© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

International Journal of Integrated Engineering

Development of A Wireless and Ambulatory Posture Monitoring System

Eugene Low[1]*, Toong Hai Sam[2], Kian Sek Tee[1], Ruzairi Abdul Rahim[3], Hashim Saim[1], Wan Nurshazwani Wan Zakaria[1], Safinaz Mohd Khialdin[4], Hazlita Isa[4], Chin Fhong Soon[5]

[1]Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, 86400, MALAYSIA

[2]Faculty of Business, Communications and Law (FOBCAL),
INTI International University, Persiaran Perdana BBN, Putra Nilai, Nilai, Negeri Sembilan, 71800, MALAYSIA

[3]Sekolah Kejuruteraan Elektrik, Fakulti Kejuruteraan,
Universiti Teknologi Malaysia, Skudai, Johor, MALAYSIA

[4]Department of Ophthalmology, Pusat Kesihatan Universiti Kebangsaan Malaysia,
Jalan Yaacob Latif, Bandar Tun Razak, Batu 9 Cheras, Wilayah Persekutuan Kuala Lumpur, 56000, MALAYSIA

[5]Biosensor and Bioengineering Laboratory, MiNT-SRC,
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2020.12.02.020
Received 29 December 2019; Accepted 27 January 2020; Available online 28 February 2020

Abstract: The wireless and ambulatory posture monitoring system monitors the movement and posture change of the human body with respect to the g-line. It is crucial to monitor the posture health of the ophthalmologist who spends a prolonged period on the static sitting posture while operating on the slit lamp which leads to any painful experience. The motivation of the proposed system is to improve the ergonomics of the ophthalmologist on their working environment and reduce any occupational potential hazard which may prompt Work-Related Musculoskeletal Disorders (WMSDs). The proposed system also induced a wireless system by using XBee wireless units to reduce the use of the wire that may tangle on the study subject which causes any uncomfortable experience to the study subject during the human trial. Inertial Measurement Unit (IMU) sensor which consists of an Accelerometer, a Gyroscope and a Magnetometer is used to measure the angle of deviation of the body segment with respect to the g-line. The data is tabulated and presented into the graphical method to identify and extract the properties of the graph on each different static sitting posture which later are used for posture recognition.

Keywords: ergonomics, ophthalmologist, static sitting posture, posture monitoring system, wireless, XBee, IMU

1. Introduction

Ergonomics is an important subject for years. Ergonomics is defined as the interaction between the workers to their working environment (Tee et al., 2017). The main objective of the ergonomics is to improve working experience of the worker with concern on the safety, health and welfare (OSHA3125, 2000). It is crucial to raise the awareness of the workers on the potential occupational hazard around their working environment which may risk their safety and health. In order to reduce the risk of potential occupational hazard among the workers, numbers of postures monitoring system

*Corresponding author: ge160116@siswa.uthm.edu.my

and instruments are developed specially for their particular field such as industrial, medical, office and so on to improve the worker's safety and health. J. Birsan et al. proposed a sitting posture monitoring system which tracks the sitting posture of the users and alerts them when bad postures are detected (Birsan et al., 2017). M. Tarabini et al. present a feasible study on the human body postures of the industrial workers with the simultaneous use of Kinect skeletal system and Notch system which consists IMU sensor in it (Tarabini et al., 2018; Tarabini et al., 2018). C. Marino et al. developed a software of non-invasive evaluation with the implementation of Kinect to monitor human body postures of the study subject at the workplace (Marino et al., 2018). Q. Wang et al. proposed a smart rehabilitation garment using IMU sensors which enable posture monitoring to prevent spinal pain and avoid compensatory movement of the human body (Wang et al., 2015).

Recently, the ophthalmologist claim to have suffer a painful experience on the Work-Related Musculoskeletal Disorders (WMSDs) (Kitzmann et al., 2012). The scenario of the ophthalmologist on their working environment is that they have maintained at a static sitting postures by leaning forward while operating on the slit lamp during eye inspection section on the patients for prolonged period which lead to neck pain, lower back pain, upper back pain and so on (Al-Marwani Al-Juhani et al., 2015; Hyer et al., 2015; Marx, 2012; Natarajan & Nair, 2016; Ratzlaff et al., 2018; Venkatesh & Kumar, 2017). In year 2010, a total number of 204,909 ophthalmologists was reported from 67 countries. The survey shows that there is significant shortfall in the number of ophthalmologists in worldwide which may lead to work overload among the ophthalmologists and impose to higher risk on the ergonomics (Resnikoff et al., 2012).

