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Mark-Less Recognition System Using Kinetic Depth Camera for Sleep Apnea Detection

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Abstract:

The experimental aims to develop the mark-less recognition system which can detect and monitor the sleep apnea by detecting any abnormal respiratory cycle. The experiment consists three main hardware part such as Kinect camera, fingertip Oximeter, shield and Arduino. The Kinect depth camera was used to observe sleep apnea symptom, fingertip oximeter to detect pulse rate and 3G+GPS shield to make emergency call. Kinect depth camera was records respiratory rate connected with special sensor used to measure oxyhaemoglobin level. Meanwhile, fingertip oximeter was detected the pulse rate and 3G+GPS shield was connected to Arduino to send and receive of pulse rate measurement and respiratory rate and make emergency call if the result in out of measurement range. This mark-less recognition system would work as complete system to detect sleep apnea, make documentation and triggered alarm in the emergency case.

Keywords:- *breathing; blood pressure; sleep apnea; Arduino; shield*

1. INTRODUCTION

The Sleep apnea also known as obstructive sleep apnea is most common respiratory disorder during sleep [1]. Sleep apnea caused creasing in the breath during more than 10 seconds and occurs more than five times per sleep hour [2]. The sleep apnea patients did not aware their problem on the morning while these patients had suffered difficulty in breath during their partial wake up.

Obstructive sleep apnea is affects 17% of women and 34% of male and most cases are undiagnosed [3]. Meanwhile, approximately 2-5% of population had meet minimum diagnostic criteria such as snoring, witnessed apnea and excess daytime sleepiness [4]. In France, obstructive sleep apnea prevalence was 4.9% among French general population aged over 18 years old [5]. The obstructive sleep apnea contributed in many complication and morbidities while cardiovascular diseases, impaired neuropsychological ability and stroke also correlated to obstructive sleep apnea [6,7,8].

Sleep apnea is detected using different methods and processes and treats with different therapies. The techniques for sleep apnea detection and treatment such as continuous positive airway pressure (CPAP), automatic detection from single lead ECG, smart pillow system and micro-electro mechanical system (MEMS) sensor based device [9]. Kiely et al. found nasal CPAP had reduced several symptoms such as daytime sleepiness, restless sleep, heartburn, nocturia, headache, enuresis and nocturnal sweating among obstructive sleep apnea patients [10]. Meanwhile, Almazaydeh et al. had introduced a neural network system through SpO2 signal features in obstructive sleep apnea and the result showed this method is useful in sleep apnea detection with high performance and improved accuracy of 93.3% compared with existing method [11].

The experimental aims to develop the tool which can detect and monitor the sleep apnea by detecting any abnormal respiratory cycle. The experiment had been combined three hardware instruments such as Kinect camera, fingertip oximeter and 3G+GPS shield in observation, pulse rate detection and make emergency call. This system is combination work between engineering with biomedical to produce logic systematic device that help in reducing the mortalities among sleep apnea patients.

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2. METHODOLOGY

The experiment consists three main hardware part such as Kinect depth camera, fingertip Oximeter, shield and Arduino. Kinect depth camera was connected to computer directly and the doctor can manipulate X-ray images and medical scans from within sterile environment without risking contamination. The Kinect depth camera was projected infrared light through diffraction grating to create random pattern of little specks scattered in front of camera. Kinect depth camera created depth image of its environment with monitoring the distortion in this pattern. The computer algorithms was recognized respiratory movements from this depth map and correlated with objects. The depth and shape masks was applied to focus sensor on specific area to obtain more precise measurements. In additions, distance between patients and Kinect camera should not exceed 140 cm, otherwise the accuracy would affect the biomedical applications. Besides, Kinect optics sets was added to help in modify light pattern.

Meanwhile, fingertips oximeter part was used as blood-oxygen monitor which showed oxygen percentage in arterial blood especially haemoglobin. The fingertip oximeter was operated with two LEDs and photodiode. The oxyhaemoglobin was absorbed more infrared light while deoxyhaemoglobin absorbed more RED light. The emitted light of LED flashes almost 30 times per second. Furthermore, the oximeter also measured pulse rate (PR). The PR was detected based on number of LED cycles between successive pulsatile signals and average out over similar variable period.

