Integration of Visual Focus into Marine Operation Simulator for Behavior Observation and Analysis

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***Abstract*— This paper presents a framework of visual focus integration into marine operation simulator for behavior observation and analysis. Towards an evaluation of trainees' situation awareness in simulators, the eye tracking device is considered an important facility of understanding trainees' operational proficiency and response capacity to uncertain disturbances. Taking advantages of programmability of Tobii pro glasses 2, the process flow for remote manipulation of the Tobii glasses from creating projects to start/stop recordings is implemented. Meanwhile, taking real-time interaction in the training program into consideration, live video transmission of visual focus is realized by means of multi-threading and pipeline streaming technology. Furthermore, visualization of both statistical data and sensor data according to the recording result of Tobii glasses is achieved, enabling intuitive behavior observation and further behavior analysis. A case study of heavy lifting operation is carried out, from which the integration of the eye tracking system is verified useful for the training of marine operation in simulators.**

***Index Terms*— Marine operation simulator, Eye tracking, Tobii pro glasses 2, Live video stream.**

I. Introduction

Marine operations such as anchor handling at deep sea, wind turbine installation and subsea pipeline deployment are demanding in Norway. The human elements, as the principal part in the process of operations, are at the same time the dominant source of errors. Norwegian Maritime Directorate (NMD) records the cause of marine accidents are often found in the interface between man, technology and organization, in which human factors contribute up to 60% [1]. Typical areas of concern are complex systems handled by crews lacking correct qualifications, unclear roles and responsibilities, as well as increasingly procedures and check lists. It is therefore a matter of priority to look into the human element in order to ensure safety and efficiency during marine operations [2].

Identifying marine operational problems in simulator is an good alternative in reducing risk and improving overall understanding of operations to be performed [3]. Nowadays, various marine operation simulators have been developed and applied in marine industry. For instance, DNV-GL has developed the Sima software from modeling to 2D or 3D graphics, making understanding the marine operational results fast and intuitive [4]. A time domain simulation program named SIMO developed by SINTEF is used to analyze the non-linear motions and station keeping operations [5]. The Offshore Simulation Centre AS (OSC) also designed a marine operation simulator to train teamwork involving all key work positions in a ship from bridge, crane to deck [6]. Similar work was done by FORCE technology for training purpose, but mainly focused on ship bridge operations [7]. Beside the commercial simulators, marine operation simulators are also implemented in academic domain, such as the work in [8]–[11].

However, today's marine operation simulators either for commercial use or for research seldom involve visual focus—even though visual focus indeed reflects the operator's behavior to some extent. With the development of professional wearable eye tracking device, such as the mobile eye from ASL [12], the SMI eye tracking glasses [13] and the Tobii pro glasses [14], the use of visual focus for behavior observation and analysis becomes possible. In fact, efforts have been made based on the eye tracking device in different areas from psychology, engineering to neuroscience [15]–[17]. From the training of marine operation perspective, eye tracking is also the important link to situation assessment of trainees. To this end, there is an immediate and urgent need to develop a new integrated visual focus architecture for planning and execution of demanding marine operations in simulators for evaluation purpose.

Our on-going project aims to leverage advanced marine simulation facilities as a driving force for safety improvement. Situation assessment is the key part of this project. Although there is no clearly understandable way to measure situational awareness whether for individual or for groups, eye tracking is considered a situation-specific mean to estimate the degree of situation awareness of trainees. In this paper, we present a framework to integrate the eye tracking system into OSC marine operation simulator platform. The

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benefit is twofold. First, visual focus integration will serve the training program for better observation and improving training effectiveness. Second, integrating eye tracking system, from research viewpoint, provides strong support for analyzing personnel executing marine operations.

The rest of the paper is organized as follows. Section II shortly introduces the overall structure of the training platform that will be developed in the OSC simulator. In Section III, the method about how/what to integrate the eye tracking system into the simulator is described and discussed in detail. Section IV presents the integration results based on a case study of heavy lifting operation. Conclusion and future work are shown in section V.

