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Normal Force Calibration for Optical Based Silicone Tactile Sensor

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Abstract

The need for calibration is important as ancient humankind at B.C. age pioneered calibration for measurable items such as length, weight, frequency and other basic measurement. In the robotic application, the precision of movement and the sensitivity of reaction also based on the calibration of its sensors and actuators. Therefore it is vital for a newly developed sensor to be calibrated thoroughly before it can be used. In this paper, the authors proposed a calibration of a new optical based silicone tactile sensor developed in our lab. Measurable item which is normal force is relates to the blob area of image recorded in the inner side of optical based silicone tactile sensor. The normal force acquired from digital force sensor in experiment conducted. The experiment produced 9 images. The 9 images acquired is processed in WiT 8.2 image processing software to find the area of the specific spot as known as blob image. A blob area VS normal force graph is plotted using experimental data. The graph is then interpolated using suitable curve fitting technique to get the optimum relationship. The result shows that the quadratic plot is the best suit for the data with the force range from 0 to 3.79 N.

Keywords: Calibration; Tactile Sensor; Normal Force; Image Processing; Deformation Behaviour

1. Introduction

Tactile sensor define as a device or system that can measure a given property of an object or contact event through physical contact between the sensor and the object[1] such as shape of an object, texture, hardness[2], moisture content, etc. Most tactile sensor application is used as processing sensory data, cutaneous sensors, sensing fingers, haptic perception, multifingered hands, analysis of sensing devices, probes and whiskers and incoming new applications.

Currently, there are several tactile sensor principle developed in this world which is stated in international proceeding papers. The tactile sensors principles currently developed are piezoelectric principle[3], piezoresistive principle[4], capacitive principle[5], inductive principle, and optical principle. To date, 3 axis optical based silicone tactile sensor principle is developed by a research team from Japan[6] and a research team from Malaysia[7]. This silicone based optical tactile sensor is equipped with an optical waveguide plate mounted on a robot manipulator. It's development is more on robot finger application which usually for human-robot interaction[8]. Basically the optical based silicone tactile sensor force measurement is depend on the image appeared in the frame grabber software which is a monocular CCD camera used to record the images changes. The nature of images changes is due to silicone based tactile sensor deformation behaviour[9]. In this paper, based on the developed optical based silicone tactile sensor, a set of reference images is recorded to give a direct relationship with the normal force exerted on the tactile sensor dome.

Calibration is important to develop a permanent or non-changeable reference image in real-time application. By using a monocular CCD camera[10], we can calibrate force measurement which have a direct relationship with the blob image's area that captured by monocular CCD camera. Many raw images are recorded by monocular CCD camera which is connected to the optical fibre tube and connected to the image processing unit. The image processing unit is very important

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to process every image to the measurable output images. These parameters produced measurable data in order to make the calibration become feasible.

The force that is measured in this paper is a normal force exerted to the tactile sensor dome where the tactile sensor will change its shape when the normal force acts on the dome surface. This robot finger-like shape tactile sensor deformed when the normal force is applied. The normal force have a direct relationship with the image's area appeared in the image processing software. In conjunction with that matter, this paper proposed a normal force calibration value in this optical based silicone tactile sensor. This experiment is significant to introduce calibrated normal force value.

