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Development of a motion system for an advanced sailing simulator

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Abstract

To train competitive sailing in a virtual setting, motion of the boat as well as haptic feedback of the sail lines is essential. When discussing virtual environments (VEs) the concept of presence is often used. In this study we develop a sailing simulator motion system to research what factors contribute to the participants' sensation of presence when sailing in a VE. The developed simulator includes the development of a mainsheet force feedback system and a novel motion platform, connected to a high-quality graphics sailing simulation. In future research, the developed system will be used to study which sail training type can be performed in simulated environments, and if the system can be used as a valid testbed for perception-action experiments.

Keywords: Sailing; dinghy; virtual reality; training simulation; force feedback

1. Introduction

Laser dinghy racing requires an advanced level of training in order to endure the physical based and skill based challenges. There are basically three ways to control a Laser: the rudder, the main sheet and the weight distribution. All three are of big importance when sailing. Due to external factors, sail training often cannot be done in the actual situation, as the conditions in competitive sailing are never exactly the same. In these situations, a sailing simulator can provide an alternative training environment, that simulates the target task and environment. However, the techniques to recreate movement by actuator-

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sensor networks are complex and consume a lot of resources. Multiple attempts have been made to develop a sailing simulator, the latest simulator was developed by Gale et al. [1]. This simulator incorporates a validated mathematical model [2] of dinghy sailing dynamics and was later developed in a simulator system that includes a moving dinghy, known as the VSail-Trainer[b]. However, after testing this simulator with experienced sailing athletes we concluded that the level of realism offered by the proposed system lacks in the display (standard small display) and graphics. The pneumatic roll system did add to the immersion whereas the mainsheet rope was experienced too short and the force feedback too linear.

1.1. Research question: What factors contribute to the participants' sensation of presence in a sailing simulator?

Virtual reality provides performance athletes tools to practise specific situations and can enhance learning speed of certain skills. When discussing virtual environments (VEs) the concept of presence is often used. Slater and Wilbur [3] defined presence as a state of consciousness, which is related to the sense of being in a place. Lombard and Ditton [4] described the concept of presence as "the perceptual illusion of non mediation '' which included social factors ('sense of being together with others').

Slater and Wilbur distinguish presence from the related concept of immersion by describing immersion as description of a technology. According to them immersion describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant. The amount of technological level of immersion afforded by the VE system facilitates the level of psychological presence. In other words, the more immersive the system, the more likely an individual will feel present within the virtual environment, and the more likely that virtual setting will dominate over physical reality in determining user responses. However the more technological features you add to a setup, system costs and usability issues will rise. Therefore, in his meta-analysis Cummings et al. [5] raises the question: How immersive is enough? As there is no straight answer to this question, Cummings et al. analyses ten immersive technology features (for example: image quality, user perspective, sound quality, etc.), which are considered to influence immersion. As this meta-study is not complete, the fairly composite list of relevant studies provides us with factors which can add to the level of immersion in a sailing simulator. In order to develop a simulator that allows athletes to effectively train we need to study what factors contribute to the participants' level of immersion and sensation of presence. Only then we can design a simulator which finds the right balance of cost and usability.

1.2. Related study

In a previous study we investigated the effect of motion on presence in a virtual sailing environment [6]. Results show a positive effect on presence and immersion when adding simulated motion in multiple degrees of freedom to the dinghy sailing simulator. Furthermore, the roll movement (movement from side to side) was proven to be essential for the feeling of presence, whereas pitch and heave are of less importance. However, the maximum roll angles could not be identified due to the limitations of the motion platform. Therefore, a new simulator setup was needed to continue the research on presence. The new setup should allow participants to experience realistic roll angles (up to 40 degrees) and allow sailing athletes to compensate boat movements with their body weight (motion capture). Furthermore, a wider display with more graphic detail should be used (wave behaviour, hydrodynamic modelling). These

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[b] http://www.virtualsailing.com.au

findings were used to develop the system described in this article, which will be used to continue our presence research.

2. Sail simulator platform

The developed sailing simulator setup is the result of the design inclusive research process to generate knowledge which one can only get through design [7]. Key objective was to develop a high performance sail simulator system, to be used for training fleet racing and boat handling skills. Due to the iterative nature of the development process many prototypes were built to generate knowledge which could otherwise not be obtained. The principles of continuous design improvement based on user feedback correspond to agile (software) development principles [8]. Therefore, we believe that implementing agile development methods in our development process methods can generate useful knowledge for multi-disciplinary product design teams. We are currently investigating which method to select to test in our development process.