In regard to the issue raised, a wireless and ambulatory posture monitoring system is proposed as the solution of the problem. The system monitors the movement of the human body and detects the change of the body postures. The data acquired will be analysed to determine the awkward body posture by measuring its angle of deviation with respect to g-line.

2. Methodology

This section includes the overview of the wireless and ambulatory posture monitoring system which explain the flow of the system during the human trial is carried out; configuration on the wireless modules which shows the full process on the configuration done to the particular wireless module and settings parameter needed to enable communication between them; system design which illustrates the hardware design of the wireless and ambulatory posture monitoring system; and the system validation which shows the procedure to validate the functionality of the system before it is ready for human trial.

2.1 System Overview

The wireless and ambulatory posture monitoring system is started by strapping the DAQ system to the upper body of the study subject. In this project, the upper body of the study subject is selected as the benchmark placing the DAQ system because the system is able to detect the slightest movement of the body when it is deviated from the g-line. After all the setup has been done and checked properly, the DAQ system is switched on for data acquisition. The IMU sensor detects the change of posture from the study subject and generates a series of data. The data is then transferred to the microcontroller for multipurpose. First, the data is stored into the memory card as the text file for back up purpose. At the same time, the data is also transmitted to PC via wireless module for real-time graph plotting. The PC received the data from the wireless module and displayed the real-time graph which responds to the change of posture of the studied subject. The scenario of the wireless and ambulatory posture monitoring system is illustrated in Fig. 1.

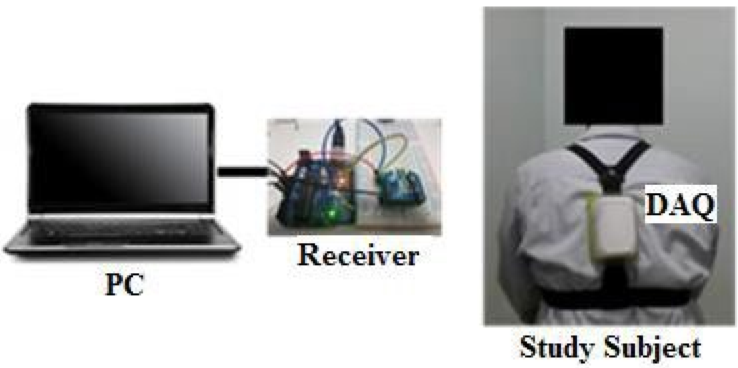


Fig. 1 - The scenario of the wireless and ambulatory posture monitoring system

2.2 Configuration on Wireless Unit

The configuration process is crucial in order to enable the wireless modules to communicate and transfer data between each other. In this project, XBee S2C [https://www.digi.com/] as shown in Fig. 2 is chosen as the wireless

module. Xbee S2C has lower latency on the data transmission, user-friendly and lower in cost as compared to other wireless units.

XCTU [https://www.digi.com/] is a free and user-friendly configuration platform for the user to communicate with Digi RF modules. The software XCTU is used in this project to configure the settings parameter of the XBee S2C. There are two units needed to be configured which are the coordinator and the router. The coordinator unit connects to the PC to communicate and receives data transmitted from the router unit; while the router unit transmits the data acquired from the sensor of the DAQ system to the coordinator unit.

