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RESEARCH ARTICLE

A NEW APPROACH TOWARDS EVALUATING THE PERFORMANCE OF MARITIME OFFICERS BY THE UTILIZATION OF MOBILE EYE TRACKING SYSTEM AND FACIAL ELECTROMYOGRAPHY

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ABSTRACT

The following paper presents the use of simulators in maritime training development, with an emphasis on ship bridge operations during the training and assessment phase using Mobile Eye Tracking System (METS) and Facial EMG (fEMG). In the maritime field research on human factors, the goal is to implement metrics of eye motions and facial muscle interaction, to explain the basic methodology, and defining several data analysis types. Using both devices is considered an essential facility to understand trainees' competence, sensitivity to uncertain disturbances, and proficiency for the evaluation of Situational Awareness (SA) and stress measurements. The process flow in real-time is implemented by the usage of both devices Tobii pro glasses 2 and (fEMG Shimmer device) connected with iMotions platform for data analysis. It is recommended that a case study be carried out of the fire onboard scenario that verifies the incorporation of both devices as useful tools for simulator training.

INTRODUCTION

Worldwide, numerous operations at marine bridges are challenging. The human factors are at the same time a primary source of errors, which are the essential part of the mechanism of operation and decision making. It has been noted that the lead of maritime incidents, especially fire onboard ships, is spotted in the interface between officers, technology, and organization, where human factors contribute nearly to 60%. Complex systems operated by crews with no formal training, confusing roles, and obligations, as well as protocols, and the increasing number of checklists are common areas of concern. The human factor must therefore be analyzed to ensure safety and productivity during bridge navigational watch. Currently, maritime simulators, either for commercial use or for research, seldom require visual focus, while visual focus represents the actions of the operator in addition to the facial electromyographic measurements of muscle activity. The use of visual attention and stress identification for behavioral monitoring and analysis is possible with the development of professional METS and fEMG such as the Tobii pro glasses eye-tracking glasses and Shimmer3 EMG. Also, efforts have been made in multidisciplinary approaches, centered on the eye-tracking system and other biometric tools[1]. Thus, to that extent, a new integrated visual emphasis and facial muscles activity architecture must be implemented to execute challenging bridge operations for evaluation purposes in maritime simulator training complexes. The proposed project aims to use advanced maritime simulation systems as a motive for improving human and environmental safety. The key aspect of this project is to measure situational awareness, stress detection, possible solutions towards their management and to recommend a new evaluation framework to be implemented in training for maritime simulators and determine levels of ship simulator competence under the IMO's STCW convention[2]. Grech et al. [3]argued that significant advances have taken place recently in the scope of the maritime human element. In recent years, working groups for maritime human elements have been set up to analyze and consult on their research studies in Europe and the United States. A variety of programs on Human Factors offer useful experience and knowledge into the field of the human element to increase understanding of human aspects in the maritime sector. The dynamic complexity of the maritime industry has contributed to steps that are now being taken on the international level to promote the safety of maritime activities. The role of international and domestic controlled organizations, especially IMO, International Labor Organization (ILO), and the most powerful classification societies, further raise this uncertainty. The IMO is a permanent international organization intended to improve maritime safety which begins with the introduction of the latest edition of the SOLAS convention, the most relevant of all maritime safety treaties. The IMO consists of governmental organizations and agencies with an interest in shipping globally in which the operation and safety of the ship under the IMO is normally controlled. The Maritime Pollution Convention (MARPOL) also empowers these organizations to control the environmental aspects of shipping. Thus, all IMO conventions deal in the first place on how to enhance the human element which will lead eventually to implement the safety practices onboard ships. The ergonomic evaluation of

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the characteristics of the human element and the construction and configuration of ship bridge equipment was considerably carried out within the maritime training simulators in the maritime training industry around the world. Also, very few interactive systems on ships' bridges focus on the dimensions of cognitive workload and stress management implementation. These studies tend to track usage impacts on safety and mental workload but provide little advice on the procedures of assessment and the production of corresponding equipment and devices concerning usability. The usability term based on ISO 9241 is defined as the degree to which specific users may use a product to achieve particular objectives in the given context of application with effectiveness, efficiency, and satisfaction [4].