2.1. System architecture

Figure 1 below shows the interaction between the sailing athlete and the virtual world. We split this interaction into four elements: the rudder, which is held in one hand; the mainsheet, which is held in the other hand; the boat hull, which the sailor sits in and a visual representation of the environment in which the boat is sailing. Identical to real-life sailing, there are three physical contact points: the hull, the rudder and the main sheet. All contact points are also controllers or connected to controllers of the game sailing boat. Unlike in flight or racing simulators, which are basically operated by keyboard and mouse, a sailing simulator relies for a great deal on subtle positioning of the centre of gravity of the whole boat which is mainly achieved by moving the body to different positions in the boat. This means that the sensors for user input in a sail simulator are much more complex than those of the before mentioned flight or race simulators. Other important control inputs for the simulation are the rudder position which is reasonably straight forward to measure and the position of the boom (controlled by the main sheet) which can be measured in much the same way as rudder position or alternately the amount of main sheet reeled in and let out can be measured to determine the input for the software. The software generates all kinds of variables regarding environmental conditions such as wind speed, wind direction, waves and current.

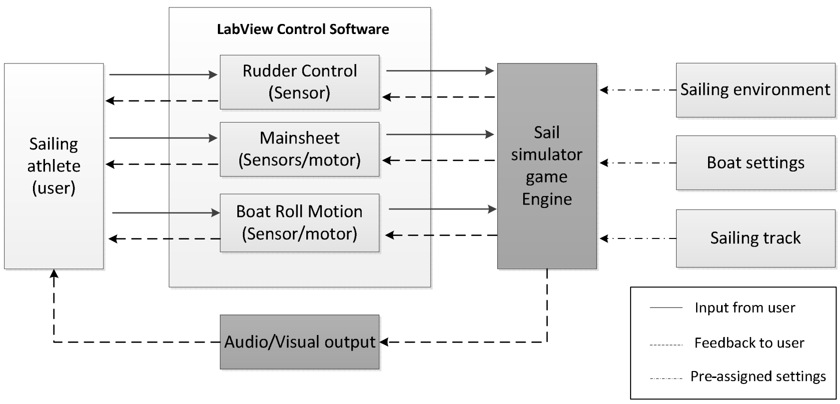

Fig. 1. Diagram of the interaction between the sailing athlete (user) and the virtual world. The control software (NI Labview 2011) manages the input and feedback from the virtual world and controls the motors and sensors

2.2. Focus points (Mainsheet, Roll and Rudder)

To answer the main research question we specifically looked at the four elements presented in the previous section. In order to determine the order of the development process of the simulator, we consulted experts and build prototypes to allow user testing. We could conclude that when looking at the bigger picture of Laser sailing, the main sheet is of most importance. Therefore, we initially focused on the development of an advanced mainsheet force feedback system and a simple rudder to steer the boat. In advanced sailing, the boat is mainly controlled by the mainsheet and the weight shift, therefore the second focus point was developing a motion system for the simulator. From a previous experiment we concluded that for advanced athletes detailed graphics and large field of view are of importance which will be our third phase of development and finally finishing with advanced rudder force feedback.

3. Putting the simulator in motion

3.1. Hardware design

The simulator setup is shown in figure 2 and consisted of an original Laser class boat hull, shortened at the front and two custom designed frames. The inner frame supports the boat hull and houses the mainsheet force feedback pulley system, whereas the outside frame is designed to allow rotation of the inner frame on its longitudinal axis (Roll). Furthermore, the outside frame houses the roll motion servomotor and offers space to mount the motor controller. The laser was equipped with standard rigging and rudder. One ultra-short throw projector is used to display a sailing scenario on a projection screen (screen diameter approximately 2 meters) and surround speakers mounted on a truss system are used for sound effects.

