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AN ACTIVITY MONITORING SYSTEM FOR ELDERLY

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ABSTRACT

Health declines due to insufficient physical activities especially the elderly. These may contribute in growing number of diseases related to insufficient physical activities. An activity monitoring system is designed to detect physical activities of an elderly in daily life and alert the user. This activity monitoring system is able to detect daily activities such as standing, sitting and walking. A multi-axial motion sensor is attached to trunk of the elderly. Kinematic data of the user could be used to assess the degree of activeness. These data provide proofs for the purpose of health monitoring, early warning and detection of falling due to poor health condition.

Keywords: activity, DAQ, elderly, IMU.

INTRODUCTION

The rapid increase in the number of the elderly is a global phenomenon. “Elderly has been defined as a chronological age of 65 years old, while those from 65 through 74 years old are referred to as “early elderly” and those over 75 years old as “late elderly” (Orimo *et al.*, 2006). In the development countries, there are several environmental factors which may discourage participation in physical activity such as violence, high-density traffic and lack of parks, sidewalk, recreation and sports activity.
Physical activity is defined as any bodily movement produced by skeletal muscles that require energy expenditure. Lack of physical activity has been identified as the fourth leading risk factor for global mortality. Moreover, lack of physical activity is estimated to be the main cause for 21–25% of breast and colon cancers, 27% of diabetes and 30% of heart disease. The term "physical activity" should not be mistaken with "exercise". Exercise, is a subcategory of physical activity that is planned, structured, repetitive, and purposeful in the sense that the improvement or maintenance of physical fitness. In elderly, physical activity includes leisure time physical activity (for example walking, dancing, gardening, swimming), transportation (e.g. walking or cycling), occupational, household chores, play, games, sports or planned exercise, in the context of daily activities.

Most people especially elderly do not realize that physical activity is very important in order to maintain their health. We believe that physical activity can improve the health of elderly. Hence, there will be a monitoring system for daily assessment of activities of daily living. Monitoring system is function as one of the tool to detect whether there is an activity or not in elderly lifestyle. In the past, ambulatory measurement of physical activity was based on various motion sensors such as pedometer. Therefore, activity monitoring with the ambulatory kinematic sensors is considered to be a good way to detect the elderly activities. Continuous activity monitoring is necessary to motivating the elderly to take more responsibility for their own health. In the busy world, activity monitoring can be the first step to prevent the elderly from the risk of chronic disease such as cardiovascular disease, cancer, chronic respiratory disease, diabetes and overweight and obesity. As saying said, “Prevention is better than cure”. Lifestyle related to disease can cause high costs in life whether direct or indirect. Direct means in healthcare costs while indirect due to lost work ability and early retirement.

PROBLEM STATEMENT

The lack of the physical activity in elderly may cause higher medical cost and reduced life expectancy. Life quality declines when health is ruined. This project proposes the development of an instrumental system to monitor daily physical activities of the elderly.

LITERATURE REVIEW

The related topics are basic terminology of human anatomy, definition of human locomotion, gait monitoring systems and recent activity monitoring systems.

Human anatomy

Anatomy is the study of the structure and relationship between body parts. Human anatomy deals with the way the parts of human, from molecules to bones; interact to form a functional whole. Human anatomical terms used to describe areas of the body, to provide orientation when describing parts of human anatomy. Basically, we will learn in a basic anatomical terms that will help us talk about the body in a way that is understood by professional in various fields.

Common terminologies regarding the human anatomy and human geometry are illustrated in Figure-1. The terminologies will be adapted throughout the paper.

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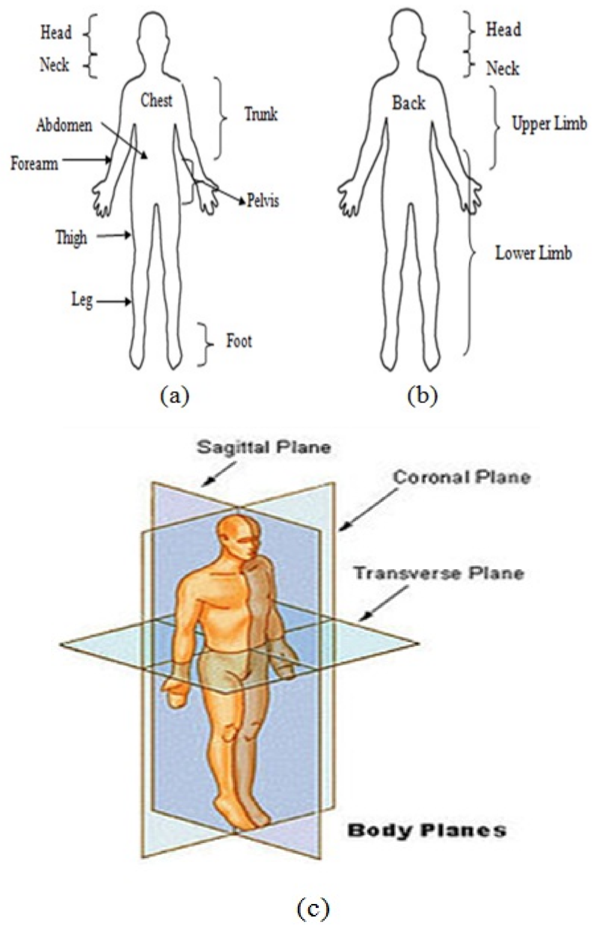