II. A Situation Awareness Framework for Training in Marine Operation Simulator

In order to build comprehensive understanding of the procedure during a demanding marine operation, a situation awareness framework for training in simulator is proposed, as shown in Fig. 1. It contains two physical parts:

- **Simulator:** The simulator is an immersive virtual environment that surrounds the user in images, sounds and other stimuli. For our case, the simulator is a spherical dome painted white and serves as a projection surface. The dome display has a horizontal and vertical field of view about $180°$ and $60°$, respectively. In addition, an overhead camera is deployed to monitor the behavior of the user. Communication equipment to the control center or other collaborative users is also available.
- **Control center:** The control center is a separate room from the simulator. Inside there are powerful computers running the simulation and tables and chairs for debriefing. The surveillance videos from several simulators are real-time collected and displayed on a big monitor in the control center. Through the monitor, the user in the control room can guild and correct the user in the simulator by means of communication devices such as intercom.

In the training program, there are two roles, i.e., the instructor and the trainee, interactively fulfill the procedure. The instructor leads the whole process. Initially, he/she gives a briefing about the operation task, through which the trainee could get an initial idea of how/what to do in the task. Then, the trainee puts on the wearable sensors such as eye tracking glasses for calibration. These wearable sensors will provide the instructor with all-round intrinsic perception of the trainee. Next, the trainee seats in the simulator and starts the operation task. During the operation, the trainee may query about information other than the one displayed on the monitor in the simulator. Likewise, the instructor could speak to the trainee when he/she encounters problems or makes inappropriate operation. Last, the trainee debriefs with the

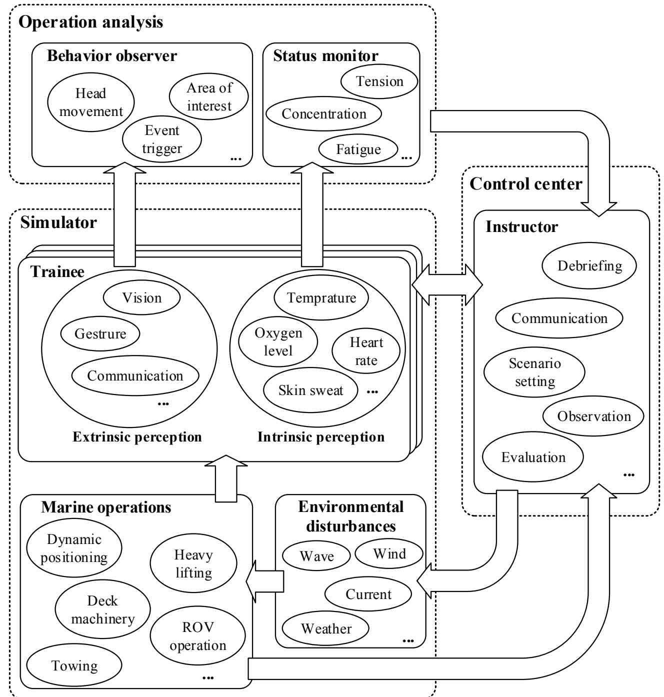

Fig. 1. The overall structure of the training program in marine operation simulator.

instructor about the operation task. The instructor evaluates and scores the operation.

Note beside normal interaction between the instructor and the trainee, Fig. 1 also depicts the process flow of environmental perturbation. This is useful to examine the response capacity of the trainee when sudden disturbance occurs. For example, for offshore crane operation, the instructor is able to change the wave height and thereby affect the ship motion. The trainee as the crane operator seating in the simulator will undergo the consequence of changing wave height and react to compensate the impact.

Situation awareness can be accessed by the instructor via the intrinsic and extrinsic perception of the trainee. During the operation, the instructor is able to take a holistic view of the trainee not only from the manifestation like the head movement but also based on the sensing information such as heart rate in a real-time fashion. Meanwhile, all the information can be gathered at the backend for analyzing the behavior of individuals or the teamwork with greater accuracy.