LITERATURE REVIEW

General Background: One of the most important measures in enhancing maritime safety and environmental protection is the study of marine disasters analysis. One of the biggest problems in the maritime sector is maritime incidents. This refers primarily to significant threats to personnel lives, infrastructure, and maritime ecology. The IMO introduced many protocols, in combination with major measures to uphold high levels of protection at sea, in order to encourage maritime casualties to be reduced. In addition, in the past few decades, the agencies in compliance with regulatory standards have tried to mitigate and avoid maritime incidents. Since maritime researchers are becoming aware of the risks, maritime incident analysis is a widely discussed subject in academia because of the frequent manner of human errors [5]. Bruzzone et al. [6] mentioned that the production of hazard and environmental impact evaluation methodologies and strategies in this field is very essential because of the changing complexity of maritime events, which are needed to be able to quantify the consequences of enhancements, on coordinated interventions and data collection. The maritime simulation setting involves various types of emergency scenarios, such as on-board fire, hazardous material spills, steering failure, and other related emergencies which are specifically related to OOW and deck operations. The purpose of this article is to establish a framework for the effective strategies for dealing particularly with an inboard fire scenario that can be dynamically connected with various models of simulation, to assist maritime specialists around the world in developing a highly efficient scheme for training evaluation. In the 15th century, maritime education and training expanded considerably to educate maritime apprentices in navigational skills. In the 15^{th} century, maritime education and training expanded considerably in order to educate maritime apprentices in navigational skills.

The need for modern onboard ship tasks management and navigation skills has grown as global discovery by European seamen has increased dramatically. The instruction and training of navigational exercises were under the control of very few training facilities established as a result of commercial activity during the sixteenth to early twentieth centuries. Nowadays maritime educational and simulation training is a regional educational operation covering much of the world's ships and related infrastructures with approximately 300 maritime training complexes. A review of the IMO's function over the past five decades reveals the organization's impact on the worldwide maritime sector and the education and training development initiatives that have taken place, representing a period of immense transition and technical development. Over several decades the use of maritime simulators has been promoted, the first radar simulator begins in 1959 and subsequently adds other types of navigation simulators in 1965, 1967, 1976, and 1992. However, radar and ARPA simulator training became compulsory in 1997 just after the introduction of the STCW 95 convention. The system is permitted and promoted in many fields. The study searched for trends of connectivity both nationally and regionally with more than a thousand marine simulators installed in several maritime simulator training complexes globally [7]. In the maritime simulator training context, the eye detection technique is used to distinguish between experienced and beginners' apprentices, showing successful teaching methods and human eye activity that could be difficult to speak, to detect from others. In addition, visual data can be used to instruct the user on scanning methods, teaching, and testing methods to enhance instruction by demonstrating appropriate action in eye movements. A series of inferential methods for the estimation of eye locations have been developed since the early 1900s. Such instruments have been critical for the assessment and further examination of the neurological visual system. Several behavioral and human factors experiment using this eye-tracking technology and techniques have been conducted to determine eye orientation. In the determination of the field of view criteria for simulator systems or in the regulation of high-resolution area of interest display devices, the data obtained from such devices are combined. The recommended portable device to be used assists in situational awareness assessment [8].