Figure-1. (a) & (b) Human anatomy, (c) Human geometry.

Human locomotion

Human locomotion is a study of gait or more specific as study of human motion. Human locomotion is defined as a translators progression of the body as a whole, produced by coordinated, rotator movements of the body segments as a result of combined and coordinated actions of neuro, muscular and skeletal system. Walking is one of the main studies that related to human locomotion. Walking is a cyclic process; therefore, the relevant information can be captured during one complete gait cycle, which is the time between successive foot contacts of the same limb. Figure-2 shows the phases of gait cycle during walking. The gait cycle has two basic components, the stance phase and the swing phase. Stance is the time when the foot is in contact with the ground, while swing denotes the time when the foot is in the air.

Human gait is defined in eight descriptive stages. The stages are initial contact, loading response, mid-stance, terminal stance, pre-swing, initial swing, mid-swing and terminal swing (Perry, 1992). For normal gait, cycle begins when foot strikes the ground and ends when it strikes the ground again.

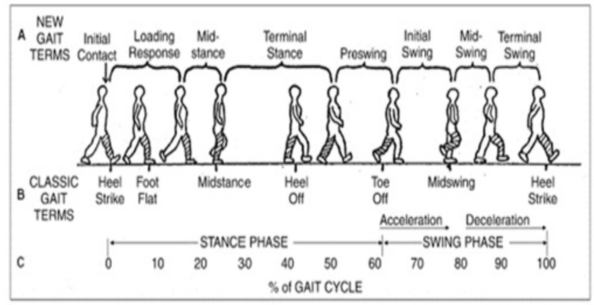


Figure-2. The phases of gait cycle during walking.

Gait monitoring systems

Gait monitoring systems is the system that monitors a particular way or manner of moving on foot. This system is likely one of the most important elements, since it allows the analysis of symmetry and comparison with the parameters known to be characteristic for healthy individuals when walking (Winter, 2009).

Activity monitoring systems

Table-1 shows the literature review of activity monitoring system for elderly. Key items such as type of sensor, sensor position, activities being studied amd cause of diseases are listed and compared. Inertial Measurement Unit (IMU) is the common choice for the monitoring of kinematic data. They are strapping their sensor position at different location of human body such as trunk, thigh and calf. The most popular activity monitoring systems are detecting the static postures such as sitting and standing and dynamic locomotion like walking. The impact of lack of physical activity is chronic disease that is cardiovascular disease. The entire previous systems project target the user of the system is elderly that is 65 year and above.

Table-1. Previous activity monitoring systems.

Author	Sensor	Location	Activity	Disease
(Najafi et al., 2003)	IMU DAQ	Chest	Sitting Standing Lying walking	Chronic
(Tanaka, Motoi, Nogawa, and Yamakoshi , 2004)	IMU	Trunk Thigh shank	Sitting Standing Lying Walking	Cardivacular
(Motoi et al., 2005)	IMU	Trunk Thigh Calf Forearm	Standing Sitting Walking	Hemiplegia
(Mattila et al., 2008)	Acc*	Lower back Upper/lowe r arm	Sleep Passivity Light activity	Cardivascular Diabetes Mental
(Yuting, Markovic, Sapir, Wagenaar, and Little)	IMU	Chest Thigh	Sitting Standing Lying Walking Transitions	Chronic Parkinson

METHODOLOGY

System development

The hardware designed has to be simple and compact in size. Figure-3 shows the proposal of the system in block diagram. It is mainly a Data Acquisition (DAQ) system. The input stage consists of the Inertial Measurement Unit (IMU-6DOF) sensor. IMU consists of triple axis accelerometer (ADXL335) and gyroscope (IDG500). These sensors are purposely to detect and analyze human movement based on kinematics motion. This activity monitoring device using accelerometers due to measurement angles in accelerating movements. The gyroscope is largely adopted to improve the accuracy of angle measurements. In process, the Arduino microcontroller board is function to control the whole system. The Arduino microcontroller will be programmed to process both measurements and get the output for the next process. The output for the system is where the data will store in a secure digital (SD) card. The Arduino microcontroller also will be programmed to read the time from the system is on until the system is off. It is known as elapsed time. The elapsed time will be display at the character Liquid Crystal Display (LCD) – 16 x 2. Besides that, A red LED will flash if the system is turned ON.

