SHIP PARAMETER EXTRACTION SYSTEM USING PASSIVE ACOUSTIC APPROACH

Ammar Aljuhne[1], Axel Hahn[1], Oliver Zielinski[2]

[1] *Department of Informatics, University of Oldenburg, E-Mail: ammaraljuhne@gmail.com, hahn@wi-ol.de*
[2] *Institute for Chemistry and Biology of the Marine Environment, E-Mail: oliver.zielinski@icbm.de*

INTRODUCTION

The rapid growth of maritime shipping worldwide increases the challenges of maintaining safe navigation and assessing the protection of the marine ecosystem. As part of the eMaritime integrated platform, the LABSKAUS physical testbed gives great opportunity for new approaches and technologies related to the eNavigation and eMaritime concepts [1]. It consists of a set of integrated services and components that cover the area from the mouth of the Elbe River up to the port of Hamburg. The components of LABSKAUS platform include:

- a Reference Waterway
- a Mobile Bridge
- an Experimental Vessel Traffic Services (VTS System)
- a Mobile Research Port test bed
- Navi-boxes

In this paper a concept of a new system is introduced to be integrated with the testbed. The Ship Parameters Extraction System (SPES) is designed to use underwater passive acoustic technologies for extracting passing vessels' operational parameters such as propeller speed, acceleration and rudder angle change. The necessity of the proposed system rises from the requirements of several applications in the maritime domain. For example, in many studies such as [2-4], there is always a need to obtain operation parameters of test ships to assess the models under development. Usually, researchers tend to overcome the absence of such parameters by using scenario based approach i.e. by having direct cooperation with some test vessels to get the required inputs. The AIS and Radar systems provide much information about the passing ships, e.g. position, draft, speed, rate of turn, etc. However, the operation parameters of the ship are in most cases not available.

Extending the service provided by the testbed with systems that remotely extract extra information from passing vessels without the need of direct cooperation is a potential advancement [5, 6]. The SPES approach does not only overcome the limitations of the scenario based method, but it also gives great advantages for users by enhancing the robustness and efficiency of the provided data exchange service.

Integration strategy

The LABSKAUS Reference Waterway within its coverage area provides basic maritime surveillance data using a set of Naviboxes. In their current state, these boxes are equipped with GPS, Radar and AIS receivers. They are used as a traffic data recording and streaming system which gives the possibility to test and apply new safety applications and ship assessment algorithms [7].

Figure 1 illustrates the reference waterway with its Navi-boxs and the proposed integration of the SPES.

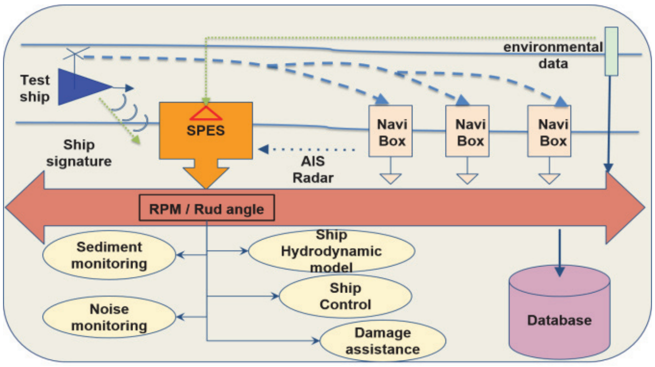

Figure 1: Illustration sketch of different components of LABSKAUS reference waterway with proposed integration of SPES.

To describe the proposed integration of the SPES, the starting point for doing so is to firstly illustrate the internal design of the system with its processing modules and input requirements.

The SPES, as an underwater acoustic system, requires a level of knowledge about the operation area and the passing vessels as targets of interest. It is based on target tracking and feature extraction algorithms. Figure 2 shows the internal design of the SPES.

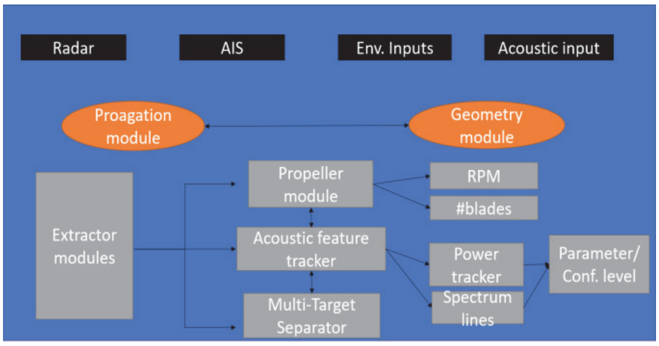

Figure 2: The internal modules proposed in the SPES. Three data layers are designed with interchangeability between them.

