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A Real-Time Monitoring of Warded Patient Via Motion Capture System

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ABSTRACT

The Microsoft Kinect Xbox 360 (Kinect) is a potentially system to monitoring and preventing further injury of a patient due to their improper posture or movement. In this paper, we purpose to a specific case study: patient who cannot sit and patient with standing, walking and running pain. In this experiment, movement performed series was captured by duplex Kinect and analysis has been done by using MATLAB R2014b. Meanwhile, the GUI system will give the real time feedback with alarm light and sound either their motion was dangerous or not that was prescribed earlier by medical staff. The combination of software and tools will indicate joint locations and angle of hip knee and ankle, it also show that the result can be further improved. The results show that this system has a great potential as a clinical approach tool to monitor and measure motions of patients.

INTRODUCTION

Since manual observation alone is not sufficient to monitor a patient who has been laid in bed with their decay in physical and cognitive ability (A. A. P. Wai et al, 2010), computerized real-time motion capture has been adopted to effectively monitor a patient to prevent them from unforeseen consequences.Conventionally, fall detection tools such as accelerometer and tilt sensors are attached to the patient's body to the emergency situation (A. Wickramasinghe et al, 2016) (A. Ejupi et al, 2016). However, this detection tools are less comfortable since it requires patients to wear them and that the patients are always tend to leave it aside. Another clinical approach tool used to monitor them is by installing a video camera in their bed space (P. Kittipanya-Ngam, 2012). This approach however is not preferred since this device is invading patient's privacy and might cause physical discomfort since it captures a routine state of the room and the patients' behavior.

The main objective of this work is to give a better alternative this patient monitoring purpose. For that reason, the aims are to develop a markerless infrared-based motion capture system with a proper Graphical User Interface (GUI) capable of giving a warning signal light and an emergency alarm system to the intended medical staff. The motion capture system is based on an in-house developed Duplex Kinect Xbox360 camera system that performs analyses on patients' motions based on 3D angle values of hip, knee and ankle in real-time.

Another requirement for the system's GUI is to have it flexible enough for the medical staff to set the system sensitivity towards specific patient's postures. Two patients with different monitoring needs are presented in this work. The real-time monitoring system is expected to convey accurate and efficient information of patients' harshness of movements based on the individual patient's ability prescribed earlier.

METHODOLOGY

Subjects

Based on the objectives of this work, two patients with different injuries were selected. The first patient (age: 22 yrs, height: 168 cm, mass: 67 kg) was having a Coccydynia injury while the other patient (age: 24 yrs, height: 155 cm, mass: 58 kg) was having a Thoracic Spine injury. Two sitting postures, two lying postures and two around the bed positions were considered as generalized postures as shown in Fig. 1. A total of six postures were involved with both patients.

For the first case of Coccydynia injury, the monitoring system should have been able to give a yellow (suspicious) alarm when the patient in standing, walking or even jogging beside the bed, but immediately changed to red (dangerous) alarm when the patient started to sit on the bed.

For the case of Thoracic Spine injury, the monitoring system should have been able to give a yellow (suspicious) alarm when the patient in sitting position but immediately changed to red (dangerous) alarm when the patient was standing, walking or jogging beside the bed.

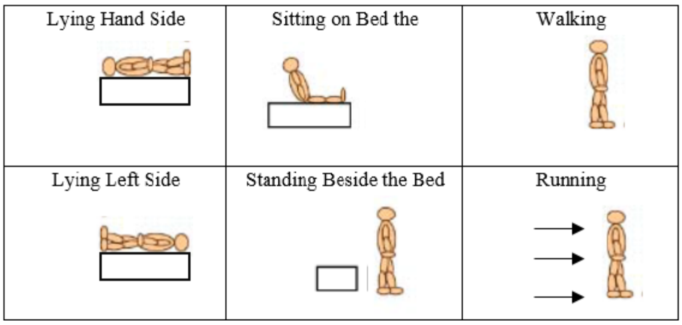

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Fig. 1 List of postures tested on Coccydynia and Thoracic Spine patients.

Visual sensors

Two Kinect Xbox360 were applied to capture the patient movement. Data from both depth sensors and color cameras on Kinect system was manipulated to provide 3D structure information of human motion (A. Ejupi et al, 2016). From 20 joints captured by Kinect, angles of three most relevant joints were selected to distinguish between all six postures. The angles cumulated on the measurement of all six postures were taken from hip, knee and ankle joints.

Algorithm platform

MATLAB R2014b software was used as the programming platform for this monitoring system. The built in image processing toolbox allows us to capture the motions of the human body and translate it into 20 body joints 3D coordinates.

A precise and efficient in-house algorithm was written to translate the data into angle values and determine the posture of the patient in real-time. The concept of Cosine Rule was applied in order to find the angle for the each joint. The sample formula is applied to obtain the joint angle as shown in Eq. 1

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

Where A is the angle of knee, b is knee to ankle segment (length of shank), c is hip to knee segment (length of tight) and a is the distance between hip and ankle.

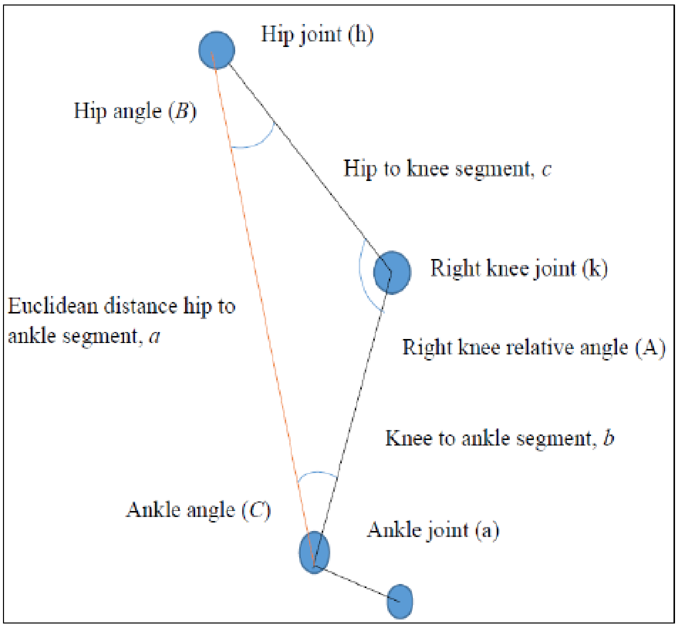

Fig. 2 Applied of Cosine rule on knee joint

Another algorithm was also developed to create the GUI for the system. In time-synched, a graph of cumulative angles versus frame number appeared on the screen while the algorithm determined the exact posture of the patient and report it to the medical staff in terms of either green (safe), yellow (suspicious) or red (dangerous) light, together with a proper alarm sound. Warning alarm or clinical alarm is an important indicator for medical staff to monitor any changes of patient's motions.

Other than that, it allows the medical staff to provide fast response to any suspicious and dangerous movement of their patients. Fig. 3 shows the flowchart on how the system behaves towards the different movement of the patients.

These features were meant to provide medical staff the real-time aid to monitor the posture of patients in the comfort of their working desk. Significantly, it reduces the needed of human intervention and labour-intensive continuous monitoring would not be needed.

