

## A posture monitoring system with IMU for ophthalmologist while operating the slit lamp

Kian Sek Tee<sup>1</sup>, Eugene Low<sup>2</sup>, Wellesly Tony<sup>3</sup>, Safinaz Binti Mohd Khialdin<sup>4</sup>, Jaysuman Bin Puspanathan<sup>5</sup>, Chin Fhong Soon<sup>6</sup>, Toong Hai Sam<sup>7</sup>

<sup>1,2,3</sup>Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Malaysia

<sup>4</sup>Department of Ophthalmology, Pusat Kesihatan Universiti Kebangsaan Malaysia, Malaysia

<sup>5</sup>School of Biomedical Engineering & Health Science, Universiti Teknologi Malaysia, Malaysia

<sup>6</sup>Biosensor and Bioengineering Laboratory, MiNT-SRC, Universiti Tun Hussein Onn Malaysia, Malaysia

<sup>7</sup>Faculty of Business, Communications and Law (FOBCAL), INTI International University, Malaysia

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### ABSTRACT

The posture monitoring system monitors the posture changes of the upper body and the spinal cord applying to ophthalmologists while operating the slit lamp. The motivation to the pursuit of this system is to relate posture changes while in a static sitting posture to the spinal deviation from the g-line. Often times, the spinal deviation from the g-line is classified as bad posture because of the shift in weight distribution on the spine causing pain and discomfort in certain areas of the spine. This paper presents the design concept, the development process and the working principle of the posture monitoring system using Inertial Measurement Unit (IMU) sensor. The raw measurement data obtained from human trials is tabulated and converted into a graphical representation in which all postures can be identified and distinguished by referring the relative wave pattern. The procedure is important in the improvement on the posture monitoring system for the human trials on the ophthalmologist in future.

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### Corresponding Author:

Kian Sek Tee,

Faculty of Electrical and Electronic Engineering,

Universiti Tun Hussein Onn Malaysia, Malaysia.

Email: tee@uthm.edu.my

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## 1. INTRODUCTION

Ophthalmologists have a distinctively high risk for hazards of a diverse nature, mainly musculoskeletal issues that are caused by the constant adjusting and movement of posture and prolonged pressure on the spinal cord caused by unhealthy posture [1-6]. Ophthalmologists specialize in eye and vision care similar to optometrists and opticians, only they differ in their levels of training. An ophthalmologist is authorized to perform eye surgery and also conduct research on the causes and cures for eye diseases [7, 8]. Therefore, posture placement is important especially for ophthalmologists because of the range of differences of patients they attend to during working hours. This diversity in patients forces ophthalmologists to constantly adjust their posture depending on the height of the patient and the position of the patient's eyes. According to the specialist, the control knobs of the slit lamp are positioned higher up which forcing them to sit with an extended arm in a praying-mantis-like posture which is very unnatural and very detrimental for the lower back [9-11]. This, in turn, has negative side effects such as back pain, neck pain caused by constriction of blood vessels and nerves and anatomical changes in the spine [2, 12-19]. Under the OHS Act, Section 2 (1), employers are required to hold the responsibility to ensure the health and safety of all workers at the work site [20]. More specifically, identifying hazards, conducting a written hazard assessment and implementing controls. Therefore as an ophthalmologist, one must acknowledge that the negative effects of incorrect posture are a work hazard and that this matter should not be disregarded.

Posture monitoring system has been invented for years to detect posture, angular rate and force. This monitoring system is usually made up of a sensor, a microcontroller, a monitoring platform or software to process the input and produce proper output that represents the movements and changes in posture. Prior researches have been conducted using the same design concept but in different approaches and applications. X. Yan et.al [21] developed a real-time motion warning personal protective equipment (PPE) which consists of a warning mechanism that enables self awareness among construction workers to prevent WMSDs. C. Antonya et.al [22] present a new algorithm for the real-time representation of the human spine with IMU sensors in which the human body posture is analysed base on quadratic Bézier curves. H. Haggag et.al [23] applied the hierarchal joint system available in the Microsoft Kinect SDK for real time ergonomic assessment in rapid upper limb assessment (RULA). P. Li et.al [24] have developed a smart safety helmet using IMU and EEG sensor which able to reduce the ergonomic risks by tracking the head gestures and the brain activity of the worker. K. S. Tee et.al [25] had done a review on the ergonomic assessment methods and devices which are often used by the researchers in the field of ergonomics.

This paper presents an instrumental system to monitor the movement and changes of posture for ophthalmologists in order to help develop data that will contribute to the research to find the solution to this problem. This instrumental system to monitor the posture of ophthalmologists will also be used to analyze the negative side effects of incorrect posture placement and the repercussion from over-stressing the spinal cord.