Three data layers are designed in the SPES, color coded in Figure 2, to ensure fast and efficient processing routine. These layers are: row data (in black) from different sensor components (Radar, AIS, Environmental Inputs and Acoustic Input), a mid-processing layer (orange) including Geometry and Propagation modules and finally extraction algorithms (gray) that combines propeller module, acoustic feature tracker and target separator.

For accurate characterization and analysis of the source radiated noise, several inputs from the target as well as from the area of operation are required. The need of these

requirements can be better clarified with examples from typical processes that are performed in the field of ship noise analysis.
One example is for instance the analysis of the propeller noise. The ship propeller, as a dominant noise source at moderate and high speed [8, 9], is a suitable representation of the ship as a point noise source. Thus, input requirements from the target (i.e. ship type, position, draft and shape information) play an essential role in estimating the actual position and depth of the propeller. These inputs are provided in the raw data layer of the SPES. The geometry module as a mid-processing layer is designed to process the data from the raw data layer and extract all the necessary information about the target. The output of the Geometry module is then passed to the propeller submodule and the extraction algorithm could then be executed.
In another typical ship noise analysis scenario, the received noise (in the acoustic sensor) is often propagated back to a reference distance from the target (typically one meter) and the source noise level (SNL) is computed. This routine enables the comparison of the target SNL at different instances of time.
This process requires the implementation of a proper model for the propagation of sound in water. Several techniques are used usually in estimating the propagation of sound. As described in [10], there are several empirical, semi-empirical and full acoustic propagation models that could be used, and choosing a proper model depends normally on the desired accuracy level, the complexity of the environment of the test area and the availability of the environmental inputs. The bathymetry, water properties, tidal information, wind and weather forecast are key parameters for propagation models. Therefore, the propagation module of the SPES is proposed to run all the required processes for utilizing a proper propagation model.
The computations run in the propagation and geometry modules are updated using key environmental data and different targets geometry models. The output is then passed to the extraction modules, which utilize all the passed information to process the received signal and to execute desired acoustic features of the target. The extraction of ship maneuvering parameters in the SPES is based on tracking the available acoustic features of the target vessel. In general, these features are sensitive to the motion state of the target and any change of this state affects in different degrees the extracted features. Trevorrow et.al [9] have proposed in their work an empirical model for correlating the source noise level with the change in speed, aspect angle and turn rate of the vessel. Jiansheng et.al [11] also proposed a statistical approach for extracting and tracking acoustic features of surface vessels for maneuver tracking applications. Several studies have been focusing on characterizing the effect of ship operational conditions on the measured acoustic signature [9, 12, 13]. This includes the speed, ship orientation, turn rate and acceleration. The detection of any significant change in the acoustic features of the target and correlating them with the maneuvering parameters of interest is the core of the acoustic feature tracker module of the SPES. The extraction modules implement different detection strategies and advanced signal processing to undermine the difficulties of eliminating external factors that affect those features, keeping only the correlated effect between the change of the feature and the desired operational parameter.

SPES integration case study

The brief description of the design of the SPES, and the communication links between the different data layers is a first step toward the realization of the integration with the testbed. With the support of LABSKAUS infrastructure and its components, the SPES could efficiently provide extra level of maritime related data which has high influence in designing ship safety and automation applications.
Understanding LABSKAUS architecture, processes and technical specifications enables the integration of new sub-modules and prototypes. Based on a communication infrastructure and polymorphic interface, the testbed gives the opportunity for easy integration of new models, software and physical prototypes [7]. As described in [14], the design of the testbed is based on multi-broker communication network that communicates through lanes and knots. An open source message broker software is implemented for handling and controlling data channels from different components as shown in Figure 3.