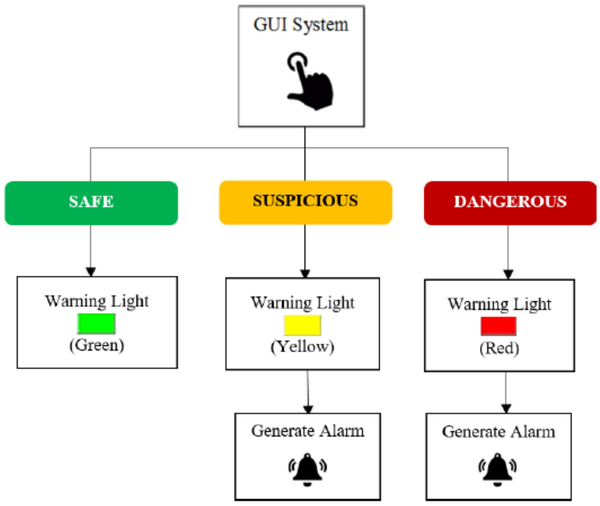

Fig. 3 Alarm system structure based on the patient motion monitoring

Data processing and analysis

The patients' posture based on the measured cumulative angles were described in Fig. 6 and 7. The figures indicate that each posture was represented by a specific range of cumulative angle. This pattern ensures the accuracy of the posture determination process.

In order to differentiate between the two case studies, sitting on the bed was set as a dangerous posture for Coccydynia patient while standing, walking and running are a dangerous movement for a Thoracic patient. In contrast, a suspicious movement was set to the posture of standing, walking and running, while sitting on the bed was considered as a dangerous posture for a Thoracic patient. Movements other than that were declared as a safe movement for both patients.

Fig. 4 shows the data flow analysis within the monitoring system. The framework starts with the data acquisition process via dual Kinect sensors. The sensors are directly connected to MATLAB toolbox where the data is translated into 3D coordinates of 20 main body joints. Once the data acquisition system and the MATLAB software are properly connected, the GUI environment is started. This is where the medical stuff is acquired to determine the severity (green, yellow and red) of all six postures, based on the specific patient being monitored.

Once done, the real-time monitoring of the patient posture movement takes place. Warning light starts to alter between green, yellow and red depending on what posture the patient is having. The sound alarm will only triggered when yellow or red light appear. Low and high-intensity sound alarms are triggered for yellow and red light indications respectively.

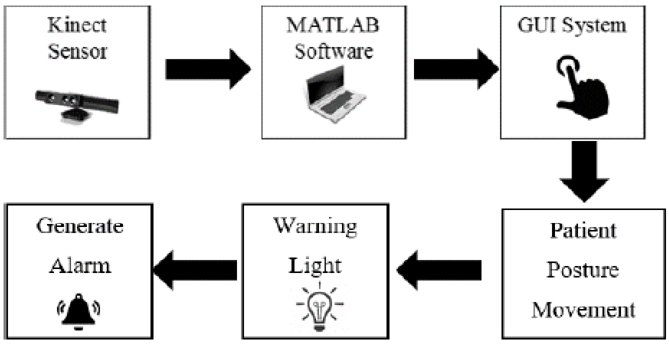

Fig. 4 Illustration of data analysis framework

RESULTS AND DISCUSSION

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In order to evaluate the performance of the monitoring system, two types of injury with different posture severities were chosen as case studies. The objective is to assure that the monitoring system is capable of producing an accurate signal for the different motion of various patient conditions.

Basically, Coccydynia is a pain felt in the last bone at the bottom of the spine (tailbone). Awkward sitting posture for long period of time can become an injury on coccyx or the surrounding muscles and ligam- ents due too much pressure put on the coccyx.

Meanwhile, Thoracic Spine is a refers to the upper- and middle-back and connects to the lumbar spine. The level of Thoracic Spine injury may involve trunk, legs, and pelvis organ. The patient was having a problem to stand up straight which causes by flexes Thoracic Spine due to gravity against bodies and pushes down the shoulder.

Case 1: Coccydynia (Tailbone Pain)

Coccydynia is typically felt as a localized pain that usually worsens when sitting or doing any activity that puts pressure on the bottom of the spine. Fig. 5 shows the posture severity indicator for Coccydynia patient. This is the input acquired to be filled by the medical staff into the GUI. The green warning light was activated, indicating a safe movement when the patient was lying down or lying left side. At the suspicious movement, which were standing beside the bed, walking and running, the yellow light was activated. The red light was activated when the patient was sitting which indicated a dangerous movement situation.