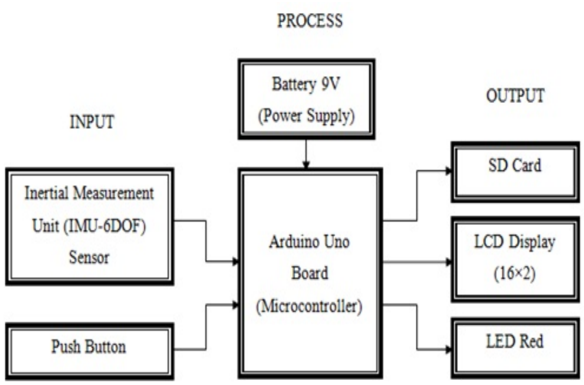


Figure-3. Block diagram of the activity monitoring system.

Figure-4 shows the system operation sequence of this project. The system starts when switch on the power supply. Then the system will initialize the SD card. If the SD card is present, system go on with the push button being triggered on to active the DAQ system. Otherwise the system will repeat until SD card detected. In DAQ, IMU sensor is read. The sensor data would be saved in the data storage. Relevant status messages would be displayed. The user has to stop the data acquisition process manually by pressing the push button again.

Figure-5 shows the overview of key components. They are Arduino Uno board as the microcontroller, Inertial Measurement Unit (IMU 6DOF), a push button and a battery (9V), a SD Cards breakout board and a CD card, LCD 16x2 and a LED as the status indicator.

The sampling rate of the DAQ can be determined by using the formula shown below. The sampling is tuned at 5Hz.

$$Frequency(Hz) = \sum Data / \sum Elapsed\ Time\ in\ sec$$

A fully assembly of the DAQ is illustrated in Figure-6.

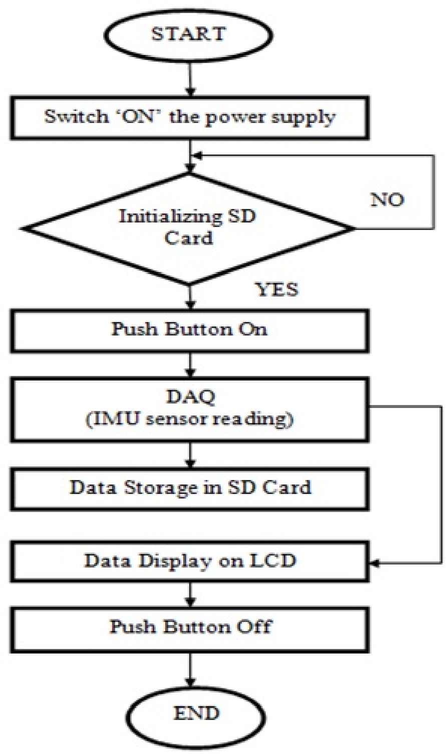


Figure-4. System operation sequence.

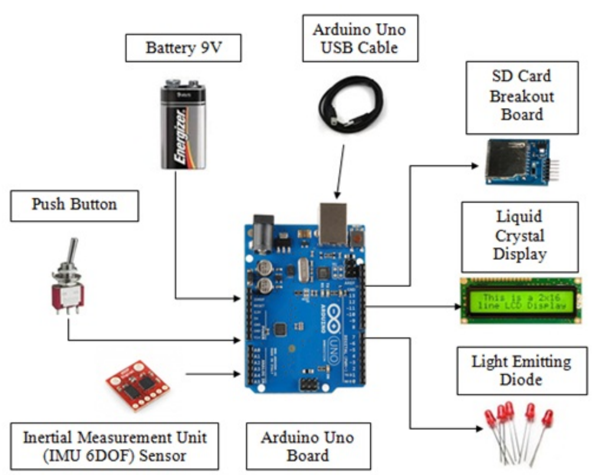


Figure-5. Overview of component project.

