Application of Wearable Device for Real Time Monitoring System of Shipyard's Fabrication Workers

Triwilaswandio Wuruk Pribadi[1,2], Takeshi Shinoda[3]
[1] Department of Naval Architecture Sepuluh Nopember Institute of Technology, Surabaya 60111 Indonesia
[2] Graduate School of Engineering, Kyushu University, 744 Motooka Nishi-ku Fukuoka 819-0395, Japan
[3] Department of Marine Systems Engineering, Faculty of Engineering, Kyushu University, 744 Motooka Nishi-ku Fukoaka

Keywords: Wearable Device, Real Time Worker Monitoring, Shipyard Fabrication Worker.

Abstract: In many areas of shipbuilding supervisors are presently assigned to monitor and control the worker's productivity. This monitoring and controlling activities are not effective as the productivity can only be measured after activities are executed. To improve the worker productivity, a real time monitoring and controlling system is required and developed using the advances of wearable device technology. In this first phase, the work will be focused in the areas of shipyard fabrication workers. The wearable device is equipped with motion sensor consisting of 2 (two) types of motion sensors namely accelerometer and gyroscope sensor that are integrated using Inertial Measurement Unit (IMU) system with Arduino as Microcontroller Unit (MCU. The typical motion gesture of fabrication workers can be recognized and used as data of productivity monitoring of a worker. In the laboratory experiment, it shows that typical gesture of fabrication worker can be seen by the value of root mean square of the resulting monitoring data from gyroscope censor worn at the lower right hand and accelerometer censor worn at the lower back spin.

1 INTRODUCTION

Indonesian shipyards commonly have similar problems with the European SME shipyards (Hubler & Frank, 2016). They are mostly categorized as small and medium sized (SME) shipyards facing specific challenges. Limited financial capabilities and resources reduce their possibilities to invest in new technologies and production facilities. In addition, typical problems such as less disciplined workers, and lack of professional skills that are experienced in general by shipyards in developed countries reduce the ability to use innovative technologies for improving their productivity. In order to be competitive, such shipyards must optimize the use of available resources. Monitoring the use of human resources both the shipyards and outsourcing companies is a key important. The present advances in real time worker monitoring system is one solution to tackle these opportunities. Applying real time data monitoring system, worker productivity of shipyards can be monitored and then using various strategies of performance monitoring system overall productivity can be maintained. The application of this system will also enable the shipyards to identify scenarios to optimize the use of available resources such as performance based salary system. It further gives insight in the options to take up and manage a larger number of projects simultaneously and effectively.

2 LITERATURE

2.1 Performance Monitoring

Monitoring is an activity to observe carefully a situation or condition, including certain behaviors or activities, with the aim that all input data or information obtained from the results of these observations can be the basis for making decisions about the next actions needed.

Performance monitoring has several objectives, among others shipyards (Hubler & Frank, 2016):

1. Compliance
2. Auditing
3. Explanation

Pribadi, T. and Shinoda, T.
Application of Wearable Device for Real Time Monitoring System of Shipyard's Fabrication Workers.
DOI: 10.5220/0008542200630072
In *Proceedings of the 3rd International Conference on Marine Technology (SENTA 2018)*, pages 63-72
ISBN: 978-989-758-436-7

2.2 Wearable Device

Wearable Device is a device that can be used on parts of the human body related to computer operations and the latest technology, and uses the principle of "Wearable Technology", namely technology that can be used also implemented in everyday life based on their aesthetics and functions.

The features and sensors that can be used presently are (Uslu et al, 2013):

1. Geofences in mobile applications only
2. Location Information
3. Maps and Maps Service
4. Device Sensors
5. Activity Recognition

2.3 Classification of Wearable Technology Devices

The wearable device classification can be classified according to function, appearance, proximity to humans, and other parameters (Chatterjee et al, 2016).

2.3.1 Smartwatch

A smart watch is a computerized device or small computer that is intended to be worn on the wrist and has expanded the functions often associated with communication (Mortazavi et al, 2015). Most of the smartwatch models are currently based on cellular operating systems.

2.3.2 Smart Eyewear

Other categories of wearable devices, smart glasses that can be used for various applications in optical head-mounted displays (OHMD), heads-up displays (HUDs), Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and smart contact lenses (Mardonova et al, 2018).