For visual focus integration, emphasis is placed on two aspects to make it comply with the proposed framework. The first demand is real-time video stream transmission of visual focus. This requires what the trainee sees during the operation together with his/her visual focus has to be displayed on the monitor in the control center. The other requirement is the data processing and visualization ability of the visual

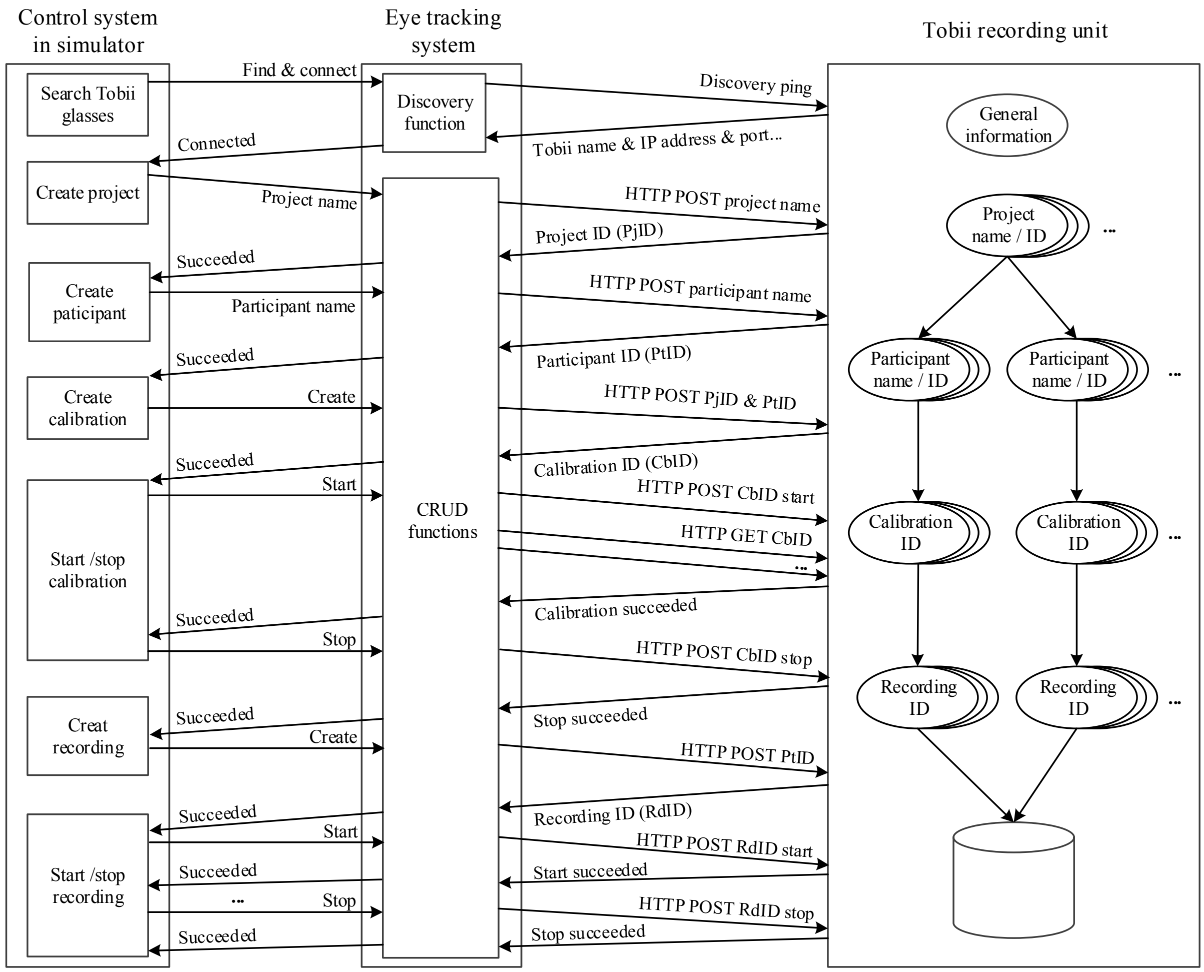

Fig. 2. The process flow for eye tracking system interaction using CRUD operation.

focus. In this way, visual focus could be considered one of the evaluation indexes and compatible to the sensor fusion algorithm for behavior analysis at late stage.