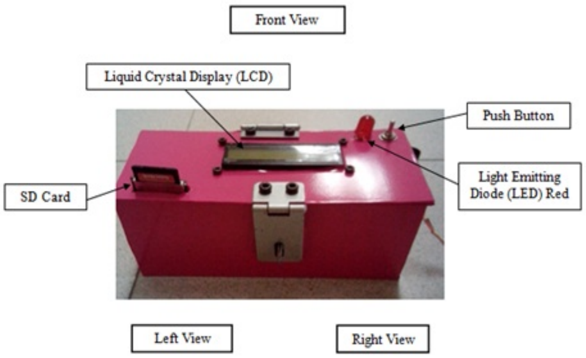


Figure-6. Prototype for DAQ assembly and test.

RESULT AND ANALYSIS

System setup

The system setup is illustrated in Figure-7. The IMU6DOF sensor is placed at the trunk of human body. Trunk or torso is an anatomical term for the central part of the many animal bodies including human from which extend the neck and limbs. The trunk includes the thorax and abdomen. The IMU6DOF is specifically placed at the thorax part which is upper sternum. The sternum or breastbone, in vertebrate anatomy, is a flat bone that lies in the middle front part of the rib cage.

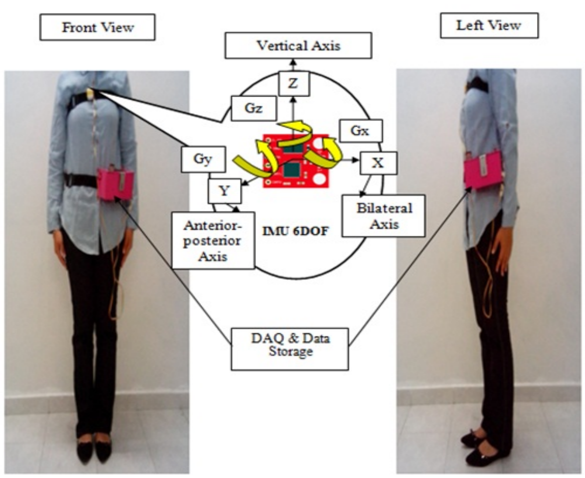


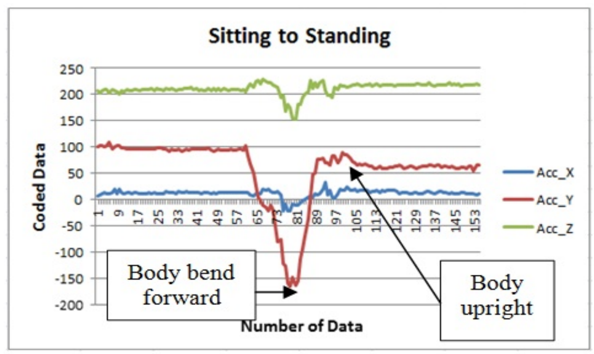
Figure-7. System setup.

Human trials

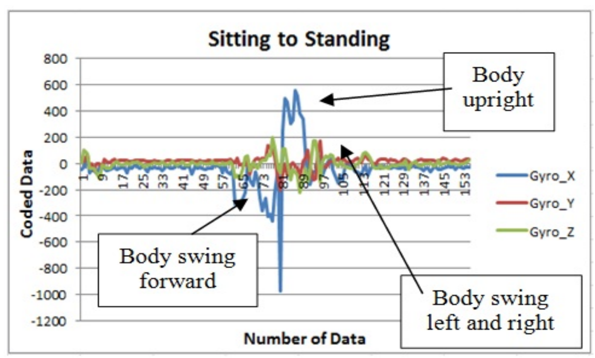
A volunteer has given her consent to perform the human trials. The bio data are: 24 years old, weigh 55kg and height 155cm. There is no reported health issue on the subjects. Normal activities such as standing, sitting and walking are investigated.

The trials are carried out in accordance with the normal activities to be monitored, i.e. sitting, standing and walking. Figure-8 shows the result when the subject is sitting to standing while Figure-9 shows the result when the subject is standing to sitting. Figure-10 shows the result when the subject is walking normally.

Figure-8(a) shows the signature of acceleration in bilateral axis, anterior-posterior axis and vertical axis when subject is sitting to standing. Human body will bend forward and quickly body upright against the gravity while standing. This changing of postures could be seen in anterior-posterior axis (Acc_Y). While Figure-8 (b) shows the signature of rotational in bilateral axis, anterior-posterior axis and vertical axis when subject is sitting to standing. According to rotational bilateral axis (Gyro_X), it show that human body will swing forward and quickly body upright against the gravity while standing. At the same time, human body also will swing to the left and right as shown in rotational anterior-posterior axis (Gyro_Y).