## 2. METHODOLOGY

### 2.1. System Overview

The flow of the posture monitoring system starts with the instrumental system attached at the upper body of the study subject. After ensure all the setup has been done, the instrumental system will be switched on. Next, the sensor detects the change of the body posture by the study subject and generate raw data in which will be process by the microcontroller later. At the same time, the data generated can be inspected from the LCD display provided. The data received by the microcontroller from the sensor will be stored in the memory card. Lastly, the data from the memory card will be extracted and transferred to the personnel computer to be analyzed. The flowchart of the instrumental Posture Monitoring System is as illustrated in Figure 1.

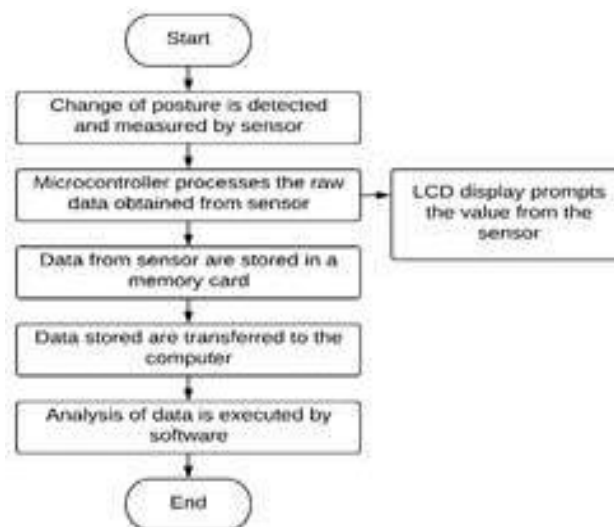


Figure 1. Flowchart of the posture monitoring system

### 2.2. Design Concept

Posture is the main point of interest in this system, the part of the body involved during sitting position should be put into consideration. The main part of the body that moves during a change in posture in sitting position is upper body-along the spine and the head. To narrow it down, the upper body is divided into three segments and the focal point of the project is the upper back (thorax).

The element of interest in this project are the parameters that become measurable variables in response to the changes of posture in ophthalmologist when working. The measurable variable when the change of posture is put into consideration is the change in angular rate in which the part of the body deviates from the

g-line. The change in posture is represented by the rotational movement that occurs within the 3 dimensional axis x, y, and z. A sensor that is able to measure angular rate is required in order to provide substantial data that gives numerical value to the posture changes so that the posture change can be analysed using graphical and statistical method as well as representing the posture changes in the form of a 3D visualization of the movement using appropriate software.

The system should also be wearable and portable considering the fact that the system will be applied on the subject for a period of time. Also, it is necessary to create a wearable and portable device which is non-intrusive to the subject's natural movements. Therefore the system should be designed in a way that is wearable and ergonomic. The sensor placement will be on the upper back. This is done to allow the sensor to fully detect the changes in posture where the angle is most sensitive to the movements of the upper body. A strapping mechanism is suitable for this system as it allows for an easy wear and remove process. Figure 2 shows the design concept of the system.



Figure 2. Design concept of the posture monitoring system

### 2.3. DAQ System Design

A circuit diagram is sketched to be used as a guideline when actual construction process for the DAQ system begins. The circuit consists of switches to start and end the running system, an SD card, variable resistors, battery, IMU sensors and LCD display. A switch will be added to control the operation of the DAQ system according to Arduino Uno. The LCD display will be connected to the digital pin of the Arduino Uno. The output voltage of the voltage divider is directed to the Arduino Uno microcontroller analogue input. The IMU sensor will be connected to the microcontroller. The IMU-GY85 connection to the Arduino is through the I2C protocol. The pin for power supply depends on the IMU module itself. If the module has a 5V pin, the module is connected to the 5V pin. Otherwise, the module is connected to the 3.3V pin on the Arduino board. The GND of the module is connected to the GND of the IMU sensor module. The SCL and SDA pins are connected between the IMU module and the Arduino board. The digital pin 2 on the Arduino board connects to the INT pin on the IMU module. All components in the system are common grounded. The block diagram of the system is shown in Figure 3.