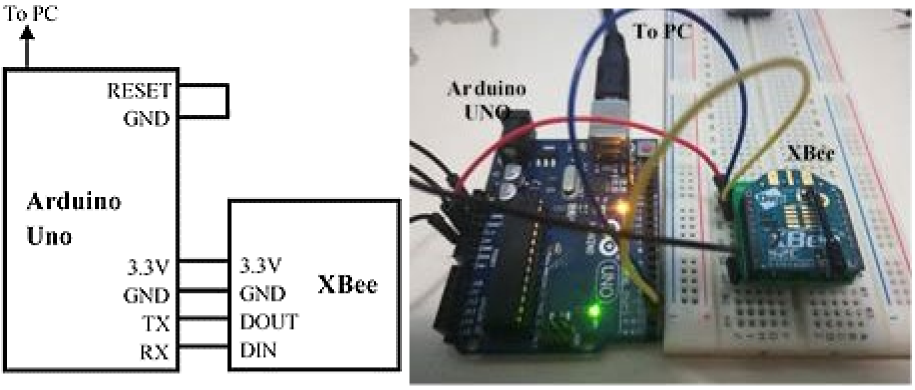
First, both units are updated to the latest firmware provided by the developer before they are ready for any configuration. For the coordinator unit, the PAN ID code is set to any desired number in order to communicate with other units which shared the same code. In this project, it is set to 1234. The Destination Address Low (DL) is set to FFFF which means the unit is broadcasting. API Enable (AP) is set to transparent mode for simple two-way communication between the units. Coordinator Enable (CE) is set to enable for the unit to be recognize as the coordinator unit. For router unit, the PAN ID code is first set to 1234 which is same to coordinator unit. JV channel is set to 1 to enable the router unit to leave its current channel if the coordinator unit is not detected or operated. Coordinator Enable (CE) is set to disabled for the unit to be recognize as router unit.

After all the configuration has been done, the communication between both coordinator and router units are verified using the same software. The connection between both units can be determined by inserting any desired alphanumeric value on the router unit. If the coordinator unit received the same alphanumerical value as inserted earlier on the router unit, it shows that both units are communicating with each other and the connection is a success.

Fig. 2 - Xbee S2C

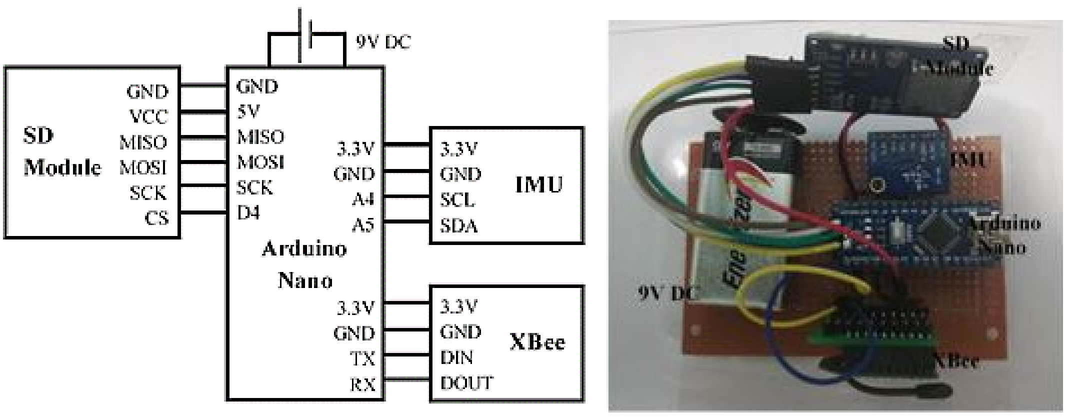
2.3 System Design

The circuitry design of the wireless and ambulatory posture monitoring system is divided into two main compartments which are coordinator and router. For the coordinator part, it contains the PC, Arduino UNO unit and XBee (coordinator configured) unit. The Arduino UNO unit is used to interfacing with the XBee unit by bypassing the Atmega 328p chip and converting it into TTL serial. The coordinator configured Xbee is acting as the receiver to receive and transfer the data to PC. The data received by the PC will be post-processed and plotted using Python [https://www.python.org/]. The schematic diagram and the hardware assembly of the coordinator part is shown in Fig. 3 For the router part, it contains 9V DC battery, Arduino Nano unit, GY-85 sensor, SD card module, 8GB memory card and Xbee (router configured) unit. The router part is powered by 9V DC supply. Arduino Nano is chosen as the microcontroller because it is smaller in size and compact. It shares almost the same functionality with other general Arduino series products. GY-85 sensor is a 9DOF IMU sensor which contains accelerometer, gyroscope and magnetometer in it. The data generated from the sensor is transferred to the microcontroller via I2C bus. In this project, only accelerometer and gyroscope are enabled for posture monitoring since the body movement and angle of deviation of the upper body relative to g-line of the study subject are interested. SD card module as the card slot for the memory card to store and back up the data received from the sensor. The router configured Xbee act as the transmitter to transmit the data acquired from the IMU sensor. The schematic diagram and the hardware assembly of the router part is shown in Fig. 4.