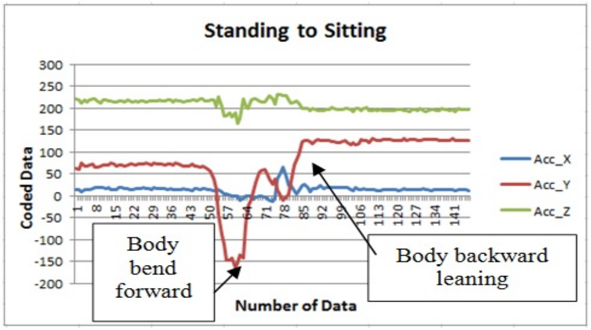
(a)



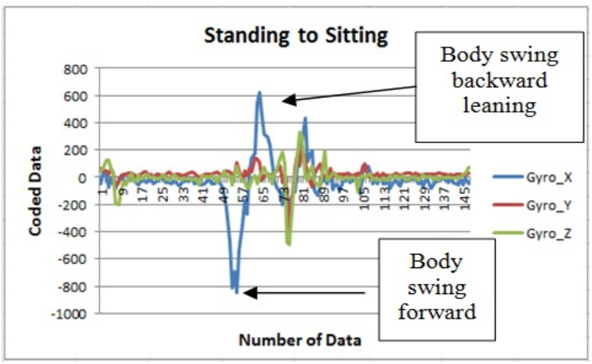
(b)

Figure-8. Sitting to standing (a) accelerometer, (b) gyroscope.

Figure-9 (a) shows the signature of acceleration in bilateral axis, anterior-posterior axis and vertical axis when subject is standing to sitting. Normal activity sitting that related with elderly is backward leaning. This type of postures preferred for resting. From standing postures, human body needs to bend forward in order to sit on the chair and sit backward leaning posture as shown in anterior-posterior axis (Acc_Y). Then, Figure-9 (b) shows that the reading for rotational bilateral axis (Gyro_X) is swing forward and swings backward leaning against the chair. It's shown that the human body is swinging in rotational in vertical axis (Gyro_Z). It happened when elderly adjust the seat more comfortable. From this pattern, it is proved that there is activity occurred.

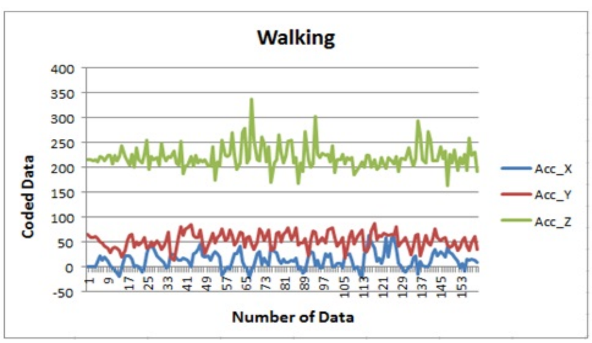


(a)

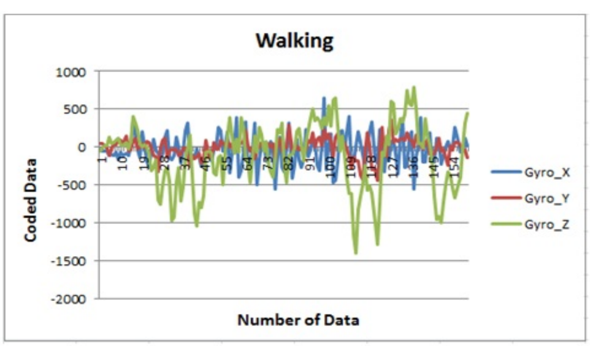


(b)

Figure-9. Standing to sitting (a) accelerometer, (b) gyroscope.



(a)



(b)

Figure-10. Normal walking (a) accelerometer, (b) gyroscope.

Figure-10(a) shows that the signature of acceleration in bilateral axis, anterior-posterior axis and vertical axis when subject is walking. Based on vertical axis (Acc_Z), it is obviously explain that when human is walking the heel is strike, the coded data will increase while when the foot is flat on the floor the coded data reading will slightly decrease. Then, Figure-10(b) shows that when walking the three axes are active. It is because human body will swing to the left and right, swing forward and backward and also rotational in vertical axis. These concepts could be proved in human locomotion. Human locomotion is study of gait. Gait cycles are divided to two phase such as stance phase and swing phase. Stance is the time when the foot is in the air, while swing denotes the time when the foot is in the air. From this pattern, it is proved that there is activity occurred.

CONCLUSIONS

An activity monitoring system is designed by using a motion sensor. It is wearable and compact in size. The system could acquire kinematic data of the user in daily life. Further analysis of the data reveals the daily activities of the user.

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