SYSTEM AND METHOD FOR USER COMPETENCY ASSESSMENT IN MARINE NAVIGATION

Technical Field

The present disclosure generally relates to marine navigation competency. More particularly, the present disclosure describes various embodiments of a system and a method for assessing user competency in marine navigation.

Background

Human and cognitive factors are the main causes of accidents in marine navigation and many of them are caused by human error. People working in marine navigation, such as operators, seafarers, and navigators, should be trained so that accidents can be reduced and navigational safety can improve. Training standards have evolved to emphasize on human factors and soft skills. Soft skills can be defined as the cognitive, social, and interpersonal skills associated with technical skills that contribute to safe and efficient performance.

Situation awareness, stress management, decision making, teamwork, leadership, etc. are all examples of soft skills and are critical to navigational safety. For example, having situational awareness means people need to be aware of the surroundings and be able to recognise potential hazards. Many accidents such as grounding and collision happen due to poor situation awareness. Some studies have shown that good situational awareness helps people to make quick and good decisions, which can help to avoid accidents.

One of the most common cases of marine navigation accidents is the condition of the navigators, including fatigue and stress, which can lead to poor performance and unsafe situations. People working under extremely high stress tend to tire easily and commit more human errors.

The situation awareness and stress management capability of the people undergoing training are currently not assessed or are assessed manually by observation. Such manual assessment has limitations such as bias, distraction, or work overload of the trainers or assessors, and may not be able to properly assess user performance or competency in marine navigation.

Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to provide an improved system and method for user competency assessment in marine navigation.

Summary

According to an aspect of the present disclosure, there is a computerized method and a computer device for assessing user competency in marine navigation. The method comprises: receiving eye tracking data measured from a user, the eye tracking data comprising a video and eye gaze data of the user's perspective during marine navigation; locating a region of interest in each of a plurality of image frames of the video based on the eye gaze data; feeding the regions of interest to a machine learning model; determining, from the regions of interest and machine learning model, a set of marine navigation tasks that the user is performing; and generating assessment data comprising the video for an assessor to assess the user's competency in the marine navigation tasks.

A system and method for user competency assessment in marine navigation according to the present disclosure is thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

Figure 1 illustrates a flowchart of a method for assessing user competency in marine navigation using eye tracking data.

Figure 2 illustrates a process for determining marine navigation tasks and assessing the user competency.

Figures 3A to 3J show some exemplary marine navigation tasks.

Figure 4 illustrates a training process for training and validating a machine learning model.

Figures 5A to 5C illustrate sample image frames of a video for assessing the user competency.

Figures 6A and 6B illustrate some statistics of the marine navigation tasks.

Figure 7 illustrates a method for assessing the user competency using eye tracking data and brain electrical activity data.

Figures 8A to 8C illustrate some statistics of the user's mental conditions determined from the brain electrical activity data.

Detailed Description

For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to a system and method for user competency assessment in marine navigation, in accordance with the drawings. While aspects of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that

the present disclosure may be practiced without specific details, and/or with multiple details arising from combinations of aspects of particular embodiments. In a number of instances, well-known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present disclosure.

In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith.

References to “an embodiment / example”, “another embodiment / example”, “some embodiments / examples”, “some other embodiments / examples”, and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment.

As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise indicated. The term “set” is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single-element set, or a multiple-element set), in accordance with known mathematical definitions. The recitation of a particular

numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range. The terms “first”, “second”, etc. are used merely as labels or identifiers and are not intended to impose numerical requirements on their associated terms.

In representative or exemplary embodiments of the present disclosure, there is a computer-implemented or computerized method 100 for assessing user competency in marine navigation, as shown in Figure 1. Marine navigation can be defined as the process of directing the movements of watercraft or vessels, such as ships and boats, from one point to another. Marine navigation can involve the planning, managing, and directing of a vessel's voyage.

The method 100 can be performed on a computer device having a processor and various steps of the method 100 are performed in response to non-transitory instructions operative or executed by the processor. The non-transitory instructions are stored on a memory of the computer device and may be referred to as computer-readable storage media and/or non-transitory computer-readable media. Non-transitory computer-readable media include all computer-readable media, with the sole exception being a transitory propagating signal per se.

The method 100 includes a step 110 of receiving eye tracking data measured from a user, such as a navigator or a person undergoing marine navigation training. The eye tracking data is measured using an eye tracker worn on the user. For example, the eye tracker is a Tobii Pro Glasses 3. The eye tracking data includes a video and eye gaze data of the user’s perspective during marine navigation. More specifically, the video records what the user is seeing from his/her eyes and the eye gaze data measures the user’s gaze position, i.e. the specific position the user is gazing or focusing on, as the user performs the marine navigation. The eye tracking data may further include timestamp data for correlating the eye gaze data with respective image frames of the video.