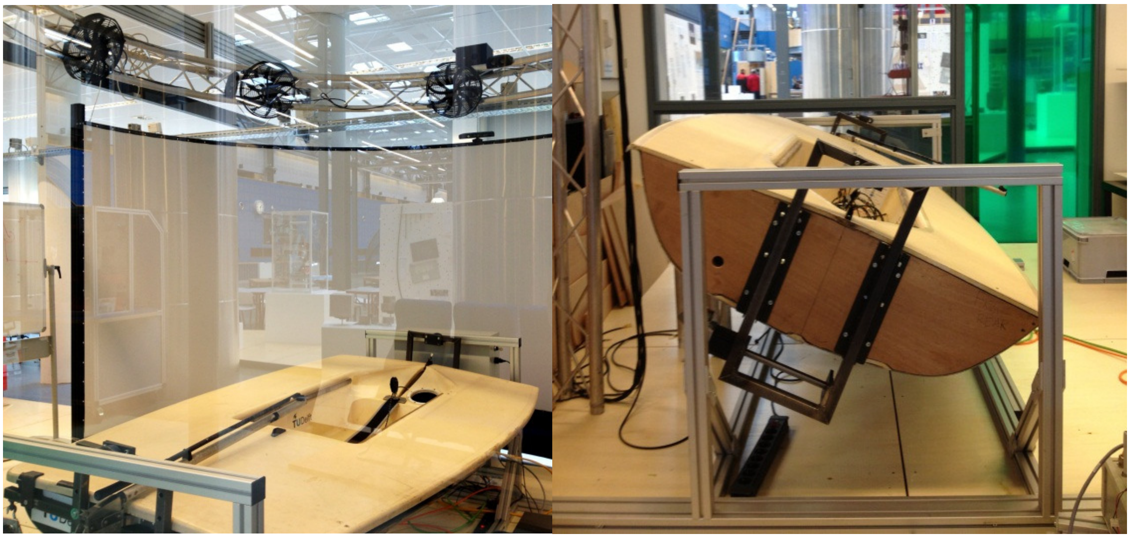

Fig. 2. The simulator setup. The athletes interact with the setup by using the mainsheet, rudder and body weight to control the boat. These controls translate the input of the athlete and provide the athlete with feedback. (Force feedback or angle change)

3.2. Mainsheet

The mainsheet is the sheet attached to the mainsail and is used to control the angle of the sail. The force feedback system consists of pulley system controlled by a servomotor (Baumuller bmaXX3000). This servomotor is connected to a motor controller which regulates the power given to the motor. The servomotor is torque controlled by using an amplified analog voltage signal ranging from 0 – 10V (zero - max torque). This signal is supplied to the motor controller by a NI (National Instruments) USB 6009 DAQ and NI Labview 2011 control software. In addition, the DAQ measures an analogue voltage signal from the motor encoder which is corresponding to the actual motor revolutions parameter, with no-rope on the spool represented by -10V (hauled in) and max-rope on the spool represented by +10V(veered). This parameter is used in order to match the rope position in the game with the amount of rope to-be-spooled. Depending on the position of the sail and the wind direction and speed the mainsheet force is calculated by the NI Labview control software. The maximum mainsheet tension is 120N depending on the wind conditions in the game and the athlete can control approximately 4.7 meter of rope which corresponds to the real laser sailing.

3.3. Roll system

The simulator inner frame rotation on the longitudinal axis was done using a low maintenance servomotor with gearbox (Bonfigioli BTD-410-30-400k). This motor was aligned in the centre under the boat and with the use of a pulley system and stainless steel cable, angles of up to 40 degrees could be achieved. The benefits of this solution is that the system is low noise, can achieve high roll angles while keeping the height of the hull low, and can operate on regular mains power. In addition, the operating cost of the system is lower than when using hydraulic or pneumatic systems.

Based on the roll angle provided by the game engine, the NI Labview control software feeds the motor controller with an analog voltage signal to set the position value of the motor. By hiking, the athlete can counterbalance the roll motion which is tracked by a low cost motion tracking system. The motion tracking system will control the mannequin athlete in the game engine resulting in the change of roll angle.

3.4. Rudder

A standard rudder was mounted on the typical position and the rudder angle was measured by using a magnetic encoders. Based on magnetic technologies, this encoder device is non-contact and ensures reliable operations. It is able to provide absolute angle detection upon power-up and provides positional data in serial bit stream. This signal is transferred to the NI Labview control software with an Arduino micro controller. Rudder force feedback will be added in a future setup.

3.5. Software

Advanced sailing athletes require detailed graphics in order to correctly judge the conditions and select the optimal sailing route. Therefore, the developed simulator uses Sail Simulator 5 sailing software [9] to simulate a realistic sailing environment (Figure 3) and track of actual racing areas (Scheveningen, the Netherlands). The software offers high resolution graphics, realistic aerodynamics with wind shear and twist and realistic wavefield and seaworthiness. Additionally, it allows simulator users to organize multiplayer races with other (desktop) users through the Internet or local network. Conditions and tracks can be set before the race. Using the integrated data-link the NI Labview control software can be used to extract game parameters and control the sail simulator setup. The control software GUI allows the supervisor to adjust the sail simulator settings and start or stop the servomotors. The disadvantage of this method is that the simulator setup is not real-time controlled which means that athletes can experience lag.

Fig. 3. Impression of the of the high resolution graphics and sailing environment of the sail simulator 5 software

4. Conclusion and future work

In order to develop a simulator that allows athletes to effectively train we need to study what factors contribute to the participants' level of immersion and sensation of presence. The knowledge required to determine these factors was generated using a design inclusive research approach.
The in this paper developed simulator is based on results from previous presence and user research with professional sailing athletes and instructors. It differs from previous developed simulators by offering high-quality graphic, multi-user sailing, electronic mainsheet force feedback system, high roll motion angles (up to 40 degrees), and allows athletes to compensate the roll motions (motion tracking). However, extensive user testing is needed to fine tune the settings of the roll motion- and athlete user tracking system. Investigating the use of agile development methods could improve the current development process and generate knowledge on using these methods for product development with multi-disciplinary design teams.

In the future, the developed setup will be used to address which factors contribute to the participants' level of immersion and sensation of presence. This we did to deliver a system which allows athletes to train in in a simulated environment and provide sports researchers with a valid testbed for perception-action experiments.

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