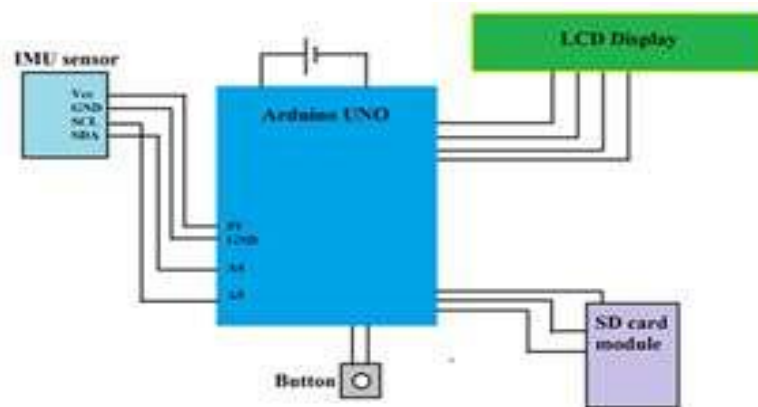


Figure 3. Block diagram of the DAQ system

**2.4. Hardware Assembly**

All the components selected at the earlier design stage are installed in a plastic box which houses the components in place to act as the DAQ of the system. The box is then placed in a waist pack that is to be clipped around the waist to secure the position of the DAQ and allow the system to be portable. The system is powered by an external rechargeable 5V battery pack. The finished product is as shown in Figure 4(a) and the circuitry of the system is as shown in Figure 4(b).

**2.5. System Validation**

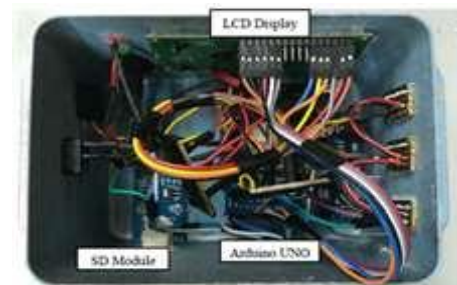
System verification step helps to evaluate the functionality of the system if its meet to the design requirement. It also reduces errors during calibration process and works as planning to build the complete working system. The first verification for this system is to build an instrumental posture measurement system in which IMU sensor, Arduino UNO microcontroller, SD card and LCD display are utilized in a complete system with other minor supporting electronic components. The second verification of this system would be to verify the system functionality whether or not the system is able to measure the posture changes in the subject correctly without any errors and minimal noise and successfully save the data into the SD card. This SD card should be able to be read by the computer for further analysis.

System testing is where the system functionality is verified by running a series of test. This instrumental system will be tested by applying the system to a subject where the subject is required to wear the system for a set period of time. First, the sensor is calibrated to a point of reference where a good posture is maintained before the system starts running. Then, the subject is order to move on its own desired motion the sensor will detect and collect data within the time period to the SD card. Finally, the data from the SD card will be transferred to the computer for analysis using software. Figure 5 depicts the scenario application of the system.



(a)

Figure 4(a). The finished product



(b)

Figure 4(b). The circuitry system

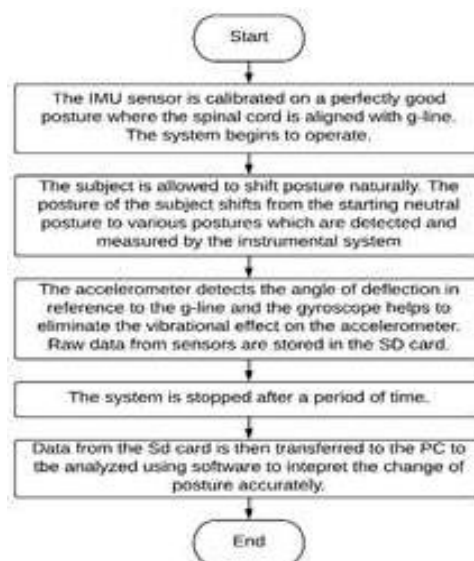


Figure 5. System testing on the posture monitoring system

### 3. RESULTS AND DISCUSSION

The trial for the system is conducted on a human to measure the static sitting posture in various types of posture deviation to verify the functionality of the system over a specified time. The data obtained will be post-processed using Excel to obtain a graphical representation of the data collected from posture deviation in static sitting position. The first trial is for the straight or ideal posture to obtain a constant reference value and wave pattern. Table 1 is a tabulated data for the measurements obtained during the static sitting posture deviation trial for the first 20 samples in which a straight sitting posture is maintained where the spine is aligned parallel with the g-line.