Two types of eye movement control methods may usually be distinguished: those tests the location of the eye in relation to the head; and those measuring the direction of the eye in the area of interest. In the analysis of the human element, the relation between eye motion and the visual environment is very important to consider, so that we can calculate when and how long the apprentice focuses on the interest area and the number of revisits. This is generally used in the research of usability, human-computer interaction, ergonomic assessment, and in many other areas in which apprentices collecting data from different areas in visual activity. Current portable eye-trackers are head-mounted devices with two eye motion cameras and an additional camera recording the visual image. The most innovative options include a compact eye-tracker that can be worn with convenience without restricting head movements [9]. It is used commonly in experiments that do not have a static apprentice. In experiments on a maritime bridge simulator, it has already proven effective and valuable. Its key benefit is that data processing can be saved time if linked to iMotions software to conduct comprehensive analysis using various features, such as heat map analysis and area of interest metrics in which data can then be transferred into other applications such as SPSS and Microsoft Excel. Wetzel et al. [8] mentioned that the data gathered, are registered and forwarded to iMotions for a thorough analysis to define the conditions of situational awareness and thereby improve the efficacy of the task by supplying the instructor with feedback.

On the other hand, in 1872, Darwin researched individual capacity to display feelings through their faces and has since conducted considerable work into the perception of mental workload, emotions, fatigue, and tiredness. The recognition of the emotion of an individual is an important skill that promotes connections between people. Various hypotheses have been constructed, from the perspective that many different emotional expressions can be used to differentiate a restricted number of unique categories of facial emotions. Electromyography can assess the facial language of emotions. EMG monitors muscle activation utilizing skin surface sensors. In response to various emotions, specific muscle movements may be detected. In fact, during signs of joy or more general happiness the Zygomaticus major muscle is reliable (Figure 1).

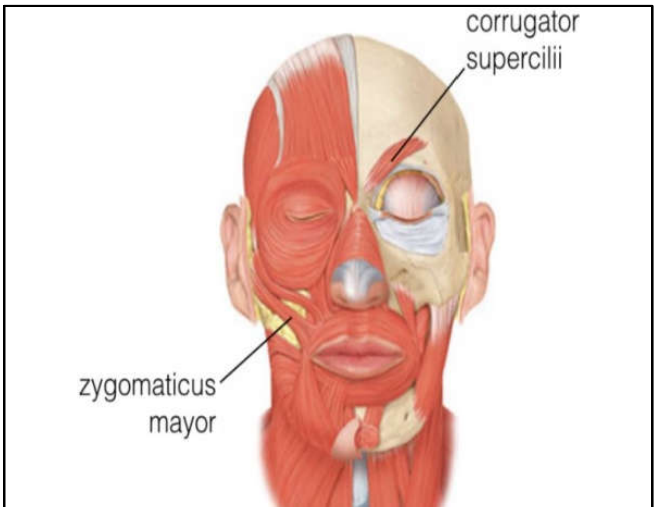

Figure 1. Zygomaticus major and the Corrugator Supercilii muscles

The Supercilii Muscle Currogator, the muscle that pushes the eyebrow down, and thereby causes frowning which is associated with angry facial expressions to unpleasant non-facial stimulation and perceptual functions with elevated pressure. Both muscles might be used to differentiate between positive and negative feelings, with corrugator behaviors specifically connected to the negatively valent feelings. Therefore, numerous studies and methods were commonly used for the assessment of the operation of these muscles to focus on facial expressions of emotion, in which different researchers investigated individual muscle variations based on gender, sensitivity, and stress among individuals [10].

Related Work

This section reflects several pieces of research related to the use of multi-biometric sensors to evaluate the efficiency of maritime simulator training trainees from a variety of peer-reviewed journals. In 2003, Koester & Sorensen[11] addressed in their article that a wide range of assessment methods range from observational and survey-based subjective elements to objective elements based on psychophysiological techniques. Psychophysiological measures are utilized specifically to measure the workload, visual alertness, anxiety, and stress. The methods are widely known that can be used for evaluation purposes. The most important techniques are Galvanic Skin Response (GSR), Electrocardiography (ECG), Heart Rate Variability (HRV), Electroencephalography (EEG), and Eye activities. Then in July 2008, Murai et al. [12] identified the skills evaluation in ship handling, including the workload, tension, heart rates, and nasal temperatures as well as the activity of salivary amylase, to be assessed on the OOW and the apprentices. They used thermography to classify cognitive workload by gathering facial and nasal temperatures. The Heart Rate Monitor is used to measure heart rate variability. The COCORO METER was utilized to measure the operation of salivary amylase to identify the tension and stress. Furthermore, in June 2016, Sanfilippo[13] argued in his article that the use of a multi-sensor framework to increase situational awareness for offshore training is essential. He used video cameras, microphones, biometric sensors (eye monitoring systems and ECG), and the maritime simulator for offshore training as stimuli. There are many other related works to show the multisensory usage in the maritime domain specifically and other related training domains in other fields in general. However, it is difficult to mention and list the most prominent here.

METHODOLOGY

Introduction: This analysis aimed to look for journal articles on simulator usage for maritime training development, with a particular emphasis on the use of the mobile eye-tracking system METS and fEMG during training and evaluation phases. As seen in Figure 2, the PRISMA flow diagram for both instruments was addressed. These systems can be integrated to improve scenarios with new approaches to assess the performance of maritime officers using both METS and fEMG.

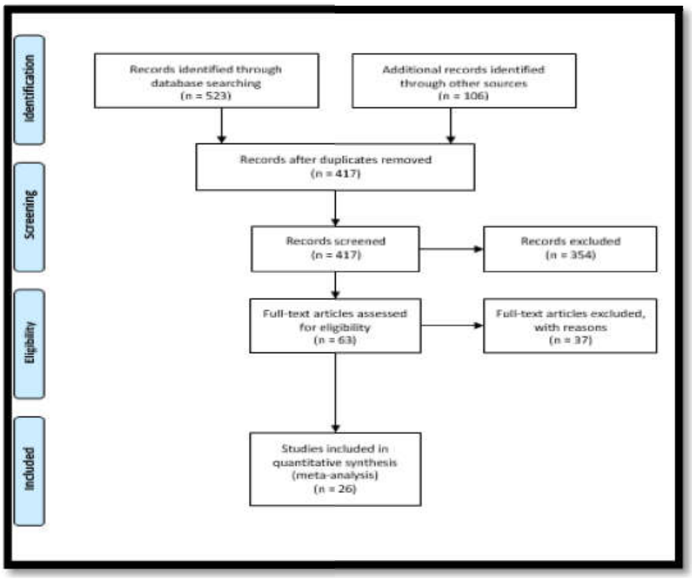

Figure 2. PRISMA flow diagram for a new approach towards evaluating the performance of maritime officers

Mobile Eye Tracing System: Tobii Pro Glasses 2 reveals exactly what a person looks at in real-time as walking across the real-world environment, offering researchers insightful insights into human actions. Data at 50 or 100Hz can be recorded. Absolute control and 3D-eye simulation technologies incorporate the most realistic visual activity and data accuracy in researchers' minds. Fast configuration and machine-guided procedures minimize field time. It consists primarily of glasses and a recording unit. There are two cameras on the glass: a wide-angle camera for catching what the individual sees; four eye face cameras for monitoring eye movements. In addition to the cameras, two sensors are mounted on the frames, including a gyroscope and accelerator. The glasses are wired to the center of the eye-tracking system, the battery storage unit, and the memory card. It is responsible for gathering and processing all sensor data in the memory card (Figure 3). Furthermore, glasses are connected to external devices. The eye-tracking device interacts directly with the processing unit, prevents the direct interaction with the control mechanism, such as the coding/decoding, during communication. The eye-tracking device facilitates the advancement of applications in the simulator control unit [1, 14].

