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The Used of Infrared Sensor for 3D Image Reconstruction

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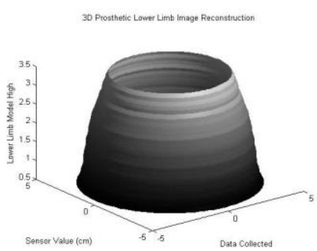
Graphical abstract



Abstract

In this paper, new development of a sensor rig device with infrared sensors is used to reconstruct the 3D image of an object's surfaces. Five sensors have been used to acquire data that measure distance from the object and sensors. A stepper motor controls the object rotation with 2 degrees per turn. A few objects such as tulip, curvilinear, flower and star shape have been selected for data collection, and the results proved that this sensor rig device is capable of reconstruct a 3D image of an object's surface. A prosthetic model with distinct size in diameter was tested to prove that this device is capable of measuring distance with different size. From the results obtained, this sensor rig device shows a capability to reconstruct 3D image of an object surfaces with simple post processing technique. A prosthetic object was tested and results show that the accuracy was around 75%.

Keywords: Infrared; 3D image; prosthetic model

1.0 INTRODUCTION

Infrared (IR) sensors have been used in many applications especially in robotics. Lower cost, small in size, simple connection, and faster response times are some of the advantages of this sensor. Nowadays, there are many systems that used IR sensors as a fundamental to obtain information and the data can be used to reconstruct 3D images. However, with the high deficiency on the reflectance of surrounding object[1], suitable objects surfaces need to be considered when dealing with this sensor. This sensor has high deficiency on the object reflectance[1], so that an appropriate surface of an object need to be consider when designing system using this sensor.

There are many different types of sensor that can be used to reconstruct a 3D image such as 3D camera, laser scanner, LVDT and ultrasonic sensor. 3D camera and laser scanner have been widely used for image reconstruction, with accurate data obtained from the laser, making these devices as first option compare to others. Unfortunately, the cost is expensive and ineffective for simple image reconstruction[2] .Other than that; it also requires high computational power, which also takes a lot of times. Meanwhile, LVDT is capable of measuring distance precisely, but this sensor is expensive and lots of signal conditioning circuits and complicated mechanism required, which is not applicable in some applications[3].

Ultrasonic and infrared position sensing devices have been used traditionally to create 3D images of an object[4-6].Unfortunately, this method has a drawback which is poor in angular resolution, it detected an object anywhere in the sensor range without focusing at the specific object.

Compared with ultrasonic sensor, the emission is in a narrow beam for IR, and it can measure distance either in offset of the reflected beam of depends on the light intensity. Infrared sensors have been proven by other researchers for its ability to detect an object[7], localization purposes[8-9], object surface-traces[5], obstacle detection[10], range estimation[11], and geometry reconstruction[12]. A new purpose of infrared sensor is presented here by measuring the distance of an object and reconstructs the outer surfaces of the object shape. Only the object surfaces will be reconstructed in the experiment to determine the capability of the IR to measure the distance between object and the sensor.

In research done by Park *et al.*[8], 12 IR sensors are rotated to determine distance between object and the sensors is rotated in order to measure a distance of an obstacle from the sensors. The capabilities of each sensor to detect an obstacle with 1.8 degree wide area, helps to eliminate blind spot that might be missed for small obstacles. The rotation of the sensor is fully controlled by the stepper motor. In this research, the sensors are used to accurately build a map for the environment with a present of obstacle. From the experiment, this sensor is able to accurately build a map of the environment with an obstacle.

In this experiment, a new application of infrared array sensor is demonstrated, as well as the capabilities of the sensor to obtain data and the reconstruction of object surface using Matlab. Although using infrared sensor with camera, ultrasound and other device are well-established method, its application is only focused on the object detection, docking guidance and object avoidance[4,13]. In this experiment, there are five infrared sensor used to reconstruct 3D image of an object surfaces. This research presents reconstruction of object surface using analog infrared sensor with part number GP2D120XJ00F (Sharp Corporation, Osaka, Japan).

2.0 SYSTEM DESIGN

2.1 Sensor Rig Design

The sensor array considered in this work consists of five infrared GP2D120XJ00F (Sharp Corporation, Osaka, Japan)[14] installed in five legs of a device with a 15 cm separation in distance from the center of the device. This sensor was chosen due to its capabilities to measure distance in a range of 4 cm to 30 cm and the resolution is up to 0.05 cm. The reflected time is 38.3 ms ± 9.6 ms, and the most output ranges are about 0.25 – 0.55 V.[9] It shows that, the ToF of this sensor helps to give faster output value to the receiver the faster it can give output value to the user.[8] In order to minimize the noise level, the distance between sensor and object surface needs to be set at least 5 cm or above, else the data received is considered as noise[8]. Furthermore, IR sensor is a hard field sensor, and it is very stable because this sensor will never bend to other directions during measurement. The size of GP2D120X sensor is shown in Figure 1.

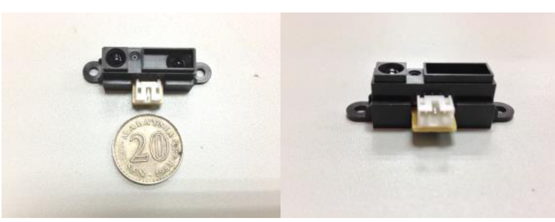


Figure 1 Top and side view of GP2D120 IR sensor

Each sensor in the device is switched independently with a control by operational amplifier LM324. A dynamic current control is implemented using transistor 2N3904. Hence, the current flow through IR can be controlled. In order to avoid any redundant signal from other sensors, only one IR is turn ON at a time.

In this experiment setup, power supply of 5 V from the Arduino as a microcontroller board will turn ON the device. The best way to harvest data was to rotate the object rather than to rotate the sensor.

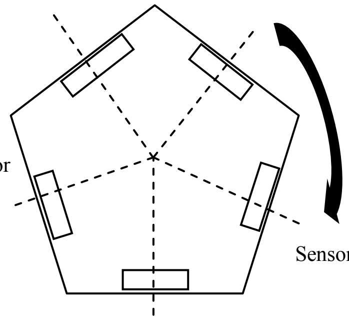


Figure 2 The arrangement of sensor rig

Stepper motor is used to control the rotation of the device, each turns need to be as small as possible to make sure that small changes of the object can be detected. Each turn of the motor is 2 degree, and it will turn until it reaches 72 degree of rotation as shown in Figure 2. This device consists of five sensors, each sensor will take only 72 data and all five sensors will collect a total of 360 data.

2.1 Data Collecting and Storage

Other than Arduino, this device is connected to the control board as shown in Figure 3, which is responsible to give an instruction to the IR. While one IR sensor collects data other sensors are disconnected to the power supply. Only one IR sensor turns ON at a time. Reflected signal received by the each sensor does not affected by other IR signal. There are three outputs from this control board, which is output to the IR sensors, Arduino microcontroller and also ground.

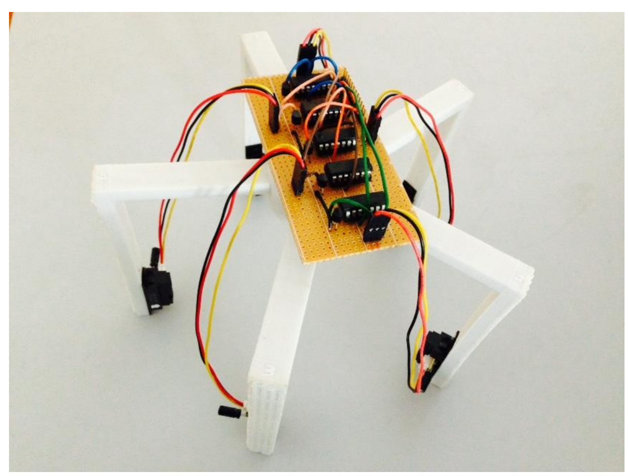


Figure 3 Circuit control board that is connected between Arduino and sensor rig

The output measurement of 2D120X is in digital, so it does not require any conversion from an analog to digital converter (ADC) and the data received can be converted into *centimeter* (cm). This board has an analog-to-digital conversions function within the voltage range of 5 V. The calculation for conversion is shown in (1):

$$V = \frac{1}{(R + 0.42)} \quad (1)$$

Where, V is a voltage and R is the range, this equation will produce a linear graph. The value of 0.42 works well for IR sensors GP2D120 based on the calibration point in Sharp datasheet.

$$y = m.x + b \quad (2)$$

y is equal to the linearized range or distance. Substituting the linearizing function from above for y and substituting V for x yields:

$$\frac{1}{(R + 0.42)} = m.V + b \quad (3)$$

Rearranging the equation, range as a function of voltage:

$$R = \frac{1}{(m.V + b)} - 0.42 \quad (4)$$

$$R = \frac{m\prime}{(V + b')} - 0.42 \quad (5)$$

$$\text{where } m' = \frac{1}{m} \text{ and } b' = \frac{b}{m}$$

After plugging in the calibration data for GP2D120 and adjusting the constant, the following formula can be derived for the sensor is:

$$R = \frac{2914}{(V + 5)} - 1 \quad (6)$$

From the equation[14], 2914 is the constant value for IR sensor GP2D120. R is the distance from the sensor and V is the voltage reading from the sensor.

2.2 Experiment Structure

Figure 4 shows the experiment setup for this device. Selected objects with a various shape have been choosing will be placed at the bottom and center of the IR device. Stepper Motor Driver (Cytron Technologies, Malaysia) is used to control the rotation of the object while IR sensors take data. Each turns of the stepper motor make the object to turn every 2-degree until the rotation completes 360 degree.

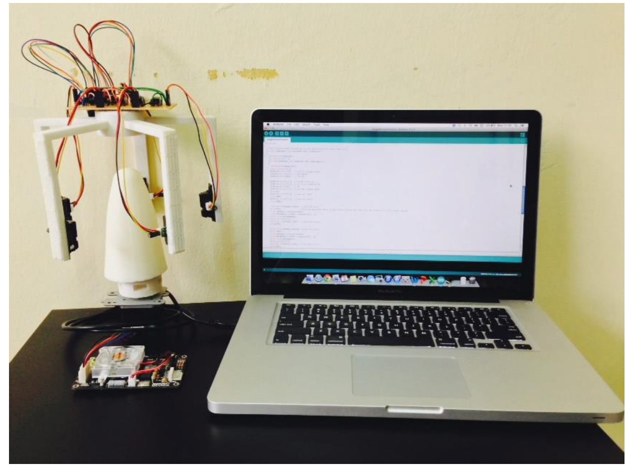
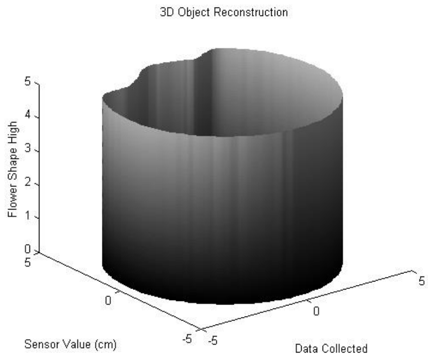


Figure 4 Experiment setup

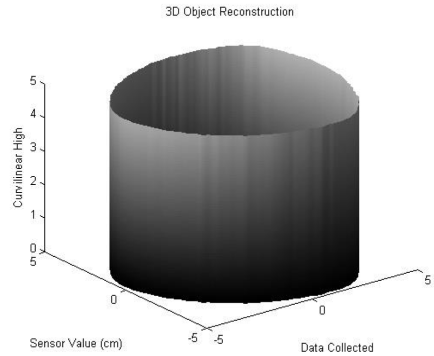
SD02B motor driver is used to drive a unipolar and bipolar stepper motor [SD02B]. There are lots of advantages by using this motor driver such as it can be operated to 8 V to 24 V circuit supply voltage, and it is capable to drive a stepper motor from 3 V to 40 V. With a new UART interface, it is easy to communicate with PCs and smoother stepper motor rotation with 2, 5 and 10 micro-stepping[15]. Dimension of motor driver (10 cm x 6 cm) is not too big and can be installed beside sensor rig. Sending a command to the stepper driver can control the speed of the stepper motor. In this device, the speed was controlled to make sure that stepper motor rotated the object at 360 degree with a step angle of 2 degree.

3.0 RESULTS AND DISCUSSION

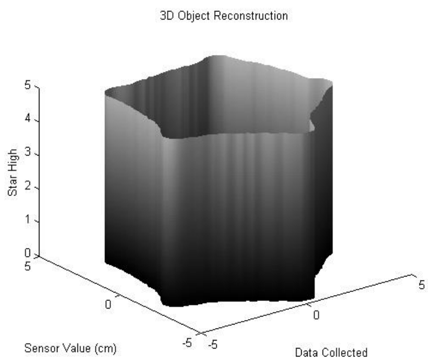
In this experiment, the model object was placed at the center of sensor rig sensors array device. The rotation of the model was controlled by stepper motor, each turn is 2 degree and it will rotate for 180 times to complete 360 degree. Data collected from the sensor array is uploaded into Matlab for data analysis. An algorithm is developed to filter noise, convert sensor value into distance (cm), and reconstruct an object image surface. In order to obtain a stable data, the surrounding area needs to be free from any light source.



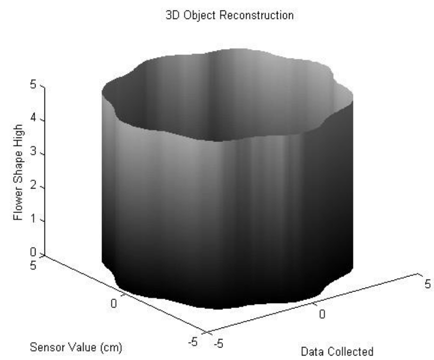
a) Tulip flower shape



b) Curvilinear shape



c) Star shape



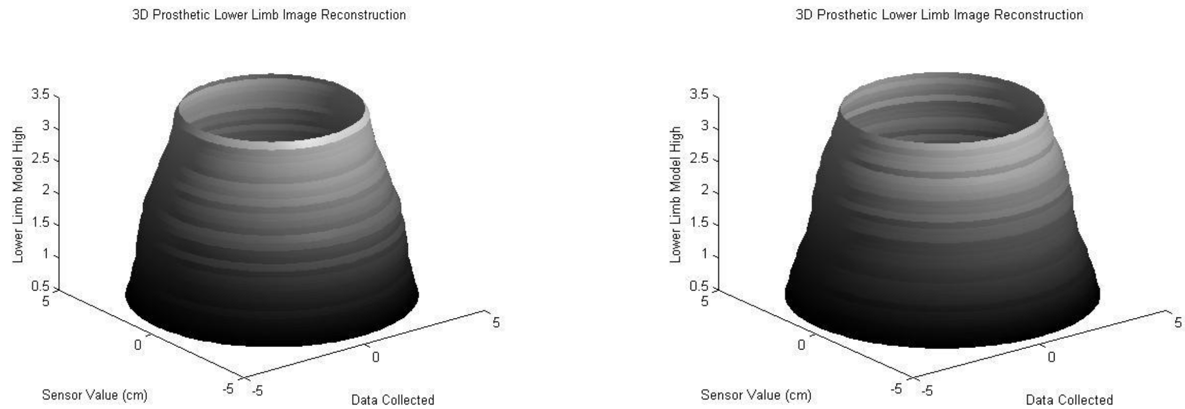
d) Flower shape

Figure 5 The graph shows image reconstruction of different objects

A few shapes of objects were selected in this experiment. There are tulip flower, curvilinear, star and flower shape. Figure 5 shows the image that is successfully reconstructed using data collected by the IR sensors.

Results proved that, 2D120X IR array sensor can produce a 3D image based on the data obtained from the experiment. A different shape of an object is reconstructed based on the data collected by IR sensors. Tulip flower shape, curvilinear, star and flower shape are the chosen object shape in this experiment. The capabilities to reconstruct the same shape show that the IR sensors collect a correct data regarding on the object surface. Lots of data can be obtained from this image, such as, the size, diameter, and object height. It is very important to prove that the reconstructed image is similar to the real image size.

There was only one slice of data can be collected for every 72 turns. In this experiment, there were 36 slices of collected data needed to reconstruction all the above image. A total of sixty seconds is required to collect a complete one slice of data. Total time of 36 minutes is required to collect all data. Moreover, in order to collect a stable data, capacitors are used in this experiment. Every single IR sensors was solder with a bypass capacitor of 100 pF at the GND and V_{IN} port. A huge different style of data can be seen with, and without the existing of the capacitor installed at the IR sensors.



a) Prosthetic model (First data scanning)

b) Prosthetic model (Second data scanning)

Figure 6 The graph shows an image reconstruction from different shape of an object

Figure 5 shows the sensor array is capable to reconstruct an object surface successfully. The objects used in the experiment have a same height and diameter, so another object of lower limb prosthetic shape has been selected in the next experiment. This model has a different size in diameter in every height. The experiment is done to test the capabilities of the device to measure distance in a distinct size on an object. The dimension of prosthetic model is 11.25 cm in height, top diameter is 4 cm and bottom diameter is 7 cm. Each layer of the model did not have the same diameter.

The results from this test are shown in Figure 6. Both of the images have been reconstructed using the same model. From the result, it is proved that this sensor device is able to obtain data from various shapes of an object. Every layer of an object can be measured, and the accuracy can be calculated. In this experiment, the accuracy for the lower limb prosthetic model is 75% based on the diameter dimension. Further data analysis will be done to measure accurately the shape and height of the object.

■4.0 CONCLUSION

In this paper, a novel five infrared sensors (GP2D120) based on the distance measurement has been presented. The main advantages of the system are the fast data collection for one layer of an objects surface, portable device to reconstruct image and low cost. Moreover, this device helps to improve the pixel resolution and also it is capable to collect data for 360 degree in rotation. Every angle of an object can be detected for the image reconstruction. In this experiment, the sensor array will measure distance between the IR sensors and object surface and reconstruction was shown to be reliable.

The device has been proved useful but with some limitations. One of the problems is the reflectance of IR signal when it deals with flat surface object and light source from the surrounding. Furthermore, the reflected of IR sensor highly depends on the color of the object surface, but this could be improved by using black color paper to wrap it. A prosthetic cone model was successfully measured and reconstructed. It is shown that the developed IR sensor array was capable to measure the distance of objects surface for image reconstruction purposes. The accuracy measurement could be improved by rotating the stepper motor into smaller degree (less than 2 degree) and place the device in a dark room during data collection.

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