2.3.3 Fitness Tracker

Fitness trackers, also known as activity trackers, are typically worn on the wrist, chest, or ear, and are designed to monitor and track outdoor sports activities and measure skills related to skills, such as speed and distance running, breathing, pulse, and sleep habits (Cadmus-Bertram, 2017).

2.3.4 Smart Clothing

Smart clothing is similar to other types of wearable devices that are used to monitor the physical condition of the wearer, ranging from sports clothing and consumer clothing (smart shirts and body wear) (Hanuska et al, 2016).

2.3.5 Wearable Camera

The appeal of this camera is very suitable for making videos and photos in real time. Two types of cameras can be used: a small camera that can be attached to the body or clothes, or even can be used on the ear, and a larger camera with an attachment to attach to a hat or helmet (Hanuska et al, 2016).

2.4 Other References

This reference is used to determine the appropriate method that will be used in the study of gesture motion of worker monitoring systems. The method and system are presently used for various purposes.

2.4.1 Microcontroller Unit (MCU)

Microcontroller is a computer system that all or most of its elements are packaged in an IC chip, so it is often called a single chip microcomputer (Gridling, 2007). Wearable devices that are currently used to do things for specific purposes are as follows.

a. Sensor-Based Intelligent Positioning and Monitoring System

The industry is currently pursing towards a production environment automatically. The position of workers who do work for production lines and monitor their movements is very important. For this purpose, the sensor consisting of 3 axis accelerometer and 3 axis gyroscope which is often called an inertial measuring unit sensor (IMU) is a good choice to do this (Edvardsen et al, 2017).

b. Self-contained Position Tracking of Human Movement Using Small Inertial/Magnetic Sensors Module

This position tracking using the Arduino microcontroller and small inertial/magnetic sensors which is used to track people who walk (Yun et al, 2007). This system is a system that is almost the same as the IMU system (Inertial Measurement Unit). The location of the difference is on the use of 3 types of sensors consisting of an accelerometer sensor, gyroscope sensor and magnetometer sensor.

c. Essential Tremor Measurement and Analysis

Computer sensor networks were developed to monitor hand position with essential tremor conditions, nervous system disorders that cause uncontrolled shaking, especially in the hands and upper body. The network collects 3D position data using two ZX Distance and Gesture Sensors, an Arduino Uno Board, and Raspberry Pi (Burt et al, 2017).

2.4.2 Android and IOS Device

Designing a system with android to determine a person's condition when he falls. This system is used in the world of health which is very helpful for tracking someone who is sick (Casilari et al, 2015). An iOS application that runs on the iPhone, which communicates with two Bluetooth low-energy modular sensors (BLE) (containing an accelerometer and 3-axis gyroscope and magnetometer).

2.4.3 Smartwatch

In particular, this device can track activity for the clinical environment and how to guarantee that the user does the desired activity. This device can track activity in real-time with sensors mounted on the user's wrist in the form of a smartwatch (Mortazavi et al, 2015). This system can be used to record and track data in large periods of time to provide a classification of movements from users. Furthermore, the identification carried out is the state of the user's posture which consists of sitting, standing, and lying down. In addition, this device can also identify the transition from all three user postures.

2.4.4 Position and Location Tracking Sensors

Location sensors and position tracking (GPS, altimeters, magnetometers, compass, and accelerometers) are the most common types of sensors in wearable devices, such as activity trackers, smartwatches, and even medical clothing where they are used for examines the physical activity and health of the patient (Khoa, 2015).

3 METHODOLOGY

A research methodology was developed in order to achieve the research objective. This can be seen in Figure 1 as a flowchart of activities and each of them described below.