Table 1. Measured data for static sitting ideal posture

Acc. X	Acc. Y	Acc. Z	Gyro. X	Gyro. Y	Gyro. Z	Mag. X	Mag. Y	Mag. Z
2.00	125	-39	0	0.49	0.14	-269	344	369
3.00	125	-40	-0.49	0.42	0.42	-265	340	370
2.00	125	-39	-0.35	0.35	0.42	-268	346	364
2.00	126	-39	-0.14	0.35	0.21	-266	347	366
2.00	125	-39	-0.83	0.07	0.49	-268	344	364
3.00	125	-39	-0.42	0.21	0.35	-268	345	364
2.00	125	-40	-0.28	0.63	0.28	-267	348	361
2.00	126	-38	-0.35	0.42	0.21	-270	343	364
2.00	125	-39	-0.42	0.56	0.28	-270	345	362
2.00	125	-39	-0.7	-0.21	0.28	-268	345	365
2.00	126	-38	-0.7	0	0.49	-267	339	369
2.00	125	-39	-0.49	0.14	0.77	-269	341	366
2.00	124	-40	0	-0.21	0.21	-270	348	366
2.00	125	-39	-0.77	-0.35	0.49	-270	338	366
2.00	125	-36	-1.25	-1.11	0.35	-268	339	369
1.00	126	-39	-0.49	-1.18	0.07	-269	341	368
2.00	125	-38	-0.35	-0.56	0.28	-265	336	367
1.00	126	-37	0	0.14	0.35	-268	335	366
2.00	125	-38	-0.14	1.18	0.83	-268	340	366
2.00	125	-39	0	0.49	0.14	-269	344	369

The sampling rate from this trial is 81 Hz. The sampling rate is calculated by using (1).


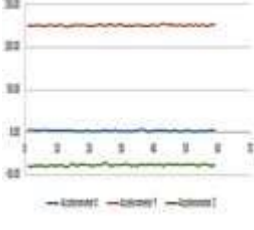
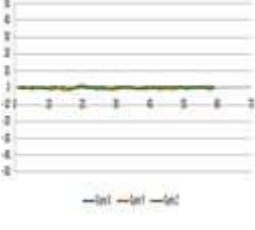
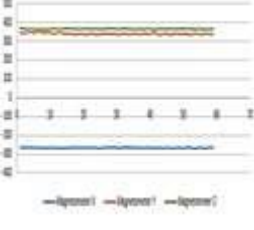

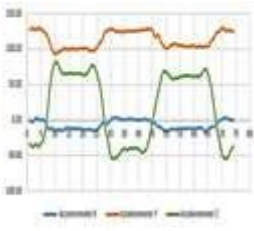
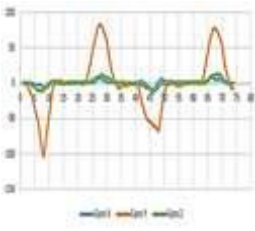
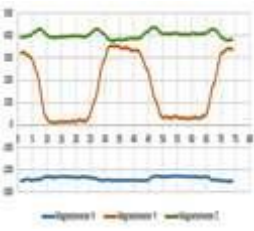

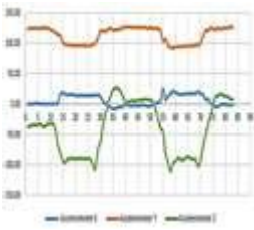
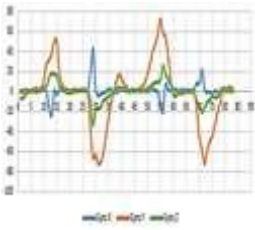
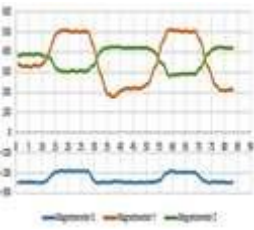

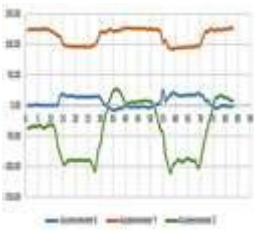
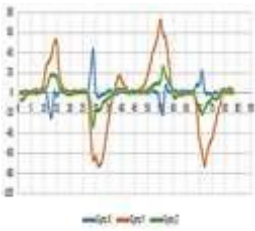
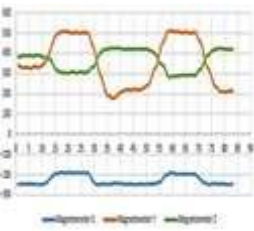


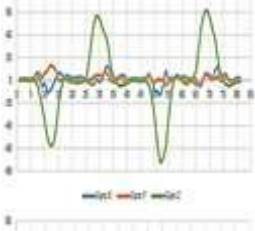
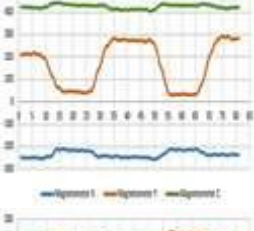




$$Frequency = \frac{No. \ of \ samples}{Time} \quad (1)$$

The second trial is to obtain the relative wave pattern for each of the 5 distinctive static sitting postures deviations with refer to the straight posture. The 5 pre-determined static sitting postures which include straight, lean forward, lean backwards, lean right and lean left is then repeated to determine its effect in the graphical pattern of the accelerometer, magnetometer and gyroscope. Each of the five postures is repeated twice consecutively for 3 seconds where the straight position is used as the interval before transitioning to the next posture. The graphs of measurement data from the sensor are tabulated in Table 2.

For straight posture, the shape of the spine is relatively straight and perpendicular to the surface of the ground and positioned parallel with the g-line. In this posture, the spine maintains its natural curve at the thoracic region. According to the graph of the measurement data, the sensor measures a straight sitting posture where the wave pattern stays relatively constant.

In summary to the data obtained and the result findings, accelerometer X responds to left and right leaning motions; accelerometer Y remain constant with sitting position; and accelerometer Z responds to forward and backward motion. As for gyroscope, gyroscope X stay still with no rotation motion at yaw axis; gyroscope Y create spikes on rotation motion at pitch axis for forward and backward motions; while gyroscope Z reacts on rotation at roll axis which falls on left and right leaning motions. As for magnetometer, only magnetometer X responds when it detects any changes in any position while magnetometer Y and Z are not deviating much from its original reading.

Table 2. Graph of the measurement data of accelerometer, gyroscope and magnetometer at different postures

Posture	Scenario	Accelerometer	Gyroscope	Magnetometer
Straight				
Lean Forward				
Lean Backward				
Lean Backward				
Lean Right				
Lean Left				

4. CONCLUSION

In conclusion, the proposed posture monitoring system was able to function properly and identify different postures from the study subject. The posture monitoring system can be further improved before it is ready to be applied on the ophthalmologist for human trial. In terms of mobility, the system can be further upgraded by implementing the application of the IoT to get rid of the wires from the developed system and the data can be acquired wirelessly. Furthermore, the numbers of sensors used can be increased and attached at



different benchmark of the body parts to widen the measure area on the study subject and get more accurate data on the posture measurement.

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**BIOGRAPHIES OF AUTHORS**

Kian Sek Tee received the B.Eng. degree (Hons.) in electrical engineering from Universiti Teknologi Malaysia, Malaysia in 1997, and the Ph.D. degree in mechatronic engineering from University Of Leeds, U.K., in 2012. He is currently an Associate Professor, as well as a researcher and a lecturer in Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia. His current research interests are industrial automation system, mechatronic system in gait monitoring, rehabilitation and exoskeleton.



Safinaz Binti Mohd Khialdin is a paediatric ophthalmologist and currently serves as both a medical lecturer and a consultant ophthalmologist in Department of Ophthalmology, Universiti Kebangsaan Malaysia Medical Centre (UKMMC), Malaysia. Her current research interests are paediatric ophthalmology and vision impairment in children.



Jaysuman Bin Pusppanathan received the B.Eng. degree (Hons.) in control and instrumentation engineering, master degree of electrical engineering (research) and the Ph.D. degree in electrical engineering from Universiti Teknologi Malaysia, Malaysia in 2006, 2010 and 2016 respectively. He is currently a researcher and a senior lecturer in Faculty of Engineering, Universiti Teknologi Malaysia. His current research interests are tomography for biomedical & process industry, sensors & transducers, drone technology.



Chin Fhong Soon received the B.Eng. degree (Hons.) in electronic system and medical electronic engineering and Master degree in electronic engineering from Institut Teknologi Tun Hussein Onn in 1998 and 2001 respectively. She received the Ph.D. degree in molecular and biomedical engineering from University Of Bradford, U.K., 2011. She is currently an Associate Professor and the centre head of Biosensor and Bioengineering Laboratory, MiNT-SRC, Universiti Tun Hussein Onn Malaysia. Her current research interests are medical engineering and bio-sensor technology.



Toong Hai Sam received the Bachelor degree in Marketing & Management from Wichita State University, USA in 1996 and the Master degree in Business Administration from Greenwich University, Australia in 2002. He received the Ph.D. degree in Technology Management from Universiti Tun Hussein Onn Malaysia in 2018. He is currently a senior lecturer and head of program in Faculty of Business, Communications and Law, INTI International University, Malaysia. His current research interests are Biomass Renewable Energy, Agricultural Light Sports Aircraft and Unmanned Aerial Vehicles (UAV), Big Data and Narrow Band Internet of Things (IoT), E-commerce solution for Small and Medium Enterprise.