Figure 3. Tobii Pro 2 Glasses

Facial Electromyography: Over the past couple of years, several experiments concentrated on the identification of eye-blinks and widely used techniques, which use three small electrodes to connect readings of the Electromyography (EMG) across e-learning environments [15]. Human elements in maritime training programs are increasingly needed. Fatigue, described by IMO as a decrease in physical, psychological, and mental capability, has received much recognition in recent years as one of the most surveyed indicators. The working state of personnel on board merchant ships is a big challenge due to the heavy workload and stringent guidelines are given to the tasks to be done. Tiredness may lead to grave accidents. In 82% of serious accidents in the northwest of European and UK waters, Exhaustion is considered a major factor. Effective approaches to track and measure fatigue during maritime activities are required to prevent future human-factor incidents. Muscle fatigue assessment through (EMG) had been studied. Multiple experiments have demonstrated that fatigue is caused by diverse physiological processes [16]. To deal with various shipboard operations and the unanticipated occurrences of a range of emergencies that may arise and through which an aspect within the dynamic structure of the merchant maritime systems is to be used, creative approaches are needed via the crew assessments via bio-metric sensors through training phases. This way, the problem can be explored as well as new resources and technology can be found in terms of solutions. Maritime simulators are supposed to be planned and constructed to implement particular research practices aimed at minimizing the incidence of injuries caused in substantial part by fatigue[17]. Boccignone et al. [18] have listed essential electromyographic details in which electrical potentials from the musculoskeletal system are measured. Facial EMG (fEMG) is based on the disparity between electric potential electrode sets that have traditionally been positioned near together on the face of the target muscle as previously seen in (Figure 1) in a way to show the most important facial muscles for studies and researches. The key benefit of fEMG is the ability to detect very low effective expressions and time resolution which enables unexpected change in expression to be detected. For emotional comprehension in a broader context, the concept of virtual fEMG derived from examining normal, non-posed face-expression can be essential. Many behavioral data researches have been documented in the last decade using various methodologies and techniques, thus providing adequate training. Thus, the fEMG contain (Shimmer 3 EMG) device. It has 2 channel EMG. It is equipped with EEPROM memory of 2048 bytes and connected wirelessly via Bluetooth with an amplifier and then send all data to iMotions platform (Figure 4).

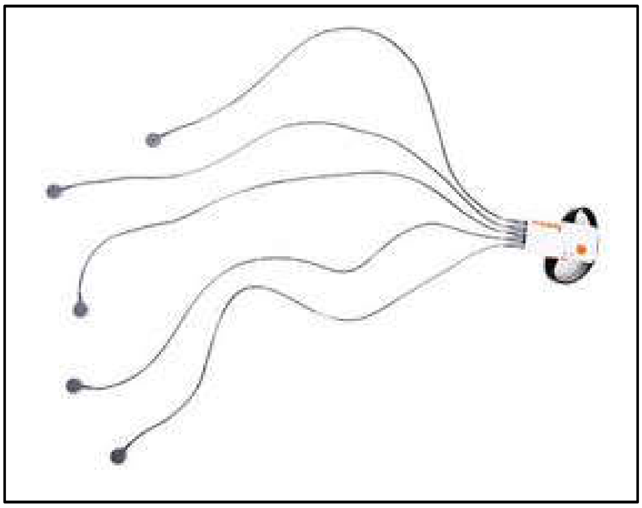

Figure 4. Shimmer3 EMG

iMotions Platform: Across several types of settings, various sensor systems are available to measure specific aspects of human responses to stimuli and the iMotions application contains them all. iMotions combines several biometric sensors with different perspectives smoothly; for example, Eye Tracking, EDA / GSR, EEG, ECG, and facial expression analysis. iMotions is a high-tech program designed to perform extremely relevant human behavior studies with high validity. The integration of multiple sensors and data sources helps researchers to perceive human activity more simply by analyzing unconscious responses in real-time. Various data sources combine to improve the precision of research. The inclusion of surveys as a research method can make the experiment more valid. For external sensor integration, API and Lab Streaming Layer are embedded (Figure 5). It allows the user to export raw data, results, and metrics to process in Excel, SPSS, MatLab. Analyze a set of data automatically with a fully straightforward R scripting. Block structures are simple to implement, and the collection of data is entirely synchronized. The software facilitates enhancement displays of pictures, videos, real-world environments, VR environments, and simulations[19].