III. Integration of Eye Tracking System into OSC Marine Operation Simulator

Tobii pro glasses 2 is the eye tracking device used in the project [14]. This section presents how we integrate it into the OSC marine operation simulator from project creation, live view of visual focus to final data processing and analysis.

A. *Control of Tobii Recording Unit*

Tobii pro glasses 2 is mainly consisted of a glasses and a recording unit (RU). The glasses is equipped with two types of cameras: one wide-angle scene camera toward outward is used for capturing what the user sees; four cameras facing the eyes are responsible for eye movement tracking. Beside the cameras, two types of sensors such as gyroscope and accelerator are mounted on the glasses. The glasses is wire connected to the core of the eye tracking device — the RU that contains a battery and a memory card. It is in charge of gathering all sensor information and storing them into the memory card. In addition, it bridges the glasses to external devices. In other words, we can implement customized software using Tobii toolkit to access the glasses.

Tobii provides the developer with interfaces for managing the RU. There are four types of elements that can be organized hierarchically in the RU:

- **Project:** The top level of element denoting a specific eye tracking application;
- **Participant:** The second level of element representing a unique person;
- **Calibration:** The third level of element depicting calibration data for a given participant;
- **Recording:** The leaf element of the hierarchical structure describing recording segments for a given participant in the specific project.

In general, there are four types of operations, i. e., Create, Read, Update and Delete (CRUD) supported by the Tobii

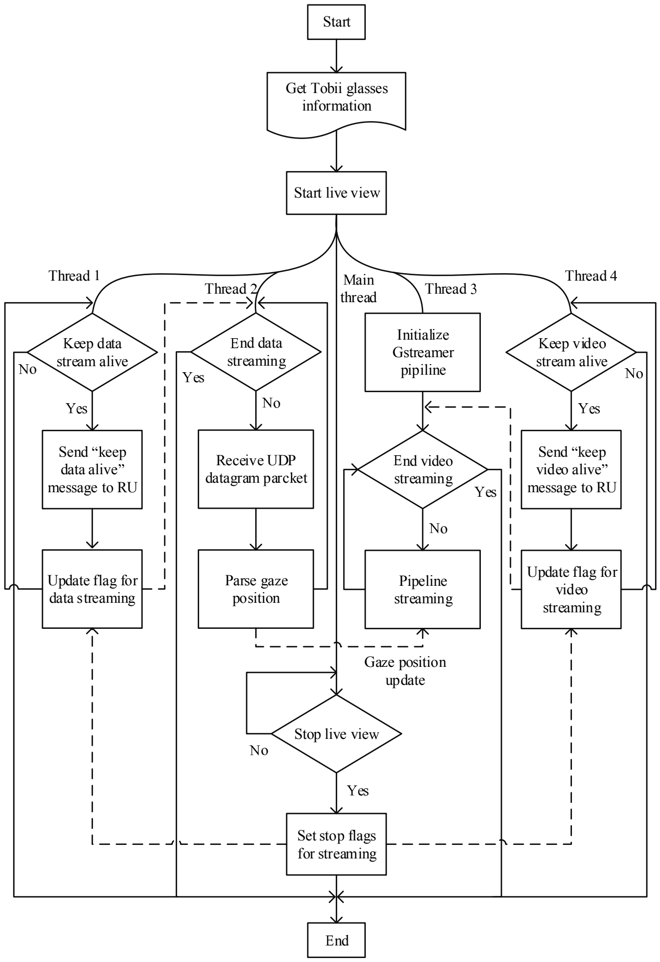

Fig. 3. Flow diagram of live stream transmission.

glasses. The developers are supposed to use HTTP methods such as HTTP POST and GET commands to communicate with the RU. The request and response contents are strictly defined and formed in JSON format. Fig. 2 shows a complete construction procedure regarding to a project starting from the control system in the OSC simulator. Note that the eye tracking system is the middleware that on the one hand directly communicates with the RU, whereas on the other hand, shields off the concrete interaction like coding/decoding to the control system in the simulator during the communication. It simplifies the software development in the control system of the simulator, making it feasible to treat the middleware as a plug-in module.

B. Real-time Video Stream Transmission

Despite real-time video stream transmission is available in the Tobii glasses controller software, there is no easy way to integrate it into the simulator. An intuitive solution is to use an extra laptop to run the controller software and indirectly transmit the desktop stream of the laptop via the

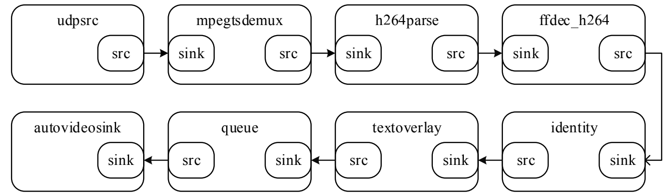

Fig. 4. Live video stream pipeline in GStreamer.

live streaming software like VLC to the control system in the simulator. However, this will increase the time delay of transmission and result in less smooth experience in the training program. Furthermore, the extensibility is not guaranteed once more information such as the data from the gyroscope is demanded in the live stream transmission.

Considering the above limitations, real-time video stream transmission is implemented by using Tobii pro glasses 2 SDK. The RU can transmit both a live video stream from the wide-angle scene camera and a live data stream for sensor data via UDP. Fig. 3 illustrates how to take advantages of multi-threading technology to manage both the data and the video streams. To request for live stream, it is necessary to obtain the information such as the IP address, the port and the message sending intervals from the RU in advance. Tobii defines a keep-alive message in JSON format to inform the RU to start, continue or stop a live stream. Thread 1 and 4 play such a role in sending keep-alive massage at a given interval. Thread 2 and 3 are responsible for receiving and processing data and video streams, respectively. In the data stream, gaze position is of great concern since it reveals the visual focus of the user. This information is parsed and shared to thread 3, so as to integrate with the live scene together. To receive and display the video stream, GStreamer, as a framework for creating streaming media applications by using pipelines concept, is utilized [18]. In thread 3, the pipeline is developed as shown in Fig. 4. Note the textoverlay element is synchronized with the gaze position to make a marker as the visual focus displayed above the live scene. Once the user stops live stream function, stop flags are sent out, terminating all the sub threads accordingly.

C. Visualization of Recording Results

So far, there is no analytics SDK for Tobii pro glasses 2. Therefore, we have to run Tobii analyzer software based on the recordings to generate the analysis results and visualize some of the results in the OSC control system.

The area of interests (AOIs) appear to be the most established term for eye tracking research [19]. In the Tobii analyzer, an operation scene image is imported first for visualization and statistics. AIOs are defined upon the image. The relevant statistical data such as AOI hit, the dwell time in each AOI and the transition between AOIs can then be added up over the recording time. After that, the statistical

Fig. 5. Experimental scenario of heavy lifting operation.

Fig. 6. Operation scene in the dome.

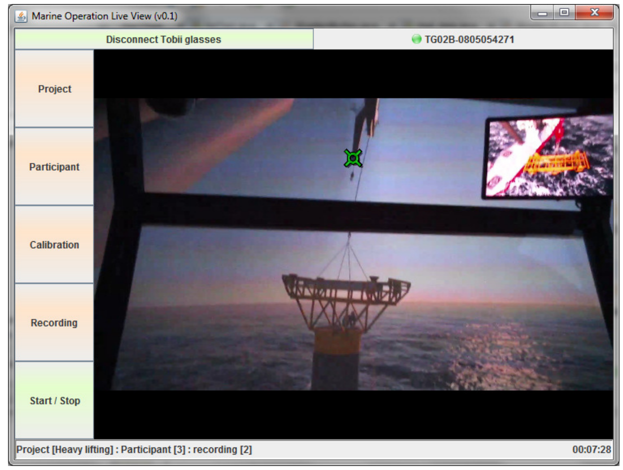

Fig. 7. The result of live stream transmission.