The method 100 includes a step 120 of locating a region of interest in each of a plurality of image frames of the video based on the eye gaze data. For example, each image

frame is extracted from the video and the region of interest in the image frame is located by cropping or demarcating the region of interest to the area defined by the user's gaze. The method 100 includes a step 130 of feeding the regions of interest to a machine learning model or artificial intelligence model, such as a convolutional neural network model. The method 100 includes a step 140 of determining, from the regions of interest and machine learning model, a set of marine navigation tasks that the user is performing. The marine navigation tasks may include use of radar and use of echo sounder.

The method 100 includes a step 150 of generating assessment data comprising the video for an assessor to assess the user competency in the marine navigation tasks. More particularly, the assessor or trainer can make use of the assessment data to assess the user competency as part of a training protocol or an after-action review (AAR) process. For example, the trainer can assess the user's situational awareness skill from the assessment data.

In embodiments of the present disclosure, there is a system for assessing user competency in marine navigation. The system includes the eye tracker for measuring the eye tracking data from the user. The system includes a computer device configured for performing the computerized method 100. More specifically, the computer device is configured for receiving the eye tracking data from the eye tracker, locating the regions of interest in the image frames, feeding the regions of interest to the machine learning model, determining the marine navigation tasks that the user is performing, and generating the assessment data for assessing the user's competency in the marine navigation tasks.

Figure 2 shows a process 200 from measuring the eye tracking data to assessing the user's competency in the marine navigation tasks. In a step 202, the eye tracking data including the video and the eye gaze data is measured from the user using the eye tracker. In a step 204, the computer device receives the eye tracking data from the eye tracker and further processes it, including by the machine learning model. More specifically, the image frames are extracted from the video and the regions of interest are located from the image frames based on the eye gaze data. For example, the

image frames are cropped to the areas where the user is gazing or focusing on. In a step 206, the regions of interest are fed to the machine learning model and the machine learning model determines the marine navigation tasks based on the regions of interest.

The marine navigation tasks may include a number of basic marine navigation tasks. The marine navigation tasks may further include a number of complex marine navigation tasks, each complex marine navigation task comprising a plurality of the basic marine navigation tasks. In a step 208, each basic marine navigation task is mapped to a complex marine navigation task. For example, each region of interest is mapped to a basic marine navigation task, and a series of basic marine navigation tasks constitutes one complex marine navigation task. For example, a complex marine navigation task includes a first basic marine navigation task performed for a first predefined duration, followed by a second basic marine navigation task performed for a second predefined duration within a predefined interval.

An exemplary list of basic marine navigation tasks is shown in Figure 3A. An exemplary list complex marine navigation tasks and the corresponding combinations of basic marine navigation tasks is shown in Figure 3B. The complex marine navigation tasks may be selected based on pre-established guidance or manuals such as the Behaviour Competency Assessment and Verification (BCAV) for Vessel Operators and the IMO Model Course 1.30 for Onboard Ship Assessment (STCW). These complex marine navigation tasks, which are composed of various combinations of the basic marine navigation tasks, can serve as indicators of situation awareness.

Figure 3C shows the combination of basic marine navigation tasks, as well as the duration for each basic marine navigation task, for the complex marine navigation task of Monitor Own Ship and Other Ship Targets. Figure 3D shows the combination of basic marine navigation tasks, as well as the duration for each basic marine navigation task, for the complex marine navigation task of Assess Closest Point of Approach. Figure 3E shows the combination of basic marine navigation tasks, as well as the duration for each basic marine navigation task, for the complex marine navigation task of Collision Avoidance. Figure 3F shows the combination of basic marine navigation

tasks, as well as the duration for each basic marine navigation task, for the complex marine navigation task of Check Equipment Functioning. Figure 3G shows the combination of basic marine navigation tasks, as well as the duration for each basic marine navigation task, for the complex marine navigation task of Assess Safe Waters. Figure 3H shows the combination of basic marine navigation tasks, as well as the duration for each basic marine navigation task, for the complex marine navigation task of Join Traffic Separation Scheme. Figure 3I shows the combination of basic marine navigation tasks, as well as the duration for each basic marine navigation task, for the complex marine navigation task of Wheel Over Point.

In one example, if a combination of the basic tasks Visual Observation and Use Radar is determined, each of them lasts for 3 seconds, and the total duration of both basic tasks is 6 seconds, then this combination can be mapped to the complex task of Monitor Own Ship and Other Ship Targets. In another example, if each of the two basic tasks lasts for 5 seconds, and the total duration of both basic tasks is 10 seconds, then this combination can be mapped to the complex task of Assess Closest Point of Approach. If more than one of the duration conditions is met, then the total duration of all the basic tasks in the combination may take precedence. For example, if the total duration of both basic tasks is 20 seconds, then it is more likely that the complex task is Assess Closest Point of Approach.

Figure 3J shows an exemplary list of basic and/or complex marine navigation tasks determined by the machine learning model, together with the corresponding timestamp data. In a step 210, the assessment data is generated and a trainer can use the assessment data to assess the user's situational awareness skills based on the basic and/or complex marine navigation tasks.

In some embodiments, the machine learning model includes a convolutional neural network model. For example, the convolutional neural network model is a VGG16 model. As described above, image frames are extracted from the video in the eye tracking data, and regions of interest are located in the image frames. The video is captured using the eye tracker worn on the user as the user performs the marine navigation tasks. The video is able to capture the user's perspective from different

conditions, such as different angles and lighting environments. The entire video is labelled as the ground truth of the marine navigation tasks. In this way, each image frame of the video correspond to the ground truth and each image frame does not need to be manually labelled, thus reducing the computational time significantly. Traditional methods of data collection and labelling is very time consuming as each image frame in the data collected needs to be labelled. For example, labelling a 30 minute video captured at 60 frames per second will result in 108,000 image frames to label.

Moreover, the regions of interest in the image frames are located based on the eye gaze data. A region of interest can be detected and localized by cropping the image frame to the size that fits into the machine learning model for training and inferencing for classification. Computational time is significantly reduced as there is no need to perform computational intensive processes, such as regional proposal, object detection, object localization, and object classification, that may be used by other models, such as the you only look once (YOLO) and region-based convolutional neural network (R-CNN) models, which are more complex models that take more time for inferencing.

Figure 4 shows a training process 300 for training and validating the machine learning model 320. Eye tracking data is measured from various users and the eye tracking data is divided into training data 302 for training the machine learning model 320 and validation data 304 for validating the trained machine learning model 320. In a step 306, the training data 302 is processed by the computer device, such as to extract the respective videos, eye gaze data, and timestamp data.

In a step 308, the image frames are extracted from the videos in the training data 302 and the regions of interest are located from the image frames based on the eye gaze data. For example, five image frames are extracted from every 1-second duration of each video. The gaze positions are detected from the image frames based on the eye gaze data and the image frames are correlated with the timestamp data. Accordingly, the region of interest within the image frame can be localized to where the user is focusing on. The regions of interest are cropped from the image frames and labelled

with the corresponding marine navigation task that the user is performing. The labelled regions of interest 310 are fed to the machine learning model 320 for training the machine learning model 320.

In a step 312, the training data 302 is processed by the computer device, such as to extract the respective videos, eye gaze data, and timestamp data. In a step 314, the image frames are extracted from the videos in the validation data 304 and the regions of interest are located from the image frames based on the eye gaze data. For example, five image frames are extracted from every 1-second duration of each video. The gaze positions are detected from the image frames based on the eye gaze data and the image frames are correlated with the timestamp data. The regions of interest are cropped from the image frames but they are not labelled unlike for the training data 302. The unlabelled regions of interest are fed to the machine learning model 320 for validating the machine learning model 320 that has been trained using the training data 302. In a step 322, the machine learning model 320 determines the marine navigation tasks from the regions of interest in the validation data 304.

In some embodiments, the machine learning model 320 is a VGG16 model. The VGG16 model includes a feature extraction layer and a classification layer. The classification layer consists of two fully-connected layers – the first layer containing 4096 nodes and the second layer containing nodes that correspond to the number of basic marine navigational tasks. Determining the marine navigation tasks may include extracting a set of features from the regions of interest using the feature extraction layer, feeding the extracted features to the classification layer, and classifying the marine navigation tasks from the classification layer. Cross-entropy may be used as a loss function in the classification layer. An optimization algorithm such as stochastic gradient descent may be used in the classification layer to optimize the task classification results. For example, the stochastic gradient descent with a learning rate of 0.0005 is used and the VGG16 model converges within 20 epochs.

In some embodiments, the image frames are pre-processed before feeding to the machine learning model 320 to expedite the training process 300. The image pre-processing includes a set of image augmentation processes, such as colour jitter,

random rotation, Gaussian blur, and random perspective. The image augmentation processes improve the validation accuracy of the machine learning model 320 and provides a better generalization of the machine learning model 320.

Although the VGG16 model has been described as a non-limiting example of the machine learning model 320, it will be appreciated that the machine learning model 320 may be constructed using other statistical and/or machine learning algorithms.

As described in the step 150, after the machine learning model has determined, from the regions of interest, the marine navigation tasks that the user undergoing training is performing, assessment data including the video is generated for an assessor to assess the user's competency in the marine navigation tasks. Figures 5A to 5C show sample image frames of the video when the user is performing basic marine navigation tasks such as visual observation, using the radar, and using the Electronic Chart Display and Information System (ECDIS), respectively. The user's gaze position is marked in the image frames.

The video allows the trainer to review the marine navigation tasks performed by the user during a marine navigation exercise. The trainer can zoom in on human errors that may have been committed by the user, find out the causation of such human errors from the perspective of the user, since the video recorded is what the user was looking at during the marine navigation exercise. The trainer can debrief the user on the user's competency during an AAR process after the marine navigation exercise.

The assessment data may include a list of the complex marine navigation tasks determined by the machine learning model. The list of complex marine navigation tasks is presented to the trainer for him/her to review and debrief the user during the AAR process. The trainer may filter out selected or certain types of complex marine navigation tasks.

The assessment data may include statistics of the marine navigation tasks performed by the user. Figures 6A and 6B show the statistics of the basic and complex marine navigation tasks, respectively, in the form of visualization charts such as bar charts.

The horizontal axis represents the percentage of time spent on each marine navigation task over the whole marine navigation exercise, and the vertical axis identifies the marine navigation tasks. Having these statistics allows the trainer to have a full breakdown of the time spent on the marine navigation tasks so that the trainer can perform a more in-depth review to get a better understanding of the user's behaviour in the marine navigation exercise.

In some embodiments, the method 100 further includes receiving brain electrical activity data measured from the user. Correspondingly, the system includes a headset for measuring the brain electrical activity data from the user. For example, the headset is an electroencephalogram (EEG) headset and the brain electrical activity data includes EEG data.

The method 100 further includes determining, from the brain electrical activity data, mental conditions or states of the user while performing the marine navigation tasks. The mental conditions may include a workload level and a stress level experienced by the user.

Figure 7 shows a computerized method 400 for assessing the user competency using the eye tracking data and the brain electrical activity data. Eye tracking data 402 is measured from the user. In a step 404, the eye tracking data 402 is processed by the computer device, such as to extract the video, eye gaze data, and timestamp data. In a step 406, the image frames are extracted from the video in the eye tracking data 402 and the regions of interest are located from the image frames based on the eye gaze data. In a step 408, the machine learning model 420 determines the marine navigation tasks from the regions of interest.

The brain electrical activity data is measured concurrently with the eye tracking data while the user is performing the marine navigation tasks. In a step 410, the mental conditions of the user are determined from the brain electrical activity data. In a step 412, assessment data is generated for visualization and interpretation by the user during the user competency assessment. The assessment data includes the video from the eye tracking data, as well as statistics of the marine navigation tasks and the

statistics of the user's mental conditions. In a step 414, a performance report of the user competency assessment may be generated. For example, the performance report includes all visualization charts and descriptions of observations based on the visualization charts.

The statistics of the user's mental conditions may be shown in visualization charts such as bar charts. The visualization charts plots the workload and stress levels experienced by the user during the marine navigation exercise, wherein the percentage of time experienced for different levels of workload and stress over the marine navigation exercise is shown.

Figures 8A and 8B show bar charts illustrating the distribution of different workload and stress levels, respectively, experienced by the user. The horizontal axis represents the range of workload levels (level 0 to level 3) and the range of stress levels (level 0 to 7). The vertical axis represents the percentage of time for a certain workload level and stress level over the marine navigation exercise.

Figure 8C shows a chart showing the continuous change of workload levels the duration of the marine navigation exercise. This continuous change is shown with a temporal resolution of 1 second. From this chart, the trainer can see changes of the user's mental conditions over time. Demanding events that happened during the marine navigation exercise such as engine failure, close quarter situation, and bridge equipment failure can be labelled in the chart (shown as the vertical boxes), such as by referencing to the eye tracking data, to enable the trainer to have a clearer picture of the user's reaction towards such demanding events.

The performance report summarizes the visualization charts for the recognized marine navigation tasks and mental conditions, together with descriptions of the performance of the user. The performance report can be used by the trainer to debrief the user for a comprehensive assessment, particularly in terms of situational awareness skills and workload and stress management.

The system and method 100 provide an automated means to more objectively assess the user competency in marine navigation, such as for debriefing and reviewing of the user's behaviour during marine navigation simulations or exercises. Multiple data inputs are used in the assessment. An eye tracker measures eye tracking data which is used to determine the marine navigation tasks being performed by the user as these are indicators of situation awareness skill. The eye tracker provides an activity review of what the user is looking at during the exercise, which can be used to find out the causation of human errors. A headset measures brain electrical activity data which is used to determine the mental conditions of the user as these reflect the user's workload and stress management skills.

The performance report is more objective and can serve as a supplementary assessment tool in an after-action review protocol. The trainer or assessor can get a deeper understanding of the user competency and to debrief the user if there are any human errors. Users such as navigators and seafarers can benefit from the improved assessment and training and enhance their navigational competence and skills. The system and method 100 can be utilized in commercial marine navigation simulators, maritime training centres, and even on board vessels.

In the foregoing detailed description, embodiments of the present disclosure in relation to a system and method for user competency assessment in marine navigation are described with reference to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments described herein.

Claims

1. A computerized method for assessing user competency in marine navigation, the method comprising:

receiving eye tracking data measured from a user, the eye tracking data comprising a video and eye gaze data of the user's perspective during marine navigation;

locating a region of interest in each of a plurality of image frames of the video based on the eye gaze data;

feeding the regions of interest to a machine learning model;

determining, from the regions of interest and machine learning model, a set of marine navigation tasks that the user is performing; and

generating assessment data comprising the video for an assessor to assess the user's competency in the marine navigation tasks.

2. The method according to claim 1, further comprising extracting each image frame from the video for locating the region of interest in each image frame.

3. The method according to claim 1 or 2, wherein locating the region of interest in each image frame comprises cropping or demarcating the region of interest to an area defined by the user's gaze.

4. The method according to any one of claims 1 to 3, wherein the machine learning model comprises a convolutional neural network model.

5. The method according to claim 4, wherein the convolutional neural network model is a VGG16 model.

6. The method according to any one of claims 1 to 5, wherein determining the marine navigation tasks comprises:

extracting a set of features from the regions of interest using a feature extraction layer of the machine learning model;

feeding the extracted features to a classification layer of the machine learning model;

classifying the marine navigation tasks from the classification layer.

7. The method according to claim 6, wherein determining the marine navigation tasks further comprises using cross-entropy as a loss function in the classification layer.

8. The method according to claim 6 or 7, wherein determining the marine navigation tasks further comprises using an optimization algorithm in the classification layer.

9. The method according to claim 8, wherein the optimization algorithm comprises stochastic gradient descent.

10. The method according to any one of claims 1 to 9, further comprising pre-processing the image frames before feeding to the machine learning model.

11. The method according to claim 10, wherein the image pre-processing comprises a set of image augmentation processes.

12. The method according to any one of claims 1 to 11, wherein the marine navigation tasks comprise a number of basic marine navigation tasks.

13. The method according to claim 12, wherein the marine navigation tasks comprise a number of complex marine navigation tasks, each complex marine navigation task comprising a plurality of the basic marine navigation tasks.

14. The method according to any one of claims 1 to 13, wherein the assessment data further comprises statistics of the marine navigation tasks.

15. The method according to any one of claims 1 to 14, further comprising receiving brain electrical activity data measured from the user.

16. The method according to claim 15, wherein the brain electrical activity data comprises electroencephalogram data.

17. The method according to claim 15 or 16, further comprising determining, from the brain electrical activity, mental conditions of the user while performing the marine navigation tasks.

18. The method according to claim 17, wherein the user's mental conditions comprise a workload level and a stress level experienced by the user.

19. The method according to claim 17 or 18, wherein the assessment data further comprises statistics of the user's mental conditions.

20. A system for assessing user competency in marine navigation, the system comprising a computer device having a processor configured for performing the computerized method according to any one of claims 1 to 19.

21. The system according to claim 20, further comprising an eye tracker for measuring eye tracking data from the user.

22. The system according to claim 20 or 21, further comprising a headset for measuring brain electrical activity data from the user.

23. A non-transitory computer-readable storage medium storing computer-readable instructions that, when executed, cause a processor to perform the computerized method for assessing user competency in marine navigation according to any one of claims 1 to 19.