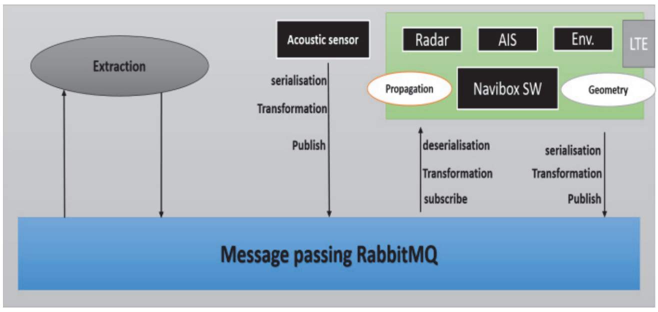

Figure 3: SPES integration in the LABSKAUS testbed. Communication is handled with the RabbitMQ message broker

The integration of the SPES is based on modules or data handlers. These modules process the data and use data stream management system to process the data streams. Sending and receiving data streams are based on Publish-subscribe pattern as part of the messaging system. Any module that requires specific data needs to subscribe to the message passing bus and the data will be transformed to any defined format and deserialised for usage.
Additionally, the design of the Naviboxes with the implementation of Orocos Toolchain approach behind the scene enables the configuration and control of the data stream with desired output [7]. This approach gives the potential of reducing the workload of the network and more independency when implementing additional modules with specific input requirements [14].
We showed in this use case the feasibility of integrating the new proposed SPES in the LABSKAUS platform. The flexibility and scalability of the testbed ensures the possible integration with systems and modules with possible large data output as it is based on loose coupling design.
In parallel to the integration design of the SPES, the system development is split into two technical phases related to the underwater implementation. This decision was due to the complexity of the underwater acoustic in river environment and for practical and logistical purposes.
Temporary phase: The first phase of the development aims to conduct some field experiments for gathering datasets and

initiating the design of the internal processing algorithms of the SPES. An initial experiment is designed and conducted at the time of writing this work. This experiment aims to record the radiated noise of a test vessel for the characterization of the acoustic features related to the maneuvering parameters of the vessel. The design of the experiment is shown in Figure 4.

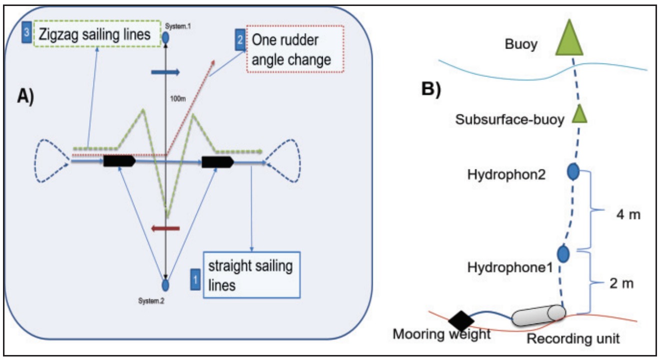

Figure 4: Experimental design sketch where A) shows the ship maneuvering plan and B) shows the components of one of the recording systems.

A test vessel route plan was design to perform maneuvering scenarios and an underwater acoustic recording system is designed for acquiring the acoustic data for later analysis. The detailed analysis of the results will be carried out in future work.

Long-term phase: The focus of the second phase of the project is to build a fixed installation of the SPES, and to extend its service to the streaming service provided by LABSKAUS testbed.

The proposal of such installation includes a buoy containing all the electronics needed for the SPES system to function over long time. Additionally, a proper method for data transmitting to land should be designed for data analysis. Figure 5 illustrates the design of phase two with its components.

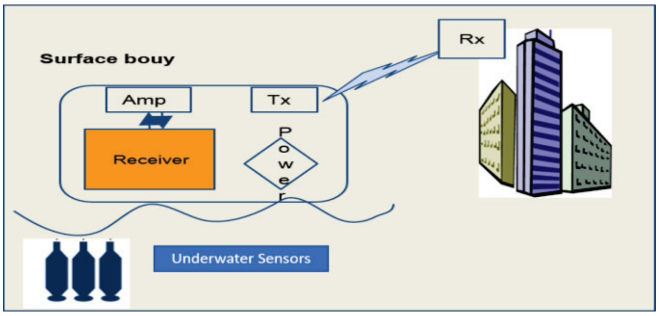

Figure 5: Illustration of the Long-term deployed system including a water proof container, underwater sensor components and TX(Transmitter) and RX(receiver).

Another approach for long-term monitoring would involve a cable connection approach where the hydrophone is installed in the water and connected directly on land with a cable [15].

Conclusion and Future work

We have proposed a new system to be integrated with the LABSKAUS testbed for extracting ship maneuvering parameters based on passive acoustic technologies. The infrastructure of the testbed and the integration design of the SPES was presented. In addition, two technical phases of development were briefly presented and an initial experimental design was illustrated.

In the next step, more experiments are to be designed to focus on the correlation of the extraction of acoustic feature changes that correlate with specific ship maneuvering parameters.

Acknowledgment

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