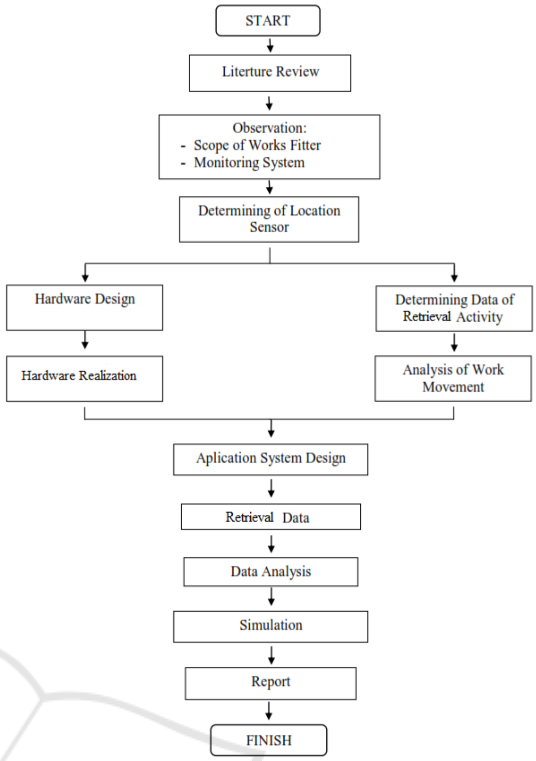


Figure 1: Flowchart of Research Methodology.

3.1 Literature Review

Literature review is the study of theories and critically review the existing systems that will be used in completing the research objective and to better understand the problems. References to work on this research are obtained from books, scientific journals, papers and browsing from the internet that is competent and accountable

3.2 Observation

The focus of the observations made is the scope of work (scopes of work) and the movement of body parts of fabrication workers in carrying out activities as well as making observations on the worker monitoring system is presently used.

3.3 Determination of Sensor Location

The tool used to capture, play back, and process video recordings from several cameras and sensor modules is the Microsoft Kinect camera. The process of recording video simulation activities or work activities using additional software applications, namely iPi Recorder. While the software application that is used to perform motion analysis is the iPi Mocap Studio application.

3.4 Hardware Design

The tool plan that will be used in this research is the Arduino microcontroller with accelerometer sensor module and gyroscope.

3.5 Determining Data Retrieval Activities

This stage is carried out to determine which body parts are dominant when fabrication worker performs related activities. The activities or activities are marking with bamboo mall aids in squatting position, straight cutting with a squat position skater, and a weld tag with a standing position.

3.6 Analysis of Work Movement

This analysis is done with Kinect tools with iPi recorder and iPi Mocap Studio software applications. The purpose of this movement analysis is to get the right place to put sensors from the tools that have been made.

3.7 Data Retrieval

Data retrieval flow as in Figure 2 as follows.

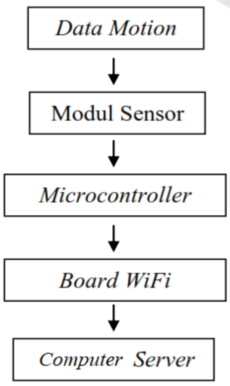


Figure 2: Flow of Data Retrieval.

3.8 Data Analysis

This stage is a stage to analyze the data obtained from the sensor module used. Data output can be used as a graph which will show a pattern of activities. Besides it can also be analyzed to identify the dominant axis when fabrication worker performs work activities.

3.9 Application System Design

This stage is the stage for creating a web server that functions as a data storage database. The output of the sensor module used will be stored in the database. In addition, there is also a plan to download data from sensor readings. So that the real time monitoring system process can be implemented. The aim is to assist in the performance monitoring process so that the process is more practical, easy, effective and efficient.

3.10 Simulation

The simulation phase is carried out to find out whether the designed tools and systems can be used to perform gesture motion monitoring. This means that the tools and systems made can recognize that the fabrication worker is carrying out a work activity properly.

4 FABRICATION WORK ACTIVITIES

4.1 Scope of Works

Fabrication is the initial stage of the ship building process. This fabrication process is carried out in the fabrication workshop where the production of this process is the components for the new building of the ship.

4.1.1 Marking

- Straight Marking
- Curve Marking

4.1.2 Cutting

- Cutting using a semi-automatic machine.
- Cutting using a blander machine.
- Cutting using a CNC (Computer Numerical Control) machine.

4.2 Hardware Devices

The type of microcontroller used is Arduino. The device is an ATMega328 microcontroller issued by Atmel which has a RISC (Reduction Instruction Set

Computer) board architecture. Figure 3 is the material and equipment used to realize the equipment to be used.

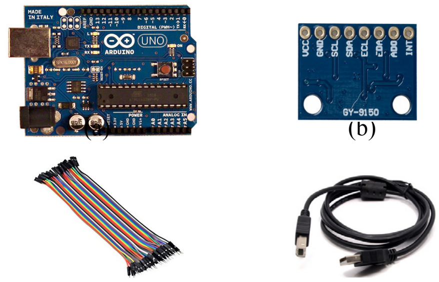


Figure 3: Equipment Components: (a) Arduino Uno (b) MPU 6050 Gyroscope & Accelerometer Sensor Module and equipped with Male to Female Jumper Cable and USB 2.0 Cable.