Improving trainee's intention and data interpretation: Several studies supported the use of biometric sensors within interdisciplinary fields for simulator training to improve trainee's intention and data interpretation. For instance, Graham et al. [20]reviewed the use of an eye-tracking system to improve consumers' ability to locate and effectively utilize nutrition information on food nutrition labels. The authors reported that using eye-tracking systems in nutrition labels could reduce the visual clutter surrounding nutrition labels and increase the visual salience of nutrition labels by using different contrasts and orientations. In addition, to improve the interpretation of data obtained through the eye-tracking system, the authors suggested that participants in eye-tracking experiments should be interviewed after an eye-tracking task to ask them about their behavior by showing them a recording of their eye-tracking movements. This idea could be achieved within maritime simulator training to perform emergencies and search and rescue activities due to the fact that eye-tracking devices have the capability to detect the exact point where an individual is looking and accurately tracks the location and the duration of individuals' visual attention using high-resolution with high-speed cameras that record as high as 1000 times per second[21].

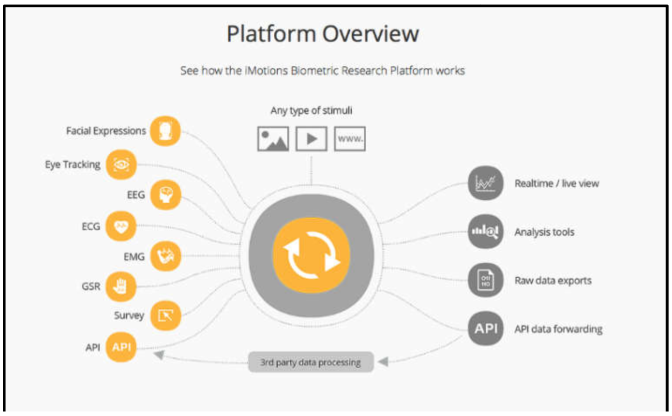

Figure 5. iMotions platform

Mehdi and his colleagues investigated the use of simulators to reduce maritime accidents, particularly in offshore renewable energy installations by investigating the navigational behavior around an offshore wind farm (OWF) and identify the relevant data to be measured[22]. The study comprises seven groups of participants who sailed near OWF. The authors investigated the use of risk assessment models to improve communication between stakeholders before, during, and after navigational risk assessments (NRAs). The authors stated that simulators can be used to gather data that can be used to improve and augment the input values for parameters used in different methods and models. Also, the authors created an artificial traffic scenario based on realistic data obtained from an automatic identification system (AIS). Participants easily interpreted these data and were able to visualize vessel tracks and ship traffic distribution which enables them to identify the types of ships and the number of ship movements in a given area. The study indicated that simulators were feasible in studying complex human behavior such as human-machine interaction to avoid navigational risks.

Furthermore, Soon et al. [23] reviewed current Artificial Intelligence (AI) image processing algorithms to enhance object detection performance of rescue missions in maritime search. The authors also explored central and peripheral vision (HVS) and their association with Field of View (FOV) in the human visual system arena. Users in this study were exposed to different maritime scenes and viewing sample images with different visual features to create an AI algorithm for object detection. Participants were asked to detect objects while standing and wearing head on a mounted display (HMD). The authors reported that FOV with 85 degrees requires the least amount of mental effort including frustration, physical and temporal demand. Thus, the authors were able to identify the optimal image setting that effectively assisted the users to interpret the content of these images with the least physical and mental effort.