(a) (b)

Fig. 3 - (a) Schematic diagram of the coordinator part; (b) Hardware assembly of the coordinator part



(a) (b)

Fig. 4 - (a) Schematic diagram of the router part; (b) Hardware assembly of the router part

2.4 System Validation

System validation is a vital process needed to be done to ensure the functionality and the stability of the system if it is meet to the requirement. It also reduces the possible errors that could affect the precision and accuracy of the data acquired which may deviate from the actual reading. Two main verifications are done in this project which includes, the connectivity between the wireless units and the functionality of the posture monitoring system.

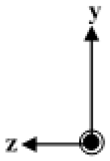
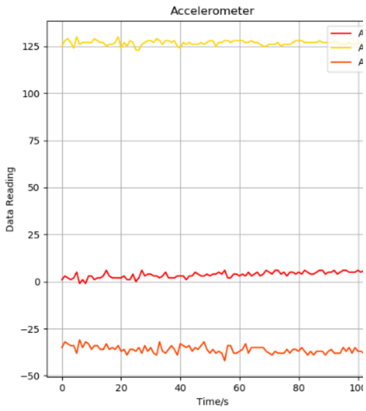
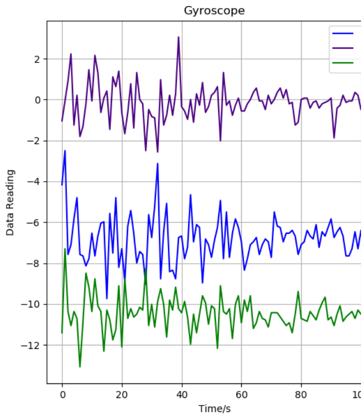
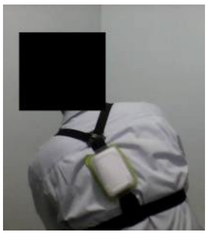
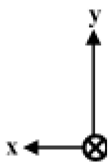
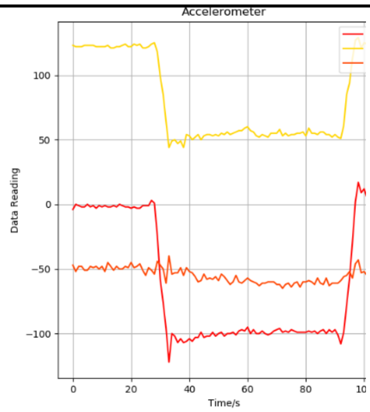
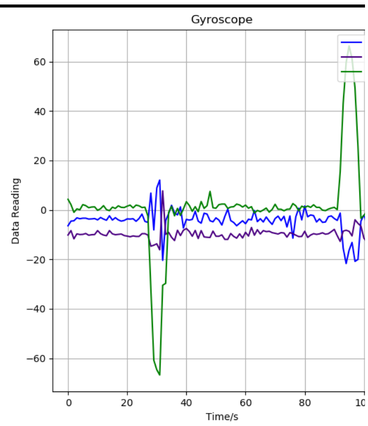
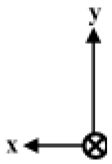
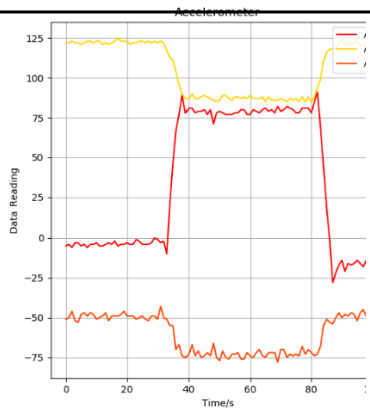
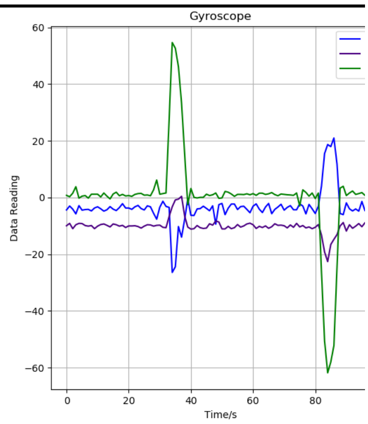
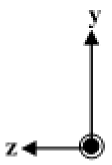
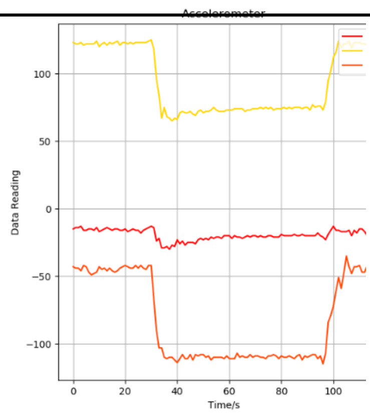
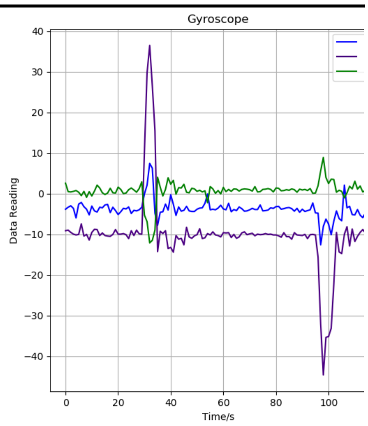
The connectivity between the wireless units is determined by repeating the communication verification process done during the wireless module configuration process. The coordinator unit may receive the same alphanumerical value as inserted from the router unit through XCTU after connected. If it’s not receiving any value as desired or giving no response at all, it means there are issues on the connectivity or the setting on the wireless unit. It is important because the firmware of the wireless unit may defect through improper care.