The 3G with GPS Arduino shield was used to record a message and make a call to reach emergency station. This shield had communicated with high speed WCDMA and HSPA cellular networks. This communication enabled possible creation of next international interactive projects.

The patients would wear the oximeter in their finger before going to sleep. The oximeter read the pulse rate from patient fingertip and signal sent to 3G+GPS shield once pulse rate drop rapidly. This Arduino shield contained SIM cards automatically call emergency station or any patients relative.

Kinect was used for developed method with using marker less tracking system to analyze natural variations in chest wall configuration during breathing. In emergency case, alarm system was work inside room to wake up the patients.

The Arduino was programmed and connected to the shield which activate once received signals from fingertip oximeter in terms of voltage. Output voltage for healthy person was 600mV while sleep apnea patients had output voltage with range of 300mV. Low output voltage was not enough voltages to turn on the shield and place emergency call. The output voltage was increased with operational amplifier circuit to achieved desired output voltage. Hence, the desired output voltages was connected to the shield input to turn ON and place emergency call when voltage level or low oxygen level.

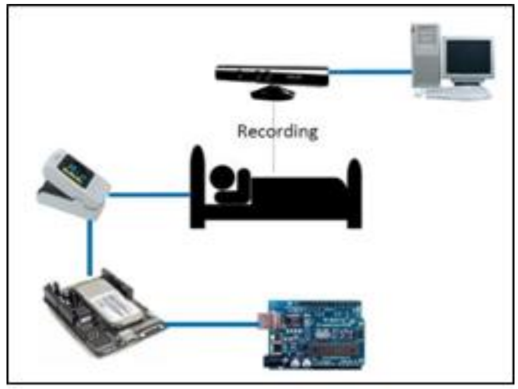

Figure 1. The mark-less recognition system using Kinect system.

3. HARDWARE IMPLEMENTATION

In this study, ATmega328** was used to communicate with computer, another microcontroller or another Arduino. The Arduino was programmed with Asduino software. The Arduino was connected with the shield. The shield was communicated with high speed WCDMA and HSPA cellular networks. This communication enabled possible creation of next international interactive projects.

The pulse oximeter sensors also used to detect oxygen percentage in arterial blood. This sensor contained LEDs that emit red light with approximately 660nm wavelength and infrared light with approximately of 905nm wavelength. In additions, Microsoft Kinect was used webcam-like cameras to remotely track user's movement without any touch controller. Kinect was used to build a small marker-less tracking system.

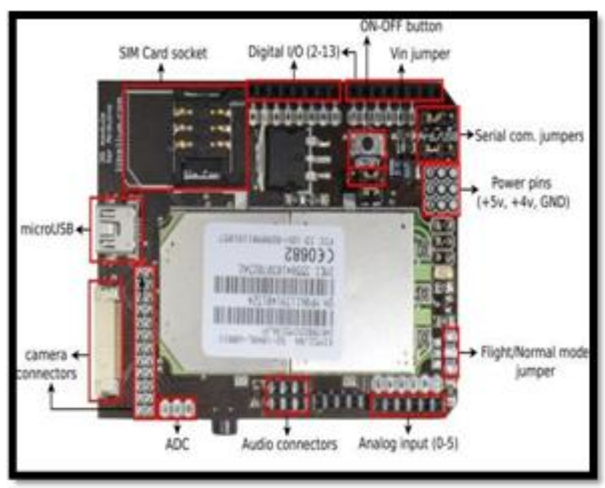

Figure 2. 3G shield PCB.

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4. SOFTWARE IMPLEMENTATION

MATLAB software was used with Kinect to make good interfacing for respiratory motion tracking system.

Figure 3. Normal status was observed when the patient is breathing normally.

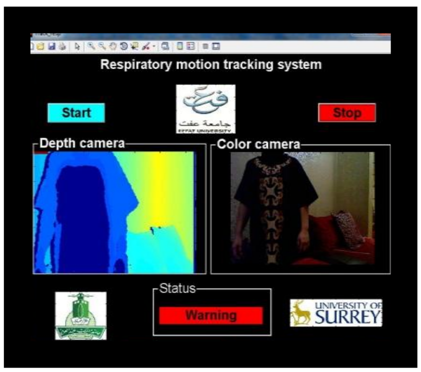


Figure 4. The "Warning" status was showed if any abnormality in patient breathing.

Initially, Kinect was start to make the record to detect the patient breath pattern. If the patient had normal breathing, the status showed "Normal" and "Warning" was showed once there was abnormality in the patient breathing. Kinect was captured depth 10 times when the patients was stopped breathing or chest was not moving so emergency call is needed.

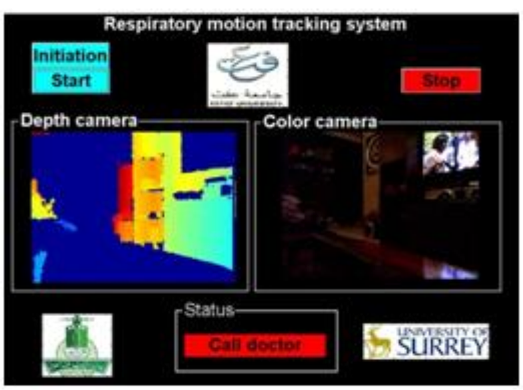


Figure 5. "Call doctor" notification appeared when patient was stopped breathing or chest was not moving.

5. VERIFICATION AND VALIDATION

In this study, the marker-less tracking system of torso upper part was developed for medical application. There were many experiments to determine Kinect depth camera accuracy such as random and backward displacements, forward displacement two sheets experiment and real volunteer test. The result was in form of video scan and analyze by using MATLAB software.

The Kinect depth camera showed depth by varying the video recorded colour. An object close to the depth sensors lower boundary is appeared bright red. As the object moves backward, the colour gradually became orange then yellow until sensor's rear boundary, the colour was appeared as bright yellow colour.

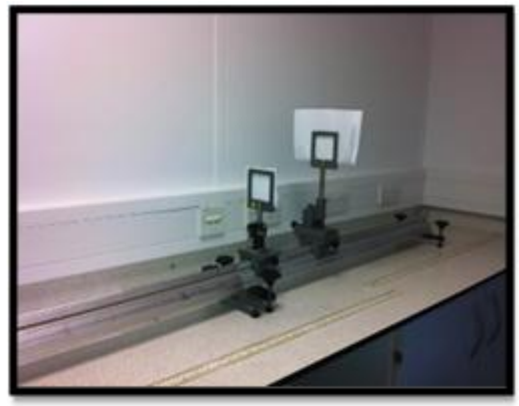
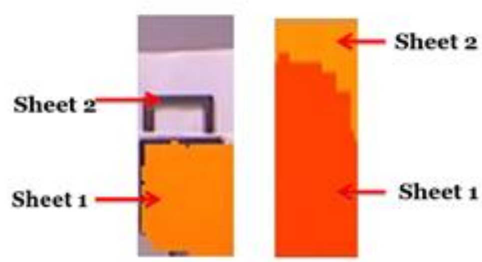


Figure 6. The different between sheet1 and sheet2.

Two paper sheets were placed in front of Kinect depth camera with different distance. The first sheet (sheet1) was placed at 98cm and second paper sheet (sheet2) was at 122.5cm.

There was limited range for Kinect depth camera as minimum and maximum which the camera was detected objects as coloured surface. Initially, front sheet was coloured and had been picked up by sensor depth because second sheet was outside range for the camera.



(a) (b)

Figure 7. (a) Sheet1 was detected by Kinect camera and sheet2 was out of range and (b) two sheets were inside the range.

MATLAB software was used to generate the chest frames with respiratory cycle, colour intensity frames and showed differences between each frame colour depended on the depth between Kinect camera and objects.

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The solid surface was placed range between 80cm and 150cm from Kinect camera and captured 30 frames of video from sensor depth. Difference displacement between Kinect and surface showed colour intensity in the image from Kinect camera depth changed as object moved further away.

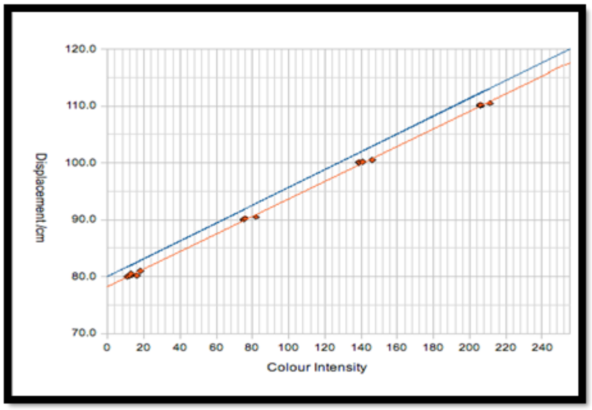

Figure 8. Each dot represented colour intensity for the surface at certain depth.

For this experiment, the limit was used between 800mm and 1200mm. Based on Figure 8, blue line showed expected result which passed through (0,80) and (255, 120). Meanwhile, red line showed actual result which consistently below blue line suggested there was systematic error during the experiment.

For more realistic technology applications, the human volunteer test was done which volunteer stand or lying on the Kinect camera and record short video of volunteer chest with normal breath. After the scan, the video was analyzed in MATLAB to produce 3D graph. Figure 9 was represented the surface in a mathematical model.

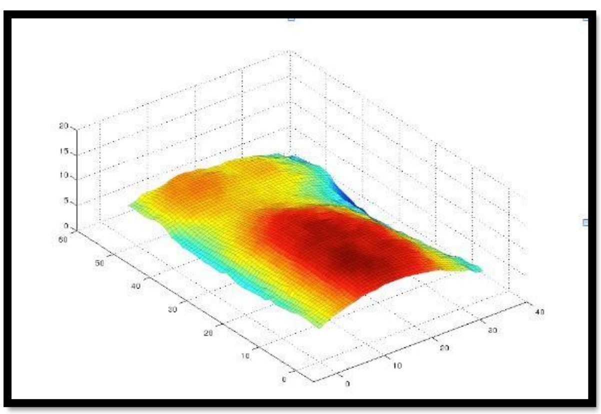

Figure 9. The graph was represented single frame from the video.

6. RESULT

In this experiment, distance between Kinect depth camera and objects changed with different times. The distance ranges were different between 5cm and 10cm with changed of 1mm and 0.5mm.The small changes was used due to respiratory cycle is undertaken with small movement on the patient chest.

The method based on distinguishable difference in colour intensity with changed in distance between camera and objects which also affected depth resolution. Therefore, each surface distance was calculated by average of depth information for each pixel in the surface as shown in Figure 10.

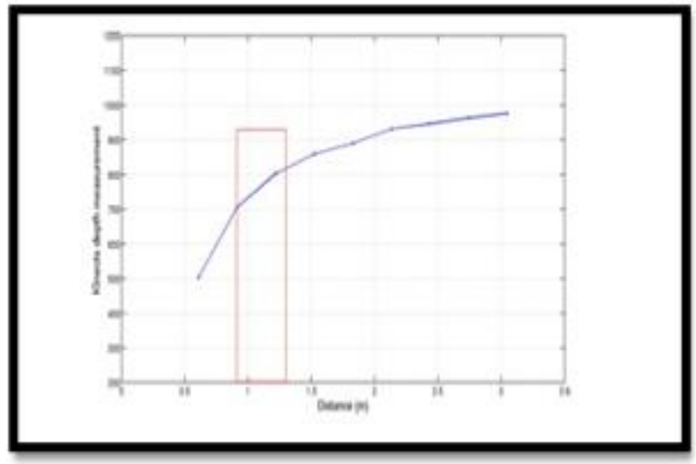

Figure 10. A two-dimensional base grid was defined in the (xi, yi) plane parallel to the anterior surface.

Furthermore, surface distance from the camera was then systematically varied from 80cm to 150cm in 10cm steps. Test object was displaced further 1,2,5 mm and 10mm to examine local depth performance.

Based on Figure 11, kinect depth camera also worked as observation system to recognize any disorder in the breathing patterns. Moreover, slowing in chest surface in 1 mm, the system would triggered alarm inside the room and other sensors and call for three different numbers. Figure 12 shows the images by Kinect camera and 3D mesh

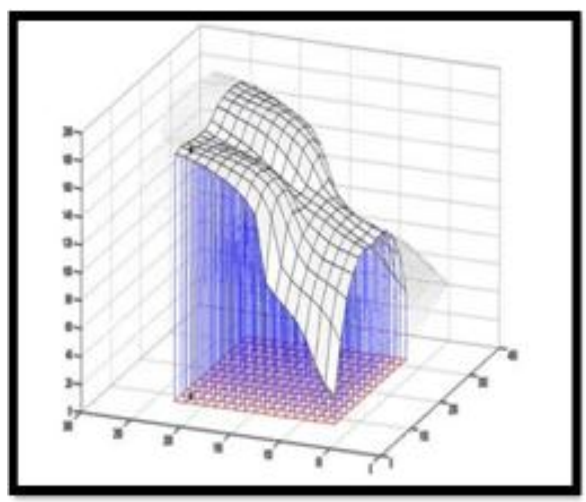

Figure 11. Non-linear relationship between true depth and Kinect pixel depth intensity. The red box illustrate restricted user-selected depth field of view.

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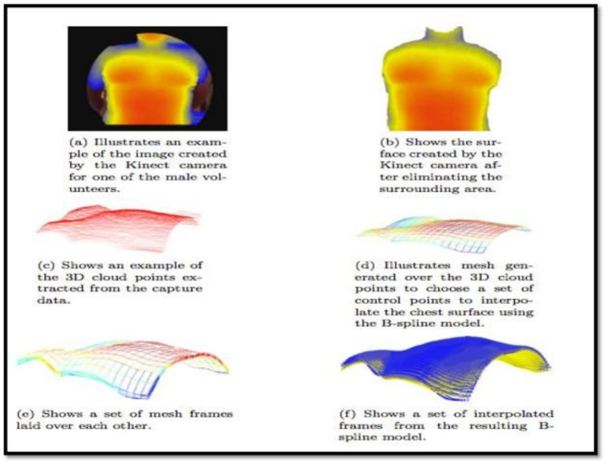

Figure 12. Image created by Kinect camera and 3D mesh frames.

Besides, 3G shield connected to the Arduino and PC with serial monitor had been to be turn ON. The serial monitor was used to make sure 3G shield is working and generate AT commands for 3G shield placed the call while waiting for the call. After displaying AT command as shown in Figure 13, the call was placed to the desired number. Kinect camera also worked as observation system to recognize any disorder in the breathing patterns.

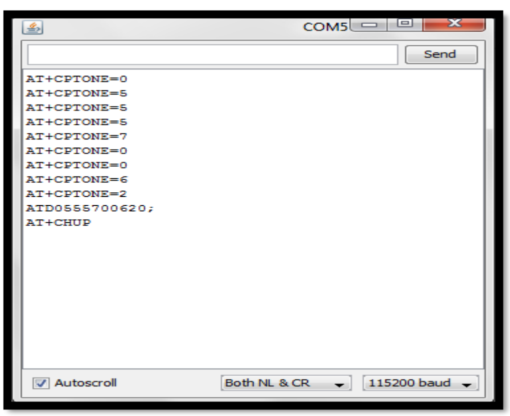

Figure 13. Serial monitor with AT commands.

7. CONCLUSION

In conclusions, the mark-less recognition system for detect any abnormal respiratory cycle had been obtained. The result also be used in many other biomedical applications. In future, the mark-less system using Kinetic is implemented instead of marked system with fingertip oximeter to avoid any imperfection with system performance. This recommend system will work directly with Kinect and alarm and the result will perform during sleeping time for more accurate result.

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