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Automated sensor rig in detecting shape of an object

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Abstract

In this paper an infrared sensor rig device is designed and developed. The ability of infrared range finder in measuring distance is applied to the sensor rig to detect lower limb shape model of prosthetic patient. Arduino is used as a microcontroller to control the whole system of this device with help from the stepper motor for the sensor rotation. Object shape is located at the center of the device and the minimum distance between object and sensor is fixed to 5 cm in order to reduce noise during data collecting. Data captured by the sensor is then saved in a text file for post processing using Matlab software. Various shape of objects have been tested and results obtained show that infrared sensor rig is capable to obtain shape data by plotting graph in 3D format.

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Keywords: Infrared sensor; Arduino; Stepper motor; Matlab

1. Main text

Robots have been widely used in industries. With the advance technologies of humanoid robots, researchers believe it will help in replacing human work in difficult task and at the same time enhance work performance with less mistake. Akihiro *et al.*[1] report that the use of robot still has its weakness that is difficult to estimate distance of an obstacle. In addition, there are high demands from the hospital that need the help from the robots especially in bio-medical application. The application of robots in medical field is also one of the most interesting areas to be explored.

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Nomenclature

V	volt
IR	infrared
cm	centimetre
ms	millisecond
mm	millimetre
deg/sec	degree per seconds
ToF	time of reflect
3D	Three-Dimensional
MRI	Magnetic Resonance Imaging
CT-Scan	Computer-tomography scan
PSD	Position sensor detector
LD	Laser diode

In the hospital, huge equipment such as Magnetic Resonance Imaging (MRI), Computer-tomography (CT) scan and ultrasound used by the technician to collect patient information before doctors make any decision regarding to their disease. MRI, CT-scan and ultrasound require patient to pay high cost and it have their own drawbacks. Even though MRI provides detail information, patient that goes through MRI will expose to the radiation that is dangerous to human body. CT-Scan used medical imaging technique that can capture an image through two-dimensional X-ray image. It captures an image slice by a slice around a single axis with predefined thickness[2]. Compare with MRI, which is a non-invasive high-resolution technology that can differentiate between soft and cartilage tissues[2]. 2D image can be used to do some simulations based on the needs from the doctor, however, result obtain need to be corrected with proper experimental tests which need some extra cost[2]. For proper simulation and better result, 3D image is very important this is because it gives a detail image needed and an efficient evaluation can be made using the image.

The used of infrared (IR) sensor in robots helps researcher to obtained better results in resolution and accuracy in distance measurement[1]. Compared to other sensor that has the same capability to measure distance, such as position sensing detector (PSD), and laser diode (LD), IR is said to be better result when it comes with accuracy. PSD offer an accuracy of 1% at a distance of 10 cm to 80 cm and give optimum results between 35 cm to 63 cm[3,4]. LD in the other hand gives an accuracy of 0.3 mm at a distance of 3 m away[5].

There are several researchers reports that IR sensor offers lower cost and faster response in detecting distance measurement of an object compare to US sensor[6]. IR sensor is widely used as proximity detectors in robots[6]. Compare with US sensor, IR sensor offers an angle distance measurement, shorter range compared to SONAR, and also low cost[7]. The wavelength range of an IR sensor is around 850 nm ± 70 nm and the transmitter signal from the sensor is depended on how far the reflecting object, the signal returns at an angle where the distance can be determined[7].

In this experiment, we are measuring the small changes in distance that can be detected by IR sensors. IR sensors with part number GP2D120XJ00F (Sharp Corporation, Osaka, Japan) are specifically for analog output distance measuring sensor. A major advantage using this GP2D120 is the beam width where a signal that transmit from the IR sensor point directly to the require object[7], which is capable in detecting any changes in displacement within the range of 4 cm to 30 cm. Results showed that small changes in displacement can be detected by sensor, and a graph has been plotted for any changes in distance.

2. Sensor Rig Implemented Device

2.1. Infrared Sensor Rig

A schematics block diagram and photograph of the prototype infrared sensor rig device are shown in Fig 1 and 2, respectively. Fig 1 shows the block diagram with the position of the sensor installed at the sensor rig. Infrared sensor is mounted on a pentagon shape that can be rotated by stepper motor.

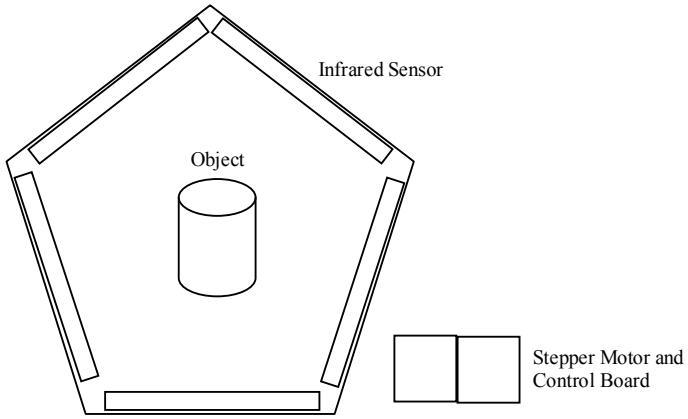


Fig. 1. Block diagram of the sensor rig.

IR sensors that have been widely used for 3D geometry reconstruction [8], distance measurements [9], object detection[6,10-13] is used in the sensor device. This study uses an infrared analog output distance measurement to collect data of an object. An overall view of the device is shown in Fig 2.

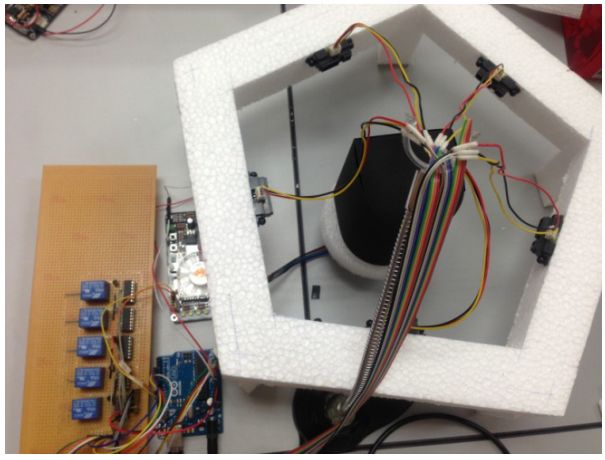


Fig. 2. Photograph of infrared sensor rig device.

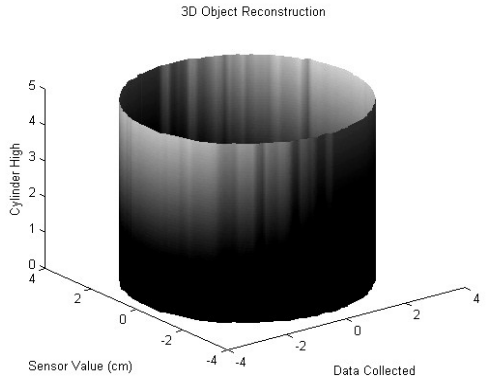
2.2. Function of Sensor Rig Device

The sensor rig device is composed of an infrared (GP2D120XJ00F, Sharp Corporation, Japan)[14], stepper motor, motor driver (SD02B 2A Stepper Motor Driver, Cytron Technologies, Malaysia)[15], and control circuit. This control board is consisting of a comparator (LM234), 5V relay, and capacitor, which will control the IR sensors during data collection. The device is controlled by the Arduino Uno (Cytron Technologies, Malaysia) as a microcontroller that will connect to the computer for data storage.

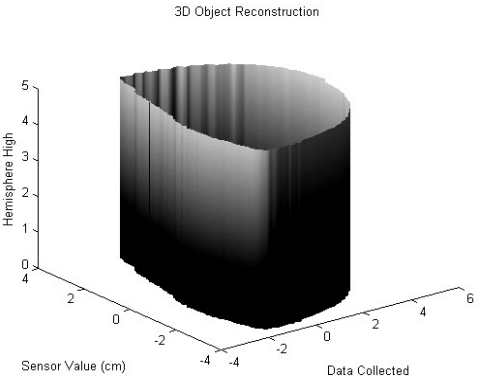
Process flow is summarized as follows. The stepper motor rotates the prosthetic model through 72 degrees with an angular velocity of 1.2 deg./sec under the controlled of a motor driver. Five IR sensors are used in the device, each sensor will cover 72 degrees area and total area is covered is 360 degrees for complete scan of a model. Prosthetic model is located at the centre of the sensor device for distance measurement. Arduino will instruct control board to turn on and off the IR sensor one by one in order to reduce noise during data collection[9]. When IR sensors detect a distance on a model, data will be transfer to the CoolTerm software and saved in a text file for post processing data. Total time needed by the sensor rig to completely scan the model is 5 minutes because of the time of reflect (ToF) of the IR sensor itself. Saved data is import to Matlab software for post processing in order to reconstruct 3D image with an application of an algorithm. To measure the accuracy of an image, real image is compared to the obtained data.

3. Results of Prototype Sensor Rig Device System

The sensor rig device is tested with a various shape for object shape detection to prove that the system is able to reconstruct 3D image of an object that have been measure the distance. The minimum distance from the sensor to the object is fixed to 5 cm, this is because of the noise occur during data collection if object is located very near to the sensor. Error reading from the IR will be collected and the output result cannot be use to reconstruct 3D image. Cylinder, rectangle, oval and hemisphere object have been chosen to be tested the functional of sensor rig device. Each shape of the object has its own measurement and the accuracy of the object is counted in this test experiment. Fig 3 shows the results of a 3D image obtained.



(a)



(b)

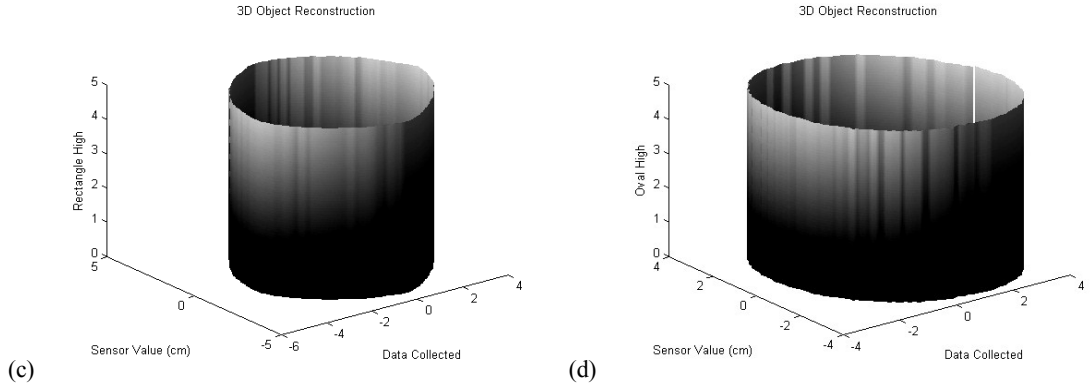


Fig. 3. Shape of a (a) cylinder, (b) hemisphere, (c) rectangle and (d) oval in 3D form obtained from the sensor rig device.

Data obtained from the sensor rig device is then saved in text file for post processing data. Matlab software is used to reconstruct 3D image of an object. Color of the surface object is fixed into black[9] in order to obtain high reflectance signal from the object. Higher reflectance signal from the object give more accurate data compared to the low reflectance signal. Other color have been tested to choose which color give the accurate and stable output data, for example yellow, red, green, blue and black all from this color, black gives stable and accurate data.

An algorithm is developed in Matlab[8] to measure the accuracy between the data obtained and the real object size. In the algorithm the comparison is make to obtain which object shape give better results. Several factors are considered during the comparison there are the average total, standard deviation, accuracy and percentage error. Table 1 shows the data obtained when all of the object shape is compared to the reference shape.

Table 1. Experimental values for a different shape of an object and its measurement

Shape	Measurement (cm)					Total	Average (cm)	Standard Deviation	Accuracy	Percentage Error (%)
Reference	7	7	7	7	7	35.00	7	-	-	-
Cylinder	6.70	6.96	6.91	6.91	6.95	34.43	6.886	0.1064	98.37	2.36
Rectangle	7.19	7.14	7.10	7.14	7.15	35.72	7.144	0.0321	102.06	-7.94
Oval	6.57	6.61	6.63	6.64	6.62	33.07	6.614	0.0271	94.49	5.51
Hemisphere	6.93	6.91	6.90	6.91	6.95	34.60	6.920	0.0200	98.86	1.14

From the results obtained, cylinder and hemisphere object gives higher accuracy with a percentage error of 2.36% and 1.14% compared to other shape. Meanwhile, rectangle shape gives a negatives percentage error which is -7.94%. This error occurs because of two factors there are, IR sensors have the limitation when it deals with a straight shape and there is a light source from the surrounding during data collection. In order to reduce noise, during data collection IR sensor rig is placed in a dark room where there is no light source from the surrounding[16]. Control board is also set to allow only one IR turn on during data collection.

4. Discussion

This paper describes the ability of an IR sensor rig device to reconstruct 3D image of an object located at the center of the device. IR sensors that have been used are an analog output data that does not require any digital to analog converter in order to obtained data. Sensor rig device is successfully collect data in distance measurement

between sensor and object. Algorithm applied in the Matlab proves that data obtained from the device can be use to reconstruct an object model.

This device can be apply in medical field, it will help pediatrics technician to reconstruct 3D image of a prosthetic patient in order to give them a new prosthetic limb. Basically, prosthetic in medical is defined as a branch of surgery dealing with the replacement of missing limbs or organs with artificial substitutes[17]. With a fast scan for complete 360 degrees (5 minutes), it will help to reduce time in collecting data compared with MRI, CT-Scan and ultrasound that require longer time. There are only five IR sensors used in the device, since the application of IR sensor in the device did not depend on the resolution of an image. Total time requires to complete 360 degrees scan of an object are 5 minutes and if too many sensor is installed in the device it will become bulky[18]. Simple experiment has been done by using prosthetic lower limb model as an object placed at the center of IR sensor rig device to reconstruct the 3D image.

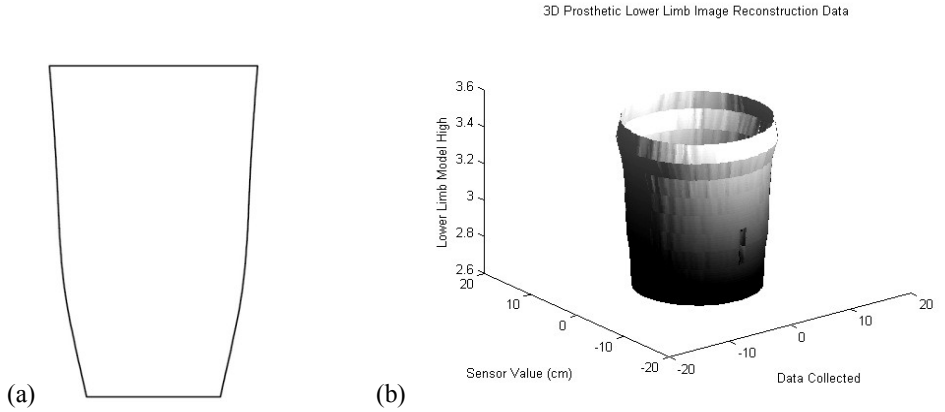


Fig. 4. (a) Prosthetic lower limb model used in the experiment (b) Image reconstruction using Matlab.

Fig 4 shows the shape of a prosthetic lower limb model and its 3D image reconstruction by using Matlab. From the result obtained, it shows that by using sensor rig device it will help pediatrics technician to reconstruct 3D image of a prosthetic patient in a faster time. Researchers suggest that to obtain stable data from the IR sensor, capacitor can be use to filter noise. The conditions of the surrounding also need to be fixed in the dark place to avoid any light source that will interrupt reflectance signal to the receiver of an IR sensor.

5. Conclusion

A new sensor rig is installed with a five Sharp GP2D120 infrared range sensor is presented. To measure distance of an object located at the center of the sensor rig in order to cover the overall area of an object. Sensor rig are then turned for 360 degrees. This experiment has demonstrated that the pattern of the plotted graph produced will be different when a distinct shape of an object is used. It is very important to make sure that the distance between IR sensors and the obstacle is more than 5 cm or above in order to reduce noise from the sensor reading. Moreover, experimental results show that the proposed sensor rig is able to measure distance and produce the 3D images of an object using Matlab image processing software. The results will be very useful in reconstructing 3D image of a prosthetic patient especially for lower limb.

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