Fig. 6 shows a sample of cumulative angle variation for a Coccydynia patient motion set. The graph shows clearly the angle range difference between standing, walking, running and sitting posture. These differences were used to differentiate all six postures and the alarm type associated to the posture. In this case, from zero to 65 frame index shows the angle of standing was between 1650 to 1750. While for 66 to 125 frame index shows the angle of walking was between 1200 to 1800. Then, for 126 to 210 frame index shows the angle of running was between 550 to 1700. Dangerous movement showed when the patient was sitting which is shown in the last 90 frame index where the red light was shown and trigger the emergency sound.

Case 2: Thoracic Spine

Thoracic pain known as paraplegia is injuries usually affect the trunk and legs. It's comprised of twelve thoracic vertebrae that are located between the cervical and lumbar spine. Therefore, most Thoracic Spine patients can only stand in a standing frame or walk with braces.

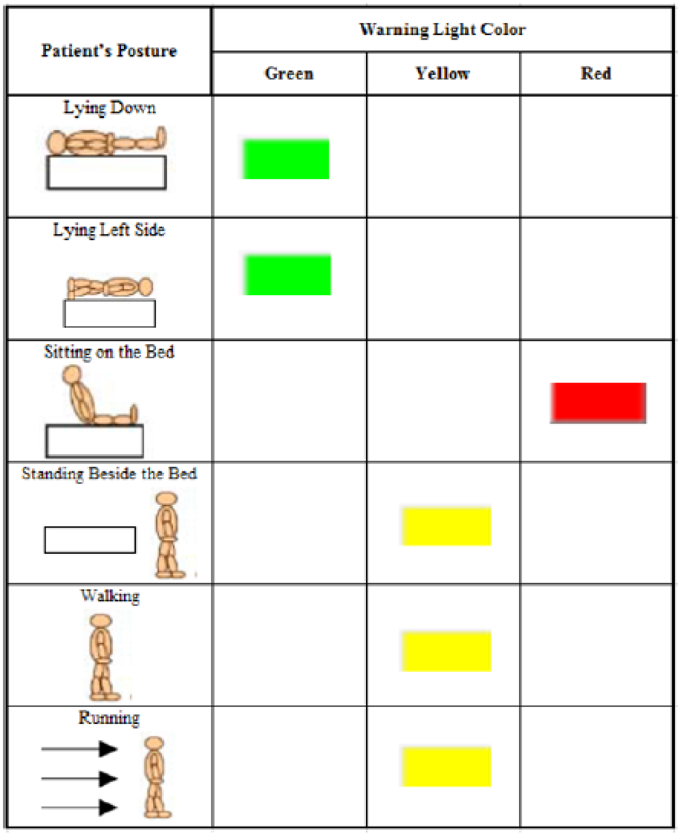

Fig. 5 Posture severity indicator for Coccydynia patient

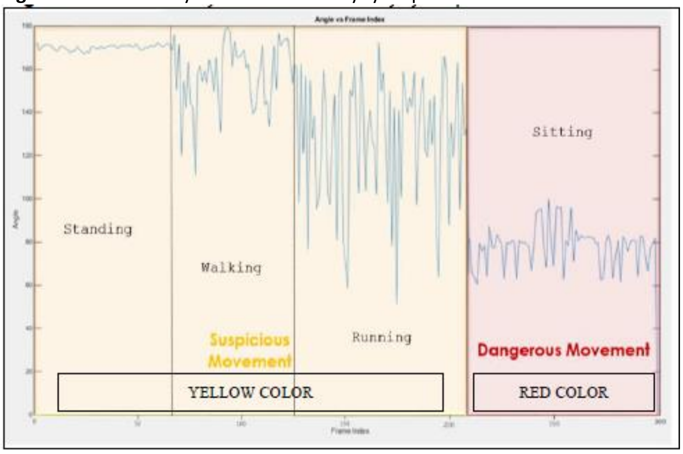

Fig. 6 Sample of cumulative angle variation for a Coccydynia patient motion set.