The functionality of the posture monitoring system is validated with a series of tests. First, the test starts with the calibration of the sensor. In this project, a simple calibration on the sensor is done by placing the sensor on the flat surface in different directions. The degree of deviation and the error on the value of the sensor relative to the flat surface are measured and adjusted. Then, the system is attached to a human model and started to run to collect a series of data. The PC will display the change of human model posture through real-time graph plotting. After that, the backup data from the memory card is extracted, plotted and compared to the real-time graph plotting by the PC earlier to determine if there is any difference between them.

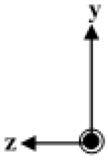
3. Results and Discussion

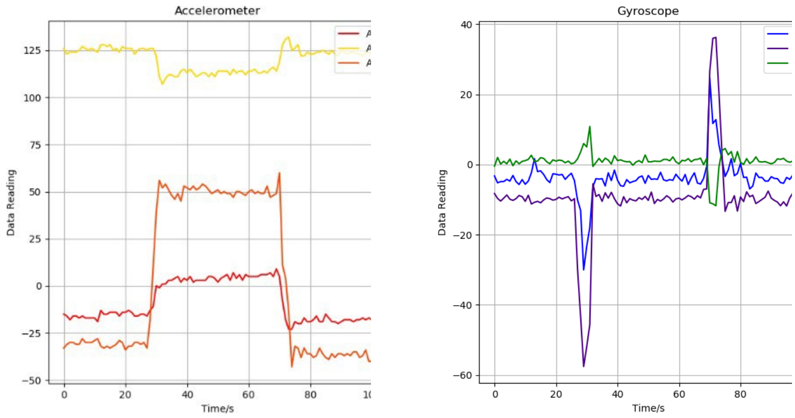
The human trial session is conducted on the study subject by simulating various types of the static sitting posture in a period of time. In this session, there are 5 different static sitting postures simulated which include, normal, left, right, anterior and posterior. All sessions are started and ended at the benchmark normal static sitting position. Each posture has lasted for 100 seconds per session. The sampling rate of the DAQ system is set to a lower frequency of 10Hz which is sufficient for static postures. The higher sampling rate is not recommended due to the higher power consumption and the delay of data transmission by the wireless units. The data acquired from the DAQ system is then transmitted via the wireless system and plotted on the Python by PC. The scenario of all the static sitting postures, sensor’s direction, the graph of accelerometer and the graph of gyroscope are tabulated in Table 1.