2. Experimental Setup & Procedure

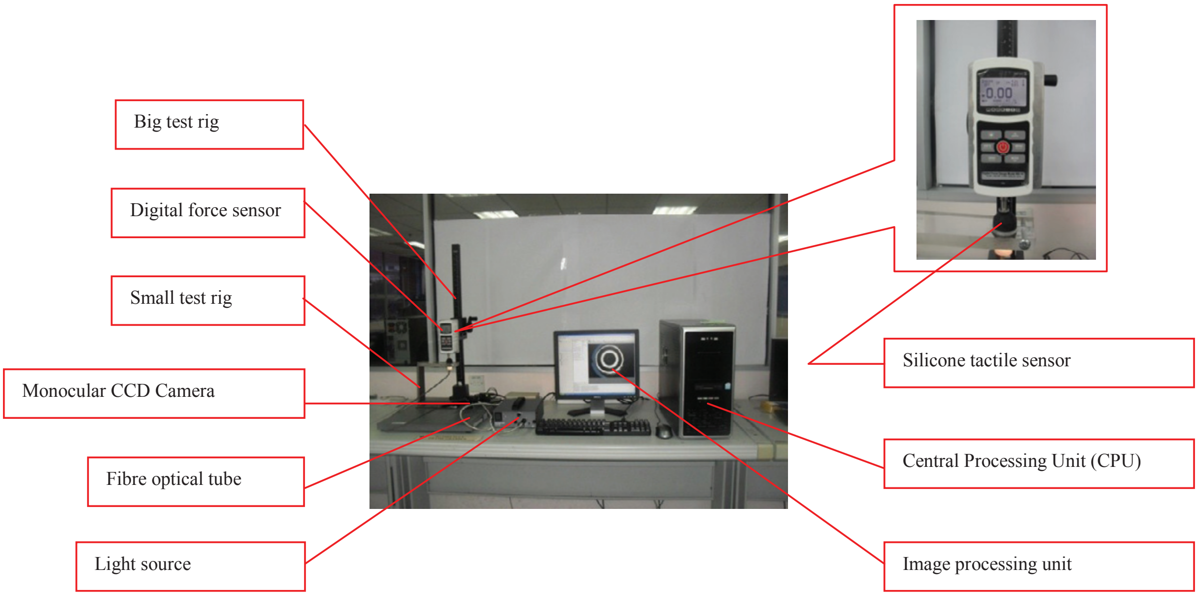


Fig. 1. Complete experimental hardware setup

The experimental setup need 3 important components. These components are tested and setup separately before it can be combined together as a complete experimental device. The 3 components consists of

i. Test rig
ii. Fibrescope
iii. Image processing unit

After combined together, the complete hardware setup is shown in Figure 1.

2.1 Optical sensing principle

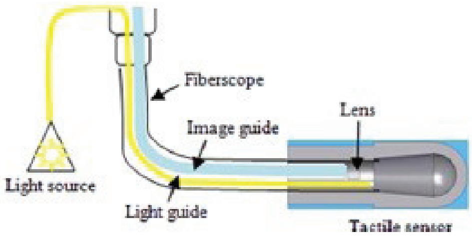


Fig. 2.Optical tactile sensing principle

As shown in Figure 2. Light emitted from light source. The light is travel from light source to the inner side of silicone tactile sensor through optical fibre tube or as known as light guide. The image is acquired in the inner side of silicone tactile sensor. The image is transmitted as light to the fibrescope and then monocular CCD camera through the optical fibre tube or as known as image guide.

When compare from other tactile sensing principle. The optical sensing principle has one significant advantage where is the optical sensing principle can sense the magnitude and direction of the force. The others sensing principle can only sense magnitude of sensing parameter. Since this is the first developed optical based silicone tactile sensor developed by authors. Its need an algorithm to calibrate a set of normal force that will be use as standard measurement specifically for this optical based silicone tactile sensor before further experiment can be conduct.

2.2 Image processing

Image processing technique is used in this experiment to enable parameters that will be measure to acquire data and present them in table and graph form. WiT 8.2 processing image software is used because its wide application in processing a lot of raw images. In order to collect data from the image, an i-graph that consist of operators is developed as in Fig. 3. The developed i-graph will display the data in a window.

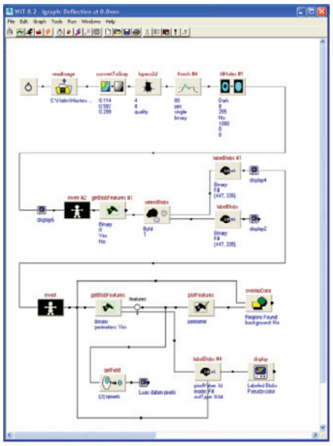
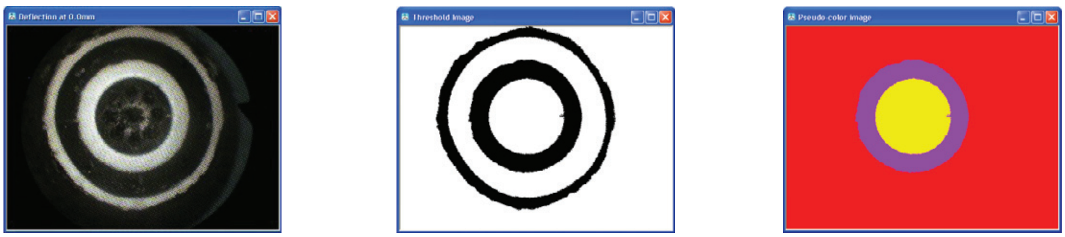


Fig. 3. Developed WiT 8.2 i-graph

As shown in Fig. 3, there are more than 10 different operators is used in this i-graph. Each one have their own function that will be contributed to the output image.



(a) (b) (c)

Fig. 4.(a) Input image (b) Threshold image (c) Output image

Each one have their own function that will be contribute to the output image. The objective of i-graph development is to measure in the blob of interest area in pixels unit. Blob is an area that bounded by specific boundary. As shown in Fig. 4 (a), the input image is a raw image that has been recorded by using monocular CCD camera. This image is processed by several operators to acquire threshold image which the image is shown in two colors only, that is black and white color. Threshold image is shown in Fig. 4 (b). The threshold image is also known as binary image. Then, the image continue processed by several operators until its clearly differentiate every blob with pseudo-color. In this experiment, the blob image selected is yellow color blob as shown in Fig. 4 (c)

3. Results and Discussion

The result is taken as an average from experiment that has been conducted 3 times. The result is tabulated as shown in table 1.

Table 1 Experimental blob area and normal force value

Reading no.	Deflection (mm)	Force applied (N)	Area (pixels)
1	0.0	0.00	40,099
2	1.0	0.50	42,621
3	2.0	1.07	46,486
4	3.0	1.81	52,446
5	4.0	2.45	58,763
6	5.0	2.98	64,997
7	6.0	3.45	73,121
8	7.0	3.72	82,154
9	8.0	3.79	91,227

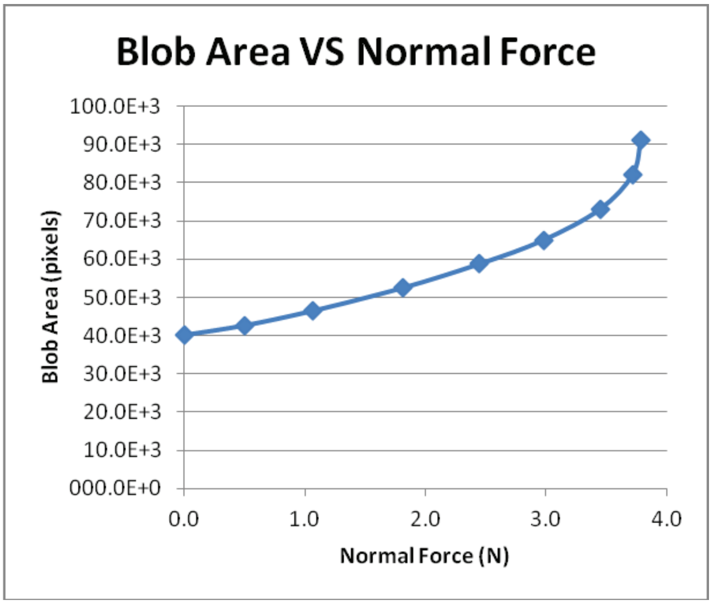


Fig. 5 Blob area VS normal force graph

As shown in Table 1, the normal force and blob area is acquired from the experiment conducted. Each image is processed to acquire the area in pixels unit. Then the data is transformed into graph form. As shown in Figure 5, the area VS normal force is plotted. The plot trend shown in the graph is almost like a quadratic graph. When normal force increasing, area increasing in quadratic trend. For the first 3 N, the area is increase steadily and consistently which the line plotted in the graph almost in linear shape. For next 3 N to 3.79N, the area is increase dramatically, showing that the line plotted in the graph almost in quadratic curve shape. The graph also tells that the optical silicone based tactile sensor deformation increase larger when more force increasing. Its act elastically to the normal force applied onto the optical based silicone tactile sensor. From the last point plotted, it can be describe that the largest force can act on the elastic silicone tactile sensor is about 3.79 N. The resolution is about 11,486 pixels per Newton. The resolution is measured from graph gradient.

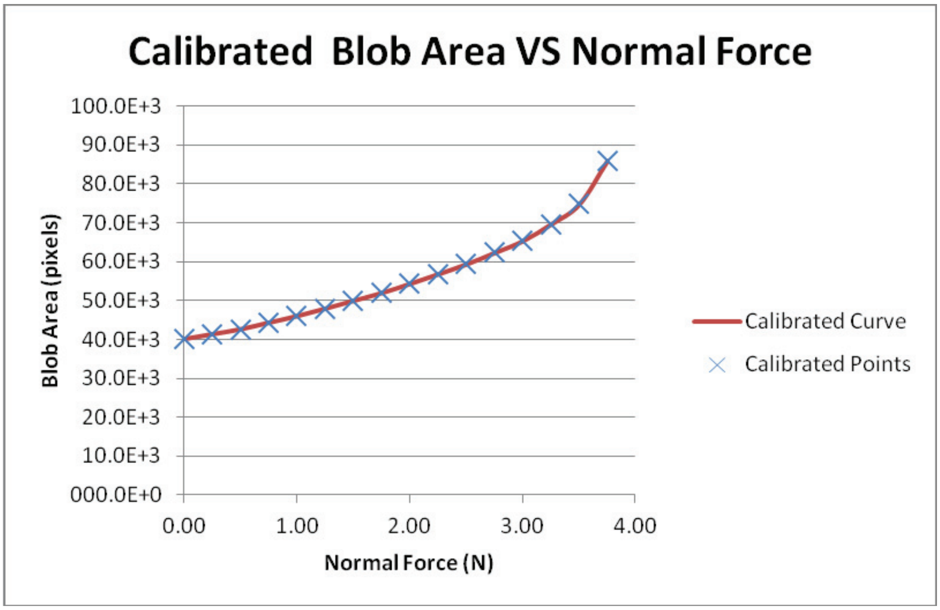


Fig. 6 Calibrated blob area VS normal force graph

Table 2 Calibrated normal force

Normal force applied (N)	Area (pixels)
0.00	40,099
0.25	41,360
0.50	42,621
0.75	44,316
1.00	46,011
1.25	47,936
1.50	49,949
1.75	51,963
2.00	54,321
2.25	56,789
2.50	59,351
2.75	62,292
3.00	65,343
3.25	69,664
3.50	74,794
3.75	86,042

By interpolation method, the calibrated normal force is acquired for each step with 0.25N increase with direct relationship to blob area. Finally the graph as in Figure 6 is acquired and has more accurate trend line than as in Figure 5.

4. Conclusion

The overall objective which is to acquire calibrated normal force for the optical based silicone tactile sensor is achieved. The standard measurement of calibrated normal force is acquired for each 0.25N step increase until 3.75N. The calibrated blob area as a dependent variable also acquired by reading the normal force as independent variable.

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