4.2.1 Arduino Board

Arduino Uno is one of the products labeled Arduino which is an electronic board that contains an ATMega328 microcontroller (a chip that functionally acts like a computer). This tool can be used to assembly electronic circuits from simple to complex.

4.2.2 Sensor Module

The following is a description of the wiring that is carried out between the Arduino Uno board and the sensor module used.

a) The VCC pin on the Sensor is connected with a 3.3 V pin on Arduino Uno R3;
b) The GND pin on the Sensor is connected to the GND pin on Arduino Uno R3;
c) The SCL pin on the Sensor is connected to the A5 Analog In pin on the Arduino Uno R3;
d) The SDA pin on the sensor is connected to the Analog A4 pin on Arduino Uno R3.

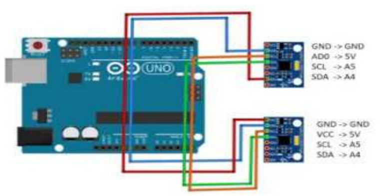


Figure 4: Arduino Wiring Board with Sensor Module.

Next step is to do the wiring between the Arduino Uno board and the ESP 8266 Wi fi shield. The wiring is shown in Figure 5.

a) VCC pin on Wi-Fi Shield ESP 8266 connected to pin 5 V on Arduino Uno R3;
b) The GND pin on Wi-Fi Shield ESP 8266 is connected to the GND pin on Arduino Uno R3;
c) Pin TX on Sensor connected with RX Analog In pin on Arduino Uno R3;
d) The RX pin on the sensor is connected to the Analog TX In pin on Arduino Uno R3.

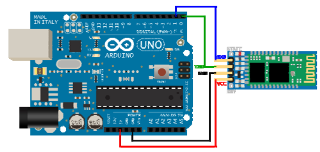


Figure 5: Arduino Uno Wiring Board with Wi Fi Shield ESP 8266.

4.3 Determination of Censor Location

Determination of sensor placement is done by making observations and observations in the real work location. Figure 6 is a diagram shows activities to determine the location of sensors used.

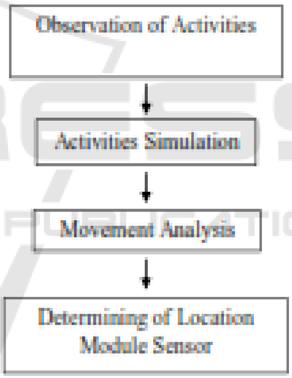


Figure 6: Activities for Sensor Determination.

4.3.1 Movement Simulation

The iPi Recorder software application can be used to simulate movements of activities carried out by a pre-determined fabrication worker.

4.3.2 Data Analysis

Figure 7 shows the result of the recording that is done using iPi Recorder, then the analysis will be done using the help of a software application, iPi Mocap Studio. The goal is to make it easier to carry out movement analysis so that a dominant body part when carrying out the activities can be identified.

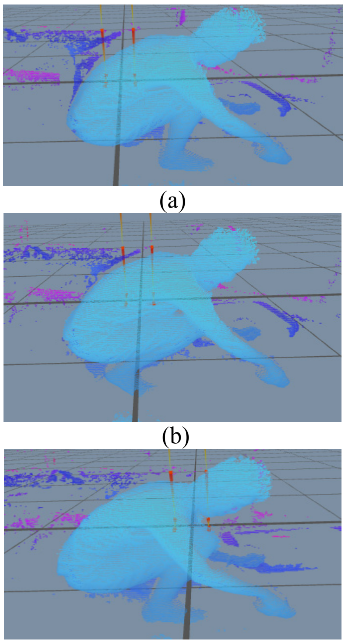

(a)
(b)
(c)

Figure 7: Changes to the movement carried out when carrying out straight cutting activities using semi-automatic machine: (a) first movement, (b) second movement, (c) third movement.

4.3.3 Censor Location

The next step is to analyze the body parts showing the typical gesture motion of a fabrication workers.