Fig. 7 shows the color selection of medical staff based on the condition of the Thoracic patient. The green warning light was activated to indicate a safe movement when the patient was lying down or lying left side. At the suspicious movement, which was at sitting position, the yellow light was activated. The red light was activated when the patient was standing beside the bed, walking and running, which indicated a dangerous movement situation.

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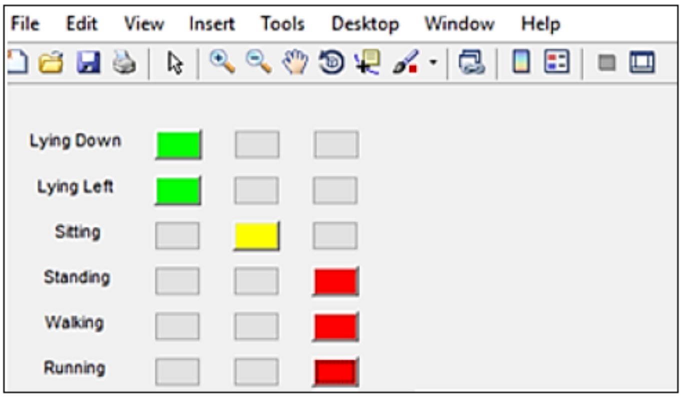

Fig. 7 Color selection by medical staff based on conditon of Thoracic patient

Fig. 8 shows a sample of cumulative angle variation for a Thoracic patient motion set. Thoracic Spine patient was shown to be in suspicious movement condition at the first 95 frame index and it produced a warning sound with angle 550 to 800. Dangerous movement is shown for the last 96 to 300 frame index and brought red light warning and triggered the emergency sound. From 96 to 175 frame index, it is shown that the angle of standing for the patient was between 1650 to 1750. While for 176 to 225 frame index, the graph shows the angle of walking is between 1200 to 1800. Then, for 226 to 300 frame index, it shows the angle of running for the patient is between 550 to 1700.

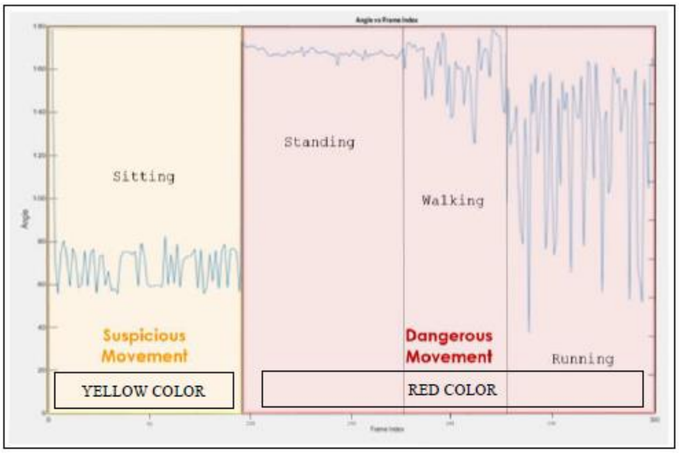

Fig. 8 Sample of cumulative angle variation for a Thoracic patient motion set

CONCLUSION

The developed monitoring system has shown a great potential as a clinical approach tool to monitor and measure motions of warded patients either at home or hospital. The system's algorithm is capable of investigating clinically relevant movements and triggering the emergency alarm system in a time-sync manner. However, for further development, it needed to increase the number of joint analysis and outlook view for more accurate and stable outcome. With balanced efficiency consideration of real-time analysis, the biomechanics analysis of this system is expected to be more robust with the introduction of joint velocity and acceleration based posture determination.

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