Table 1 - The scenario, sensors direction, graph of accelerometer and graph of gyroscope

Scenario	Sensor Direction	Accelerometer	Gyroscope
 Normal			
 Left			
 Right			
 Anterior			

Posterior





From the results obtained, both accelerometer and gyroscope data readings remain constant for the whole normal posture. When the study subject leaned to the left, there are a decrease in Accelerometer x and Accelerometer y values and spike down in Gyroscope z value. When the study subject leaned to the right, there is an increase in Accelerometer x value, decrease in Accelerometer y value and spike up in Gyroscope z value. When the study subject leaned to anterior, the value of Accelerometer y and Accelerometer z are decreased and spike up in Gyroscope y value. When the subject bend leaned to posterior, the value of Accelerometer y decreased, the value of Accelerometer z increased and spike down in Gyroscope y value. In order to summarize the finding, the Accelerometer x, Accelerometer y and Gyroscope z are responded to the left and right motions; the Accelerometer y, Accelerometer z and Gyroscope y are responded to the anterior and posterior motions.

The human trial is proceeded to the next session in which the study subject is permitted to perform any body postures as desired. According to the results as illustrated in Fig. 5, it shows that the user is able to identify and recognize the body postures through the wave pattern of the accelerometer and gyroscope. The sequence of the body postures are such as normal, left, normal, right, normal, anterior, normal, posterior and normal.

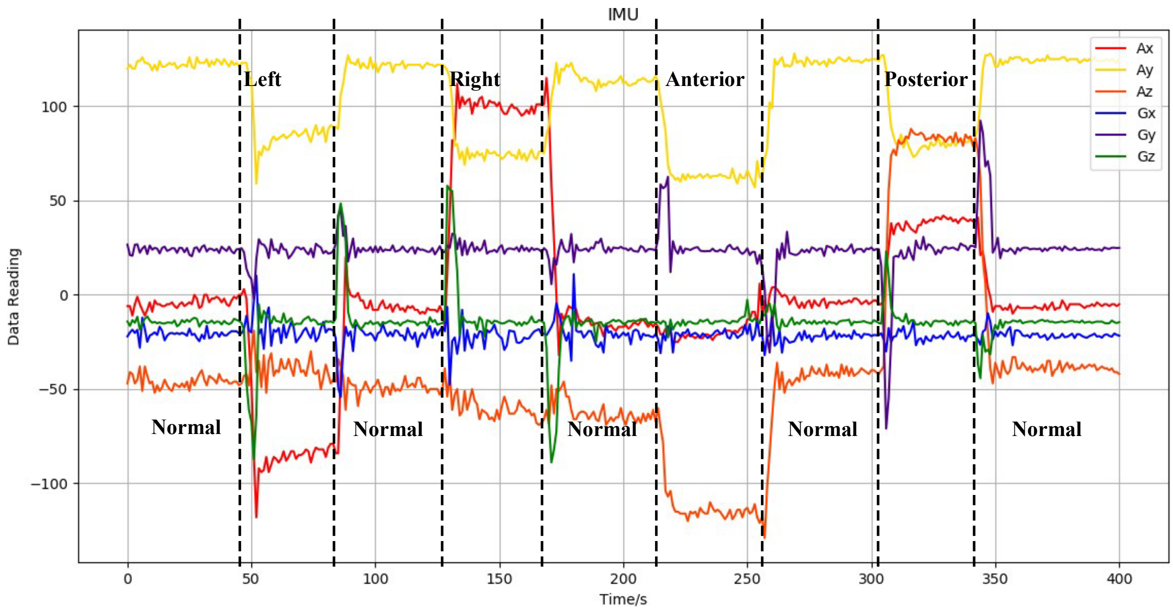


Fig. 5 - Random postures and posture identification

4. Conclusion and Future Works

In conclusion, the development of the wireless and ambulatory posture monitoring system is a success. The DAQ system is able to read and identify the posture change of the studied subject relative to its previous posture. The data acquired from the DAQ system is transferred successfully via wireless module to the PC for real-time graph plotting. The posture monitoring system can be further improved in the future by implementing a few recommendations like applying more detail calibrations to the IMU sensors for more accurate data acquisition on the human posture; applying distance-frequency test to the DAQ system to check for the distortion of data as the distance of data transmission is increased; adding multiple sensors to the DAQ system for more detail in the mapping of the whole upper body of the studied subject in posture analysis; and reconstruct the human trial session into several hours for more accurate and better results in justification on bad postures.