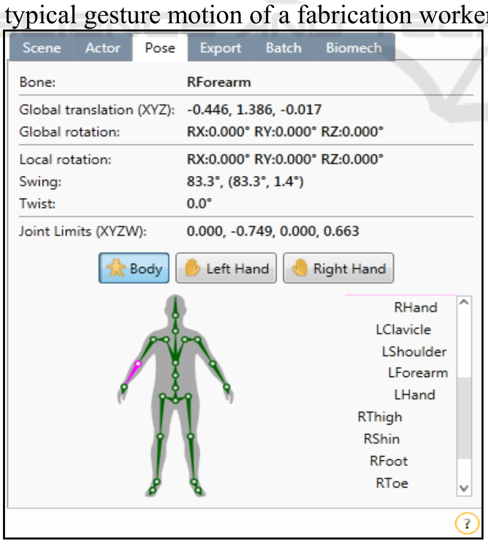


Figure 8: Information obtained from iPi Mocap Studio.

In Figure 8, the output for conducting motion analysis was shown. It was identified that the location of the body parts showing the most significant movement during activities performed by fabrication workers was the Right Fore Arm to record hand gesture motion using gyroscope and Lower Back Spine to record linier movement of the body using accelerometer as shown in Figure 9.

Figure 9: Location of Censor and Arduino Uno.

4.4 Application Design

Observations made on the monitoring system in the real shipyard situation are used to design an application system. Simulations are carried out starting from the log-in page carried out by the user, registration or registration, up to log-out as in Figure 10, Figure 11, and Figure 12.

From this application data will be displayed for every 60 seconds from each sensor, namely the accelerometer sensor and gyroscope sensor. The data will be stored in the server database and can be downloaded to the server computer.

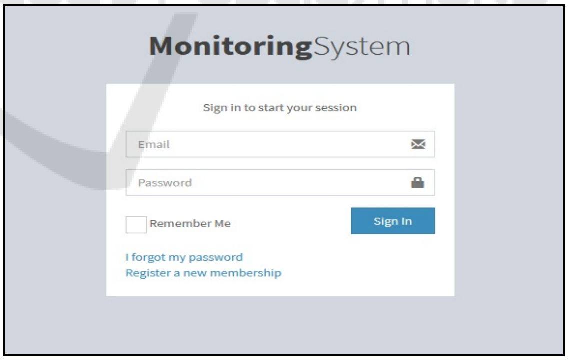
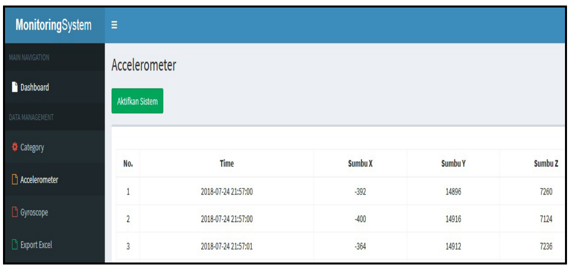
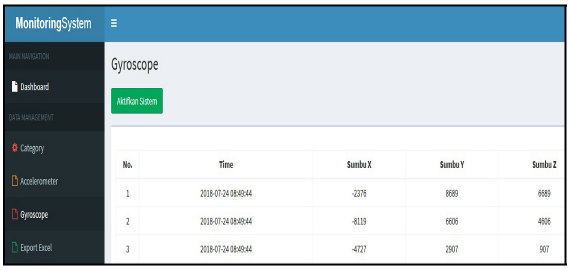


Figure 10: Display of Application Log-In System.



(a)



(b)

Figure 11: Display of Data Output (a) Accelerometer, (b) Gyroscope.

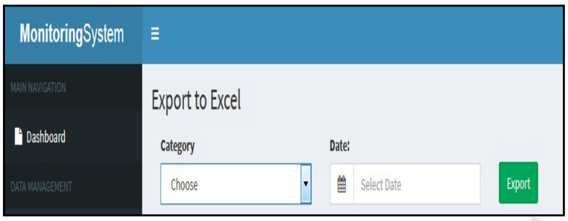


Figure 12: Export Display of Monitoring Results Data.

5 RESULTS

The experiment was carried out with the MPU 6050 sensor module with the output of 3 axis (coordinates) namely the x axis, y axis and z axis. The microcontroller unit (MCU) used is Arduino Uno. Data retrieval is carried out for 60 seconds with the result of 2000 data for each axis on each sensor. The specified time delay is 0.03 seconds.