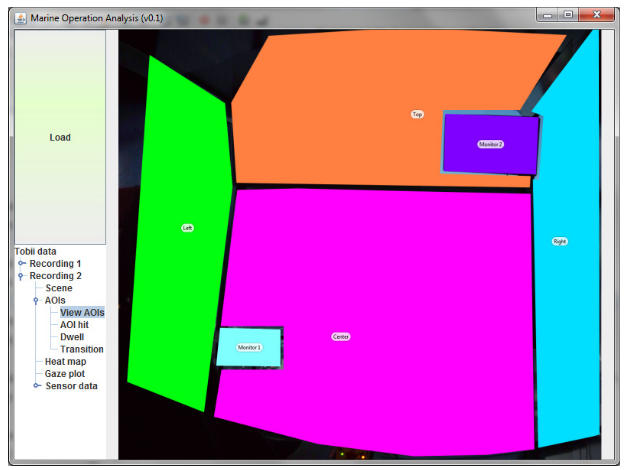

Fig. 8. Defined AOIs according to the screen segments.

data is visualized on the operation scene image in terms of heat map and gaze plot.

In addition, as the on-board sensor data from the gyroscope and the accelerator of the Tobii pro glasses 2 are stored per recording, it is also able to be visualized for brief understanding of the head movement. This information will be synchronized and combined in future with other channels of sensor data monitoring the trainee in Fig. 1 for sensor fusion, so as to quantify the situation awareness of the trainee. Since this part of work is now underway and the content is beyond the paper, we only present the results in the next section regarding to the eye tracking integration.

IV. Experiment

The goal of the experiment is to pilot-test visualizing of trainee's visual focus through the use of Tobii pro glasses 2 in the OSC marine operation simulator. The participant is a trainee of crane driver who is requested to operate a 250 tons knuckle boom crane to lift a suction anchor with a weight of 80 tons from the deck of an offshore construction vessel to the seabed at 100 meter water depth, as shown in Fig. 5. The scene in the operation dome is shown in Fig. 6.

The participant worn on the glasses and powered it on first. The instructor in the control center then connected the eye glasses and executed the CRUD operation from creating the project to the recording. As far as the participant entered the dome and started operating the heavy lifting of the anchor, the instructor enabled the real-time video transmission, as shown in Fig. 7. This function could be turned on and off depending on the instructor's observation needs.

The operation lasted about 10 minutes. The recording was imported to the Tobii analyzer to obtain the visual statistical data and the other sensor data. Following this the results were presented in a debriefing session in the control center. Fig. 8 shows the AOIs defined according to Fig. 6 for the heavy lifting operation and Fig. 9 is the corresponding AOI hit

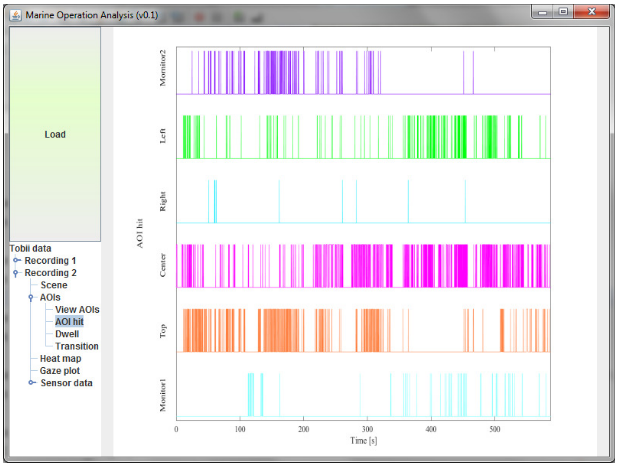

Fig. 9. AOI hit based on AOI definition.

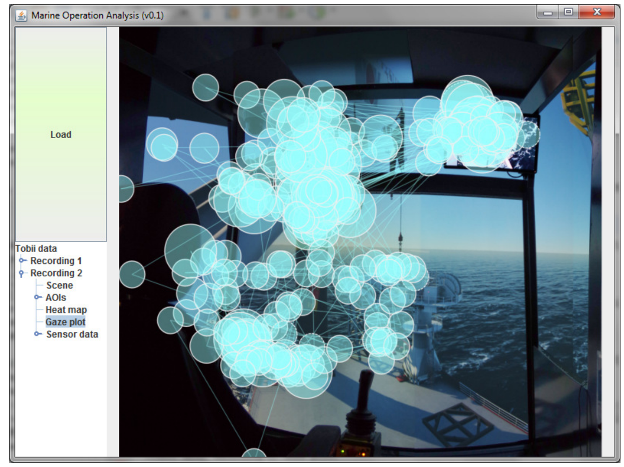

Fig. 10. Gaze plot result for the heavy lifting operation.

during the operation. It is noted that visual attention was mainly at center and top AOIs. The AOI hit in Monitor 1 appear predominantly in the first half period, during which the anchor was hooked, lifted up and positioned overboard. Heat map and gaze plot are also available in the integrated system. In Fig. 10, the gaze plot, as a scan path, describes how the eye physically moves through space. It can be seen that the result is consistent with the result in Fig. 9 to some extent.

Beside the statistical data, the sensor data from the gyroscope and the accelerator of the Tobii pro glasses 2 was tested. The plot can be checked per axis. Fig. 11 visualizes the gyro data about the x and the z axis. The positive x axis is from the right eye to the left eye and the z axis is towards the front. Therefore, the spikes in Fig. 11 can reflect the corresponding head rotation during the operation.

From the experimental results, we conclude the integration of the eye tracking system is successful and effective for visualization.

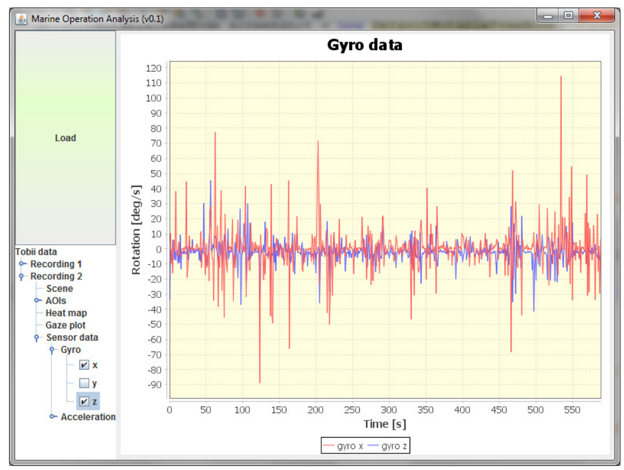

Fig. 11. Gyro data obtained from the experiment.

V. Conclusion

In this paper, we focus on integrating the eye tracking system into the marine operation simulator. As a sub-component of the framework for situation awareness evaluation, efforts are made on three parts for integration of Tobii pro glasses 2. First, four types of operation of the RU, i. e., the CRUP operations, are developed. Second, live video stream of visual focus is implemented. Third, visualization of recording results is realized. A case study of heavy lifting operation demonstrates the effectiveness of the integration of the eye tracking system.

For future work, attention will be paid on two aspects: (1) Combine multiple channels of information from other sensors such as heart rate sensor to improve the intrinsic perception of trainees. (2) Quantify trainees' situation awareness, in particular the degree of fatigue for long-term marine operation.

Acknowledgement

This research is supported by the project "Integrated marine operation simulator facilities for risk assessment including human factors" funded by MAROFF, Knowledge-building Project for Industry, Norway (project nr.: 234007/O70). The authors would like to thank Jo Even Tomren for contacting the participant and organizing the experiment.

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