Optical Mouse Sensor as 2-Dimensional Position Controller

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1. Introduction

In recent years, many sensors have been developed to measure the movement and position of human limbs. Some of which considered the physical changes of human's limb, cause by the contraction or relaxation of human muscles, the sensors lies in this category are stress, strain, and muscle volume sensor etc. Other sensors used to find the human intentions to motions are EMG [1] & EEG sensors, which are direct function to human thought and its action. Few sensors detect the force or pressure exerted by the human limbs in particular manner to analyze the limbs motion [2]. Using Inertial sensors like gyroscopes and accelerometers are another active field of research for the analysis of human limbs movements and position. However, these all sensors required direct contact with the human body which may alter the behavior of human muscles/limbs by exerting extra load on it. There are various sensors which detect the displacement without being contact with the subject. Thus for measuring the changes without contact & altering the human motion, makes optical sensor a good choice. There have been considerable developments in the use of optical techniques in sensor system for the monitoring of most physical parameters [3].

In 1999, Agilent Technologies uncovered the world first optical mouse which uses an optical sensor to measure the displacement, unlike mechanical mouse that uses a rubber ball with two rollers rolling against x & y axis to give the two dimensional displacement. Since then the optical sensor is used in a number of application such as displacement sensor [4], harmonic oscillator detector [5], region-of-interest position recorder in microscopy [6], and 3-DOF motion measurement sensor [7], digital readout sensor in manometer [8] and deformation sensor for viscoelastic materials [9]. The optical sensor is capable to detect two dimensional motions in millimeters. Our goal is to detect the smallest motion of human wrist and drive the wearable robotic arm to assist the human being in performing the high-caliber tasks with precision and accuracy. For this purpose, suitability of optical sensor as 2D position controller is investigated.

This paper will begin with the sensors working principle following with the functional setup of experiment. The paper then concentrates on the experiments conducted with the sensor to control the selected position with the 2-dimensional test bench designed for this purpose. In the preceding section, we will discuss the results of the experiments, comment the advantages and shortcomings of the proposed technique.