5.1 Marking

During the experiment, activity of marking by using bamboo mall tools as shown in Figure 13 the fabrication worker is obtained data graph as shown in Figure 14.

Figure 13: Characteristic of marking movement.

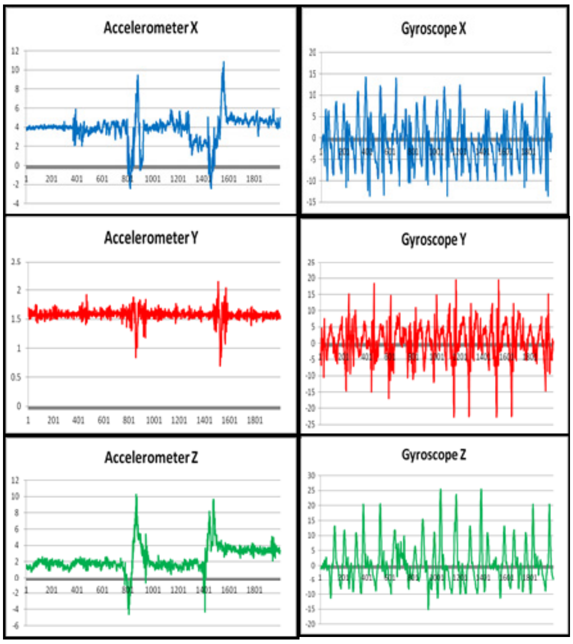


Figure 14: Output Data Module Sensor Accelerometer and Gyroscope on Marking Activities.

5.2 Cutting

In the experiment the activity or activity of cutting work straight by using a semi-automatic gas cutting as shown in Figure 15 is obtained the data graph as shown in Figure 16.

Figure 15: Cutting Movement Characteristics (Cutting)

5.3 Tag Weld

In the experiment the activity or activity of welding point (tag weld) as shown in Figure 17 by a fabrication worker obtained data graph as shown in Figure 18.

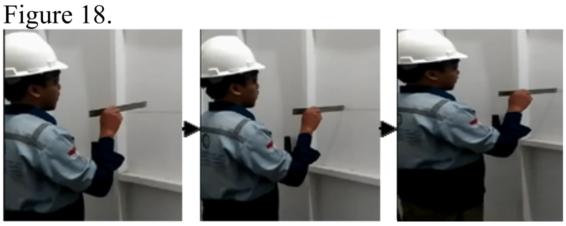


Figure 17: Characteristics of Weld Tag Movement (Point Welding).

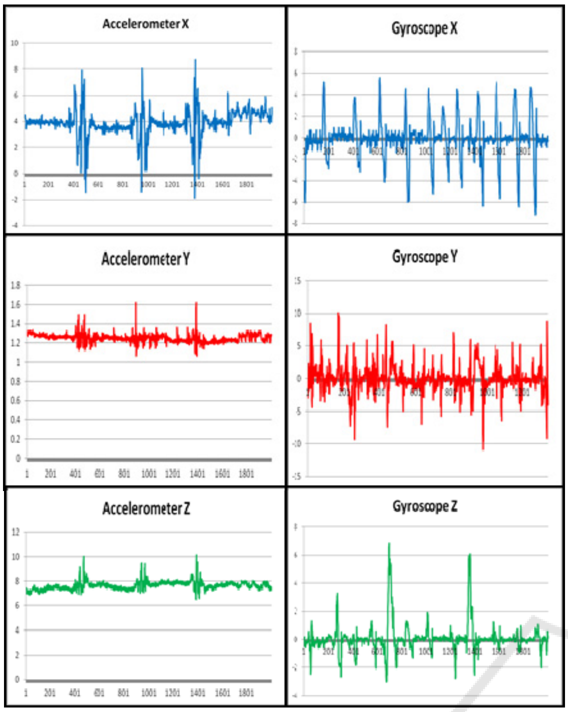


Figure 18: Output Data Module Output Sensor Accelerometer and Gyroscope on Tag Weld Activity.

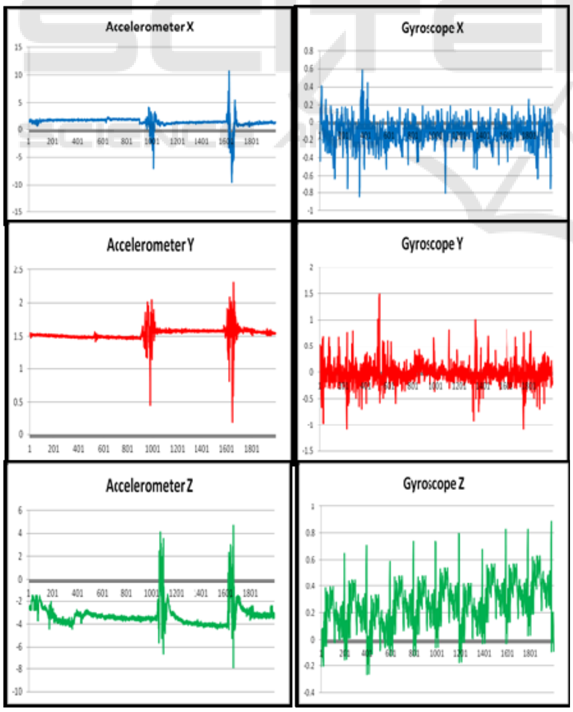


Figure 16: Output of Data Module Accelerometer and Gyroscope on Cutting Activity.

5.4 Summary of Experimental Data

Table 1 below shows an example of summary of experimental data.

Table 1: Summary of Experimental Data.

Activity	Accelerometer			Gyroscope		
	X	Y	Z	X	Y	Z
True Marking	1,847	2,846	1,766	0,100	0,228	0,013
False Marking	12,426	12,858	12,881	1,300	1,528	1,013
True Cutting	17,847	6,846	4,766	43,856	42,744	50,900
False Cutiing	0,100	0,228	0,013	12,900	34,123	0,837
True Tag Weld	2,336	2,495	1,313	13,885	8,115	10,418
False Tag Weld	0,064	0,111	0,137	3,148	3,891	3,477

6 TRIAL SIMULATION

Trial simulations are carried out to determine the accuracy of the designed system. Comparative analysis of the value of MSE (Mean Squared Error) between the simulation data of proper activities and the correct simulation with the wrong activities will determine whether the hardware and application system can be used to justify the fabrication workers do the activities properly. Table 2 is the result of a comparison of the MSE scores from the experiments carried out.

Table 2: Summary of Mean Square Error (MSE) Value.

Activity	Data Character	Accelerometer			Gyroscope		
		X	Y	Z	X	Y	Z
Turning Marking Squat Position	Minimum Data	-2320	6946	-4588	-13440	-22637	-15108
	Maximum Data	10932	21346	10244	14219	19404	25466
	Average Data	3891	15750	2351	-574	407	398
Straight Cutting Squat Position	Minimum Data	-9452	2048	-7856	-834	-1038	-264
	Maximum Data	10724	22984	4668	584	1481	884
	Average Data	1320	15368	-3226	-117	-19	253
Standing Tag Weld Position	Minimum Data	-1884	10704	6524	-7176	-10906	-3040
	Maximum Data	8740	16212	10132	5584	10117	6816
	Average Data	3856	12250	7642	-97	60	55

7 DISCUSSION

In this paper, a key important of real time data monitoring system for improving worker productivity in a shipyard of developed countries has been addressed. In such a shipyard the worker productivity is monitored only by the presence of workers in the location and then by recording the resulting interim products executed by supervisors.

While supervisors have difficulties to closely monitoring the real performance of workers, especially to differentiate between workers with acceptable performance and under performance during they are doing the activities. This will finally make shipyard management difficult to estimate the overall project performance and frequently will affect the ship delivery time.

Further problems will arise if new approach in salary system based on real performance of workers is implemented in order to improve the overall productivity and finally the profit of shipyards. This new approach will require the real time monitoring system as the basis of performance measurement activities of workers. Many skills and competences of workers involve in the process of shipbuilding from fabrication, sub assembly, assembly and erection. It was observed during the research that every worker has typical gesture motion in doing their activities. If such typical gesture motion of workers can be identified and recognized by the developed system, it will make possible to improve significantly the overall shipyard productivity.

In this first phase of the research, an observation was focused on the development of the real time monitoring system to record, to identify and to recognize of gesture motion of fabrication workers. It was also identified that the most important part of the system is censor location in the body of workers. The censors must be located in the part of bodies that moves dominantly to express typical motion gesture. This has been executed by doing video recording to the fabrication activities. Further this was followed by simulating and captioning the typical motion by using Microsoft Kinect and IPi Motion Capture Studio Software.

An analysis using IPI Motion Capture Software can then be executed to determine the dominant parts of bodies that can show the typical gesture motion of worker. It was identified that the position or location of the body parts showing the most significant movement for all activities performed by fabrication workers was the Right Fore Arm to record hand gesture motion using gyroscope and Lower Spine to record linier movement of the body using accelerometer.

A prototype of the developed system based on wearable devices consisted of Arduino microcontroller and two sensors accelerometer and gyroscope has been explained clearly in the previous paragraphs. This is then followed by trying the system prototype to the workers in the laboratory in order to evaluate the performance of the system. During the system trial, various configuration of fabrication activities of workers has been tried and the resulting gesture motion of workers has been recorded by two censors simultaneously. The gyroscope censor records the gesture motions of right hand of the worker and accelerometer censors records the linear gesture motions of lower spines of the worker. The two censors record the motions in the three directions X, Y, Z.

A graph showing the gesture of worker motion and its calculated MSE (Mean Squared Error) were obtained from each work activity performed. The application system will recognize the typical proper work activities through the MSE values generated by the recording data. If the MSE value on three each axis X, Y, Z has a small value, the application system will recognize as a proper work activity. However, if the MSE value produced is large, the system will state that it is improper work activity.

8 CONCLUSION

From the facts and discussion above, it can be concluded as follows.

- The dominant body part when fabrication worker performs typical activities is right forearm signing as hand gesture motion and lower spin showing linier movement of body.
- A prototype of proposed system developing a combination of the IMU (Inertial Movement Unit) system with the accelerometer and gyroscope sensor modules and the Arduino Uno microcontroller can be used to perform motion capture and monitor the gesture motion.
- A graph showing the gesture of worker motion and its MSE (Mean Squared Error) were obtained from each work activity performed.
- Proper work activities can be recognized by the MSE values generated by recorded motion data. If the MSE value on three axis (X, Y, Z) has a small value, then it will be recognized as a proper work activity. On the other hand, if the MSE value produced is large, the activity will be recognized as improper work activity.
- It was recognized the factors that influence the recording data is because of noise data generated by accuracy of censor readings.

REFERENCES

Burt, e. a., 2017. *Essential Tremor Measurement and Analysis*. New Jersey Governor's School of Engineering and Technology. New Jersey, USA.

Cadmus-Betram, L., 2017. Using Fitness Trackers in Clinical Research: What Nurse Practitioners Need to Know. *J. Nurse Pract*. Finlandia.

Casilari, e. a., 2015. *Analysis of Android Device-Based Solutions for Fall Detection.* Universidad de Malaga. Malaga.

Chatterjee, e. a., 2016. Classification of Wearable Computing: A Survey of Electronic Assistive Technology and Future Design. *Proceedings of the 2016 Second International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), India,* pp. 23 - 25.

Edvardsen, e. a., 2017. *Sensor-Based Intelligent Positioning and Monitoring System.* Uppsala Universitet. Uppsala.

Gridling, G., 2007. *Introduction to Microcontrollers, Courses 182.064,* s.l.: Institute of Computer Engineering, Vienna University of Technology.

Hanuska, e. a., 2016. Smart Clothing Market Analysis*. J. Nurse Pract*. Finlandia.

Hubler, M. & Frank Roland, 2016. *Developing Smart Technologies for Productivity Improvement of European Small and Medium Sized Shipyards.* European SMARTYards Consortium. Hamburg.

Khoa, T., 2015. *Wearable Smart Technologies: New Era of Technology.* Lapland University of Applied Sciences. Lapland.

Mardonova, e. a., 2018. *Review of Wearable Device Technology and Its Application to the Mining Industry.* Pukyong National University. Busan.

Mortazavi, e. a., 2015. *Can Smartwatches Replace Smartphones for Posture Tracking?*. University of California. Los Angeles, USA.

Uslu, e. a., 2013. *Human Activity Monitoring with Wearable Sensors and Hybrid Classifiers.* Computer Engineering. London.

Yun, e. a., 2007. Self-contained Position Tracking Human Movement Using Small Inertial/Magnetic Sensor Module*. IEEE International Conference on Robotics and Automation Roma*. Italy.