Acknowledgement

The authors are grateful to the financial support by INTI International University Conference Funding.

References

[1] Al-Marwani Al-Juhani, M., Khandekar, R., Al-Harby, M., Al-Hassan, A., & Edward, D. P. (2015). Neck and upper back pain among eye care professionals. Occup Med (Lond), 65(9), 753-757. doi:10.1093/occmed/kqv132

[2] Birsan, J., Stavarache, D., Dascalu, M.-I., & Moldoveanu, A. (2017). SpiMO-Sitting Posture Monitoring System. Paper presented at the RoCHI.

[3] Hyer, J. N., Lee, R. M., Chowdhury, H. R., Smith, H. B., Dhital, A., & Khandwala, M. (2015). National survey of back & neck pain amongst consultant ophthalmologists in the United Kingdom. International Ophthalmology, 35(6), 769-775. doi:10.1007/s10792-015-0036-z

[4] Kitzmann, A. S., Fethke, N. B., Baratz, K. H., Zimmerman, M. B., Hackbarth, D. J., & Gehrs, K. M. (2012). A survey study of musculoskeletal disorders among eye care physicians compared with family medicine physicians. Ophthalmology, 119(2), 213-220. doi: 10.1016/j.ophtha.2011.06.034

[5] Marino, C., Vargas, J., Aldas, C., Morales, L., & Toasa, R. (2018). Non-invasive monitoring environment: Toward solutions for assessing postures at work. Paper presented at the 2018 13th Iberian Conference on Information Systems and Technologies (CISTI).

[6] Marx, J. L. (2012). Ergonomics: Back to the Future. Ophthalmology, 119(2), 211-212. doi: 10.1016/j.ophtha.2011.09.001

[7] Natarajan, S., & Nair, A. G. (2016). Is ophthalmology becoming a pain in the neck? Indian Journal of Ophthalmology, 64(6), 413-414. doi:10.4103/0301-4738.187648

[8] OSHA3125. (2000). Ergonomics: The Study of Work: U.S. Department of Labor Occupational Safety and Health Administration.

[9] Ratzlaff, T. D., Diesbourg, T. L., McAllister, M. J., von Hacht, M., Brissette, A. R., & Bona, M. D. (2018). Evaluating the efficacy of an educational ergonomics module for improving slit lamp positioning in ophthalmology residents. Canadian Journal of Ophthalmology.

[10] Resnikoff, S., Felch, W., Gauthier, T. M., & Spivey, B. (2012). The number of ophthalmologists in practice and training worldwide: a growing gap despite more than 200,000 practitioners. Br J Ophthalmol, 96(6), 783-787. doi:10.1136/bjophthalmol-2011-301378

[11] Tarabini, M., Marinoni, M., Mascetti, M., Marzaroli, P., Corti, F., Giberti, H., . . . Eger, T. (2018). Real-time monitoring of the posture at the workplace using low cost sensors. Paper presented at the Congress of the International Ergonomics Association.

[12] Tarabini, M., Marinoni, M., Mascetti, M., Marzaroli, P., Corti, F., Giberti, H., . . . Mascagni, P. (2018). Monitoring the human posture in industrial environment: A feasibility study. Paper presented at the Sensors Applications Symposium (SAS), 2018 IEEE.

[13] Tee, K. S., Low, E., Saim, H., Zakaria, W. N. W., Khialdin, S. B. M., Isa, H., . . . Soon, C. F. (2017). A study on the ergonomic assessment in the workplace. AIP Conference Proceedings, 1883(1), 020034. doi:10.1063/1.5002052

[14] Venkatesh, R., & Kumar, S. (2017). Back pain in ophthalmology: National survey of Indian ophthalmologists. Indian Journal of Ophthalmology, 65(8), 678.

[15] Wang, Q., Chen, W., Timmermans, A. A., Karachristos, C., Martens, J.-B., & Markopoulos, P. (2015). Smart Rehabilitation Garment for posture monitoring. Paper presented at the Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE.