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Mobile Bridge - A Portable Design Simulator for Ship Bridge Interfaces

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ABSTRACT: Developing new software components for ship bridges is challenging. Mostly due to high costs of testing these components in realistic environments. To reduce these costs the development process is divided into different stages. Whereas, the final test on a real ship bridge is the last step in this process. However, by dividing the development process into different stages new components have to be adapted to each stage individually. To improve the process we propose a mobile ship bridge system to fully support the development process from lab studies to tests in realistic environments. Our system allows developing new software components in the lab and setting it up on a ship bridge without interfering with the vessel's navigational systems. Therefore it is linked to a NaviBox to get necessary information such as GPS, AIS, compass, and radar information. Our system is embedded in LABSKAUS, a test bed for the safety assessment of new e-Navigation systems.

1 INTRODUCTION

In recent years, various new software components for ship bridges have been proposed in research (e.g., for novel ways of interacting with ship bridge systems [2]). However, while more and more technologies are presented in research the speed at which these technologies appear on real systems is rather slow. This is mainly due to limited access and high costs of testing these technologies on real ship bridges. However, for the development of new software components tests are essential. To solve this problem and to reduce the costs of the development, the process is divided into different stages. Thereby, the final test on a real ship bridge is only the last step of this process. By taking the approach of different development stages, first steps can be done in a laboratory environment. This is beneficial because early stage software requires shorter development cycles that support an uncomplicated execution which is simply not given on a real ship bridge. However, due to the problems of testing software components on a real ship bridge, many researchers and developers used training simulators for their development in the past. These simulators support the fast development process in the early stages but generate a new problem when the components need to be transferred to a real ship bridge. To solve this problem a system is needed that can be used in all development stages that easily adapts to these stages.

We propose Mobile Bridge, a mobile ship bridge that is easy to recreate and setup. It supports the early stage development in short development cycles with an additional simulation environment as well as later stage development as a parallel setup on a real ship without altering the live system. The Mobile Bridge is a configurable ship's bridge system in which new eNavigation technologies can be tested and demonstrated. In particular new interaction concepts are within the focus of the development. This includes both, the providing of information to nautical personal as well as new control concepts. The portable structure of the system allows a straightforward demonstration and evaluation of these concepts in a real system environment, e.g. on real ship bridges as the system can be connected to a NaviBox [6] to get necessary information and run in parallel with the real systems. An additional vision system supports the design, development, evaluation, and demonstration of these interaction concepts within a virtual environment.

2 RELATED WORK

In the beginning, maritime simulators have been mainly developed to allow mariners training under realistic circumstances without the potential risk of harm to a real environment or themselves. Its development evolved from rudimentary graphics and text-based simulation (e.g. port simulator from Hayuth et al. [8]) to complex 3D virtual environments that assist in learning specific tasks (e.g. offloading maneuvers [16]). A detailed overview of first maritime trainee simulators can be found in the paper from Hayuth et al. [8]. The development towards 3D virtual environments was foreseeable since several papers proposed to use virtual reality for more immersive simulations already at the end of the nineties [18], [11].

But not only the visual possibilities increased also the purpose of maritime simulators extended fast to cover additional topics like research and development. Since the motivation of just having a virtual ship crash and not a real ship stays the same for these topics. Additionally, a simulation is able to simulate a specific part of reality and for that reason is more adaptive to new techniques.

Especially for the development of user interfaces, different concepts have been proposed based on maritime simulation. All these concepts focus on taking the human factor into account for the development process of new interfaces. Since accident investigation showed that the human error is the most frequent reason for accidents [15]. Although, there is a connection between the design of user interfaces and the capability of nautical officers to understand their current situation and to decide correctly [5]. As a first step, research focused on creating simulator environments to develop new user interfaces. Therefore, training simulators were adapted and combined with tools and techniques to set up an environment for user interface development (e.g. the design simulator for offshore ship bridges from Kristiansen and Nordby [10]). With respect to aspects of easy access and low price a simulator is a better choice over a real ship bridge, but cannot compensate it (e.g. the important fieldwork). But the general idea of using a simulator as a valid strategy to conduct user studies got strengthened by the findings of Hareide and Ostnes [7:201]. They did a comparative study between a real ship bridge and a simulator for navigation training and found no differences in comparing the eye-tracking data of both environments. To use simulators for a redesign to create more user-centered solutions is only one goal of research. Another goal is the development of more unified interfaces that are consistent over different systems on one or more vessels. Therefore, Nordby and Komandur presented a laboratory for the design of advanced ship bridges [12].

But more than new environments for developing maritime user interfaces are also new design principles necessary since the given environment differs in many points from others. An approach for radical concept design is presented by Wahlström and Kaasinen [17].

For research not only the simulator environment is relevant also the operator is of high interest. For example the effect of the spatially distributed space on a ship bridge on information demand and supply [3:2]. In the paper from Hontvedt and Arnseth, a ship bridge simulator has been used to investigate the social organization of nautical instructions [9]. Therefore, they looked into training sessions with nautical students and experienced mariners and observed their behavior. Such investigations can be used to create a model of the crew members behavior and simulate it. These virtual nautical officers were for example created in the paper from Brüggemann et al. [1].

The Concept for our mobile ship bridge was first introduced by Hahn et al. as part of the eMIR Testbed [4]. The idea of the eMIR Testbed is to set up a testing environment for simulation and physical real-world demonstrations. The focus is on how to validate and verify e-Navigation technologies. The related project HAGGIS [13] provides modeling and simulation tools. The physical testbed embedded in HAGGIS is called LABSKAUS [14]. It is also mentioned that testbeds already exist in the automotive domain but are missing in the maritime domain.

3 DESIGN OF MOBILE BRIDGE

In our approach, we designed a mobile bridge to fully support the development cycle of new software components. Key to our approach are flexible boxes called "BridgeElements".

Our mobile bridge system, consists of three equal segments that can be combined and connected with each other. Each of these segments is build up of one information and one control element. Whereas the information element is realized as a multi-touch monitor. The control element could be either a multi-touch monitor or a set of bridge control elements like thrust levers or a steering "wheel". The multi-touch control element enables the testing of new concepts for virtual handles and controls. Every segment can be operated independently. This allows using more or less than three segments. The system is highly configurable, e.g. distance and position of displays and components can mimic a broad variety of real ship bridge configurations.

3.1 *Requirements*

To support the complete development cycle, our Mobile Ship Bridge needs to be transportable. Further, to fulfill the requirements of small and large ship bridges we need a modular design. This allows us to adapt the size of Mobile Bridge to the existing space on ship bridges. Our system consists of two main components: The Mobile Ship Bridge itself and the vision system.

Our mobile ship bridge was implemented with regard to the following assumptions:

- The Mobile Bridge will be composed of multiple (1 to 3) Bridge Elements
- A Bridge Element shall be transportable and easy to install
- A Bridge Element that can be set up faster shall be preferred
- A table to hold the Bridge Elements is not considered in this decision

3.2 *Implementation*

A Bridge Element is a hard coupled combination of a computer, a display monitor and a control element (monitor or classical bridge controls). The flexibility for different kinds of experiments is ensured by the flexible combination of different Bridge Elements.

A Bridge Element consists of a flight case containing the following components:

- An industrial computer (Intel I7 processor, 8 GB RAM, SSD hard disk) directly integrated into the flight case
- A power supply module
- A network switch
- Two 22'' multi-touch monitors
  - One monitor mounted on the bottom of the flight case, using an open frame case
  - One monitor mounted in the cover of the flight case, using an inclinable VESA mounter
  - A flexible cable duct for the monitor mounted in the flight case's cover
- A face plate for external power and network supply
  - The face plate is split into an input section for external power supply and network interface
  - A power - output element allows connecting different Bridge Elements in a row (daisy chain)
  - An additional network output element allows the network connection between two or more Bridge Elements

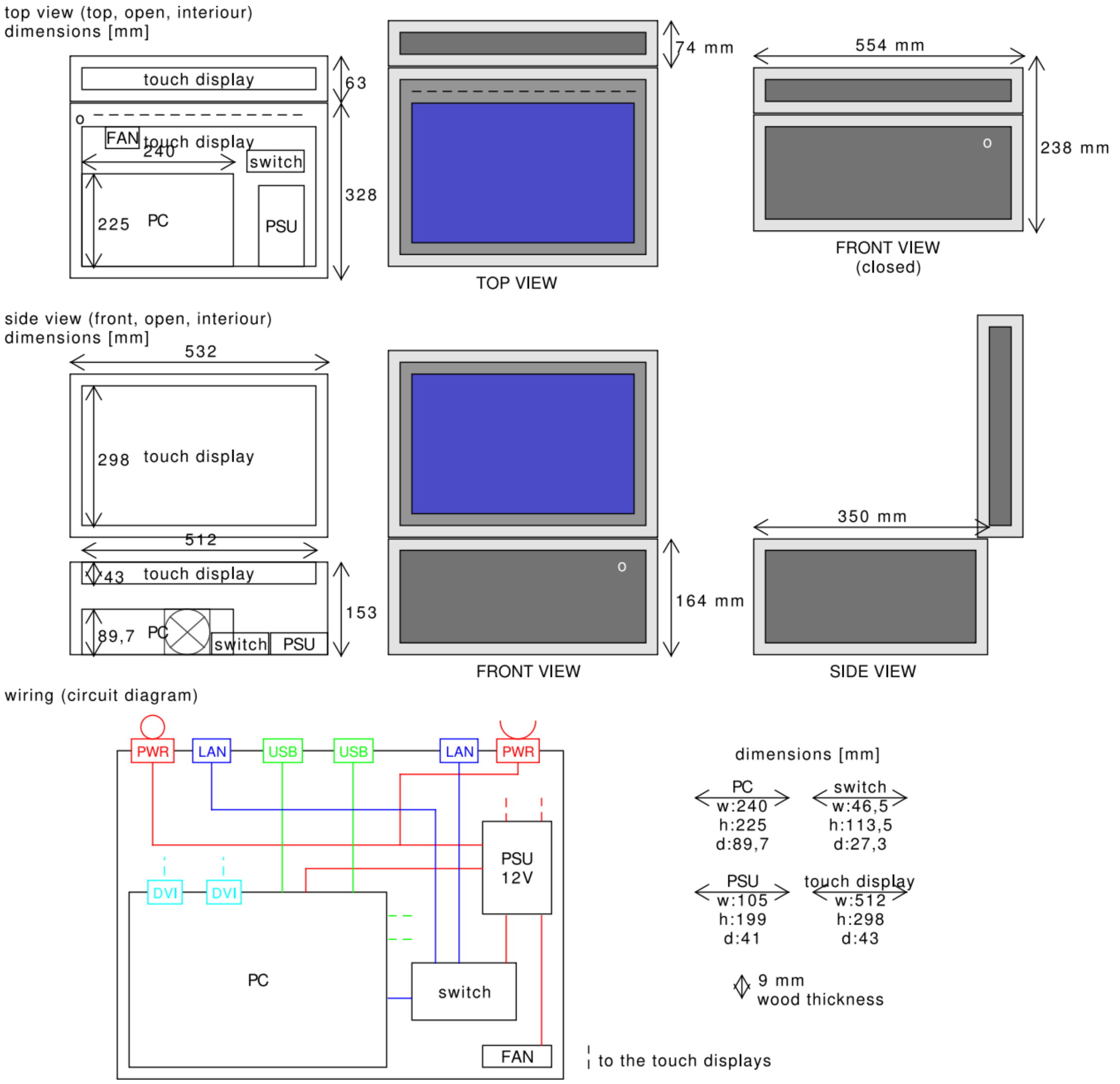

Figure 1. The Hardware placement in the case, the case sketch with dimensions and the wiring diagram.

Figure 1 shows the hardware placement in the case, the case sketch with dimensions and the wiring diagram. Detailed information on how to build a mobile bridge can be found in our Github repository1. By mounting the display monitor into the cover of the flight case, we can ensure an easy installation of Bridge Elements during experiments or demonstrations. In addition, there is no need for another monitor holding facility. On the other hand, we do lose a little bit on flexibility to rotate the monitor, if mounted inside of the flight case cover. By integrating the computer into the flight case, no additional hardware needs to be carried. On the other hand, this will increase the cost for one Bridge Element by the means of 2/3 of the cost of one computer.

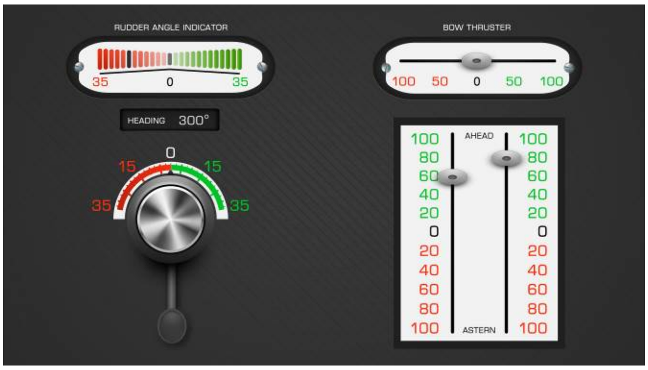

Figure 2. Example screen of Virtual Handles with rudder and machine telegraph.

In Addition to the Mobile Bridge Hardware, we created a huge set of virtual devices, such as GPS, VHF, light controls, machine telegraph, rudder, rudder angle indicator etc. that can be connected to a simulation to populate Mobile bridge with information displays and controls. The full software toolkit is documented and hosted on Github as open source software under the project name Virtual Handles[2]. Figure 2 shows an example screen with multiple devices.

4 TOWARDS VIRTUAL ENVIRONMENTS

The second component, our vision system, is used to visualize a traffic simulation within a 3D environment. For this purpose, the vision system consists of three additional displays, which are realized by a high-definition curved television system but can be easily replaced by utilizing video projectors. To further ensure the portability of the bridge system, the hardware of the vision system is totally decoupled from that of the bridge system.

Combined, the two components form a fully functional Ship Bridge Simulator using either the open source Simulator Software Bridge Command[3] or our own in-house developed traffic simulation and models. Further, the Mobile Ship Bridge supports commercial simulator software.

5 TOWARDS REAL ENVIRONMENTS

The portable structure of the system allows a straightforward demonstration of these concepts in a real system environment, e.g. on real ship bridges. The system can be either connected to the sensors on board the ship or to a NaviBox[4] to run on live data in parallel with the onboard systems. Figure 3 shows Mobile Bridge in use on our research vessel Zuse.

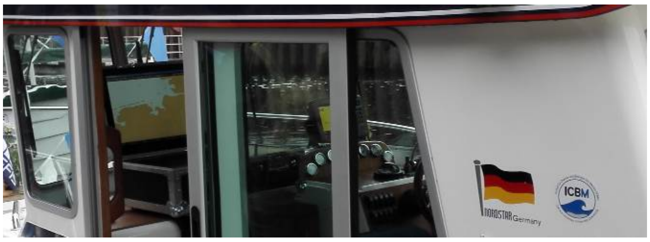

Figure 3. Mobile Bridge on Research Vessel Zuse (Source: OFFIS e.V.).

The parallel setup enables researchers and system designers to test their novel software and interaction concepts in the field. We tested this with our own research vessel Zuse.

6 USE-CASES AND APPLICATIONS

Our system can be used as a mobile ship bridge for in-situ studies on in-duty container vessels. It is transportable in an aircraft and runs in parallel to the existing systems. It can be connected to the ship's sensors or get the navigational data from a NaviBox [4].

In combination with a vision system, it can be used for lab studies. The Mobile Bridge implements a full mission ship simulator. It is also possible to connect the Mobile Bridge to an existing full mission ship simulator. Other application scenarios are the use as a demonstrator on exhibitions and as tangible interface for augmented reality solutions. The main use case of Mobile Bridge is to evaluate novel e-navigation software and prototypes.

So far, we successfully conducted two lab studies using the Mobile Bridge as a simulator. Furthermore, we connected Mobile Bridge to the research vessel Zuse of the research institute OFFIS[5].

[1] https://github.com/tcstratmann/MobileBridge, last retrieved: November 16, 2018
[2] https://github.com/tcstratmann/VirtualHandles, last retrieved: November 16, 2018
[3] https://bridgecommand.co.uk/, last retrieved: November 16, 2018
[4] https://www.emaritime.de/services/labskaus/navibox/, last retrieved: November 16, 2018
[5] https://offis.de/, last retrieved: November 16, 2018

Figure 4. Mobile Bridge set up as Full Mission Simulator.

6.1 *Application: Explore Novel Touch and Tangible Interaction Methods for Maritime Applications*

To enable the fast development and evaluation of new interaction techniques for maritime user interfaces, the display areas are designed to support multi-touch and tangible interaction. Both interaction methods are supported simultaneously. For the tangible interaction, we describe two different concepts in the implementation section. One method with a continuous input of the tangible controller and one method that only triggers an input, when the user touches it. This enables a correction of the GUI orientation and prevents possible misentries, e.g. through movement of the controller on the interaction area during a heavy swell.

As explained in section Design of Mobile Bridge on software side virtual handles are used to interact with the Mobile Ship Bridge via direct touch input.

6.2 *Application: Standalone Full Mission Simulator*

In this application, Mobile Bridge was used as a Full Mission Simulator during a user study. It was used in combination with the Open Source Mission Simulator Bridge Command.

6.3 *Application: Full Mission Simulator for Special Labs*

The mobility of Mobile Bridge enables user studies in special laboratories such as anechoic chambers. Stratmann et al. used such a setup to compare moving and static acoustical pointers in an simulated acoustic ship scene.

6.4 Application: Mobile Bridge in the Field

Mobile Bridge can be setup in parallel to the existing bridge on in-duty vessels to test novel user interfaces. In Addition to that,we successfully used a Mobile Bridge Element to control our research vessel Zuse (rudder, machine-telegraph).

7 DISCUSSION

The strong flexibility of the presented design simulator comes along with some compromises. There is a trade-off between the realism and mobility of Mobile Bridge. On the one hand, the choice of touchscreens as display and input units supplies us with an unlimited flat design space for visualizations, touch and tangible input methods. On the other hand, we have to deal with the disadvantages of touchscreens in maritime environments, such as input problems with wet hands. As the standard configuration only consists of touchscreen surfaces, the system is more sensitive to bright environmental lightning conditions than native systems.

8 CONCLUSION

We presented Mobile Bridge, a mobile modular platform for testing novel interaction concepts and software for ship bridges. The platform will enable system designers to implement and evaluate novel maritime HMI applications in the lab and in the field. We tested Mobile Bridge in four different use-cases, which highly benefited from or were not even possible without the platform.

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