Contributions

There is limited research on the use of eye-tracking systems to evaluate the performance of maritime officers. In fact, it was argued that current maritime operation systems lack integrations and understanding of other systems such as human involvement; emphasizing that a strong connection between humans and technology exists, and such a relationship should be taken into consideration in future research[24]. Nonetheless, Zheng[25] examined the influence of eye trackers on maritime training experience. The author designed a new training method for manual maneuvering operation with eye trackers to help trainees perform two tasks namely, helping trainers' intervention and providing eye-tracking videos for debriefing activity. The study reported that the use of an eye-tracking system improved the quality of the training experience for both the apprentices and instructors. Also, other studies investigated the use of eye-tracking systems in maritime research [26]. Also, previous studies focused on the use of eye-tracking technology with either Electroencephalography (EEG) [11] or Electrocardiography (ECG) [13]. Thus, the combination of eye-tracking technology with fEMG has not been used before to assess the performance of maritime training programs especially using it in performing onboard emergency situations. This represents a gap in the literature as the use of both mobile eye-tracking systems and fEMG increases the proficiency for evaluating situational awareness, identifying stress, and produce less noise compared with other combinations such as EEG and ECG. This article, therefore, contributes to the body of knowledge by investigating the application of a mobile eye-tracking system with fEMG to assess maritime training programs. Using both techniques together would enable researchers to explore new features such as detecting and interpreting different human emotions facial muscle activation and movements to better understand the responses of humans to various circumstances.

Conclusions

This paper proposes a modern methodology based on simulation training evaluation and its related analysis of the common emergencies on shipboards especially fire onboard, that caused miserably misfortunes and deaths among mariners. This article focuses on the development of the evaluation methodologies to this research by implementing all possible means with new technologies particularly the usage of recent biometric sensors and robust platforms that can be integrated to ease the assessment procedure and to find sturdy training analysis in real-time. Emphasizing the role of integrating the usage of mobile eye-tracking glasses and the fEMG as this combination is seldom mentioned and utilized in the literature per se. The combination of both mentioned sensors will open a wide gate for the researchers and instructors who are interested to perform new approaches of evaluation for maritime apprentices as the literature mentioned the usage of other combinations such as the eye-tracking system with EEG and ECG. The obvious point is that EEG and ECG have much noise created via the movement of the apprentice that sometimes goes away from control compared to the EMG especially the fEMg which has considerably low noises and these noises could be eliminated by applying some noise filters to reveal gathered signals clearly. One of the essential aims of this paper is to redirect the focus of the subject matter experts SMEs that there are other vital solutions to evaluate the merchant maritime apprentices through conducting simulator training with emphasizing the importance of train them on different emergency scenarios onboard ships for example but not limited to (Grounding, Stranding, Fire, Collision, Flooding, Excessive list, Equipment failure, Loss of cargo and Security threats). Integrating simulator training with the psychophysiological sensors opens new research and development barriers such that mistakes of the human element could be mitigated which most of the time leads to painful catastrophes. After 2015, in most maritime activities, the IMO and its related organizations have proposed a human element design and development strategy. However, a gap in research is identified where the maritime training on simulators and the focus on these new sensors and technologies related to it are indeed needed specifically the usage of fEMG in conjunction with other sensors. The following graph represents the conclusion of the current article (Figure 6)

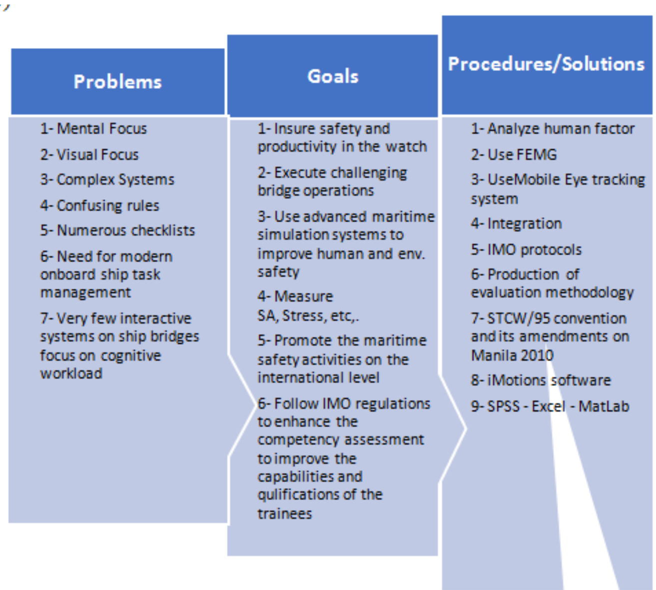

Figure 6. Article's Flow Chart Conclusions

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