reliable, fast data transmission among all stations mentioned above.

The ANCHOR team has developed an innovative combination of these elements. It increases the safety of ship traffic inside the harbor as well as in the coastal area for approaching ships. By providing the quickest and most effective route to the pier, ANCHOR saves significant amounts of time and fuel, accompanied by major cost and CO2 emission reductions.

2.1 System design

To reach the objectives, ANCHOR will provide a so-called "Harbor Captain Assistant for Navigation, Observation, and Data Routing System" for the coastal area of the harbor. This system consists of three main parts as depicted in figure 1: The Pilot Assist Sub-System (PAS), the Communication Sub-System (CS) and the Harbor Infrastructure (HI).

PAS: As part of the *Pilot Assist System*, a ship module will be installed on the vessel, outside the captain's bridge. This module contains a GNSS module (with GPS, Glonass, EGNOS- and Galileo-ready options), an integrated INS, a battery pack, and a control unit. This ensures accurate and reliable ship localization and orientation under every environmental condition. The ship module is battery powered and easy to install. The pilot terminal is realized as tablet/ laptop with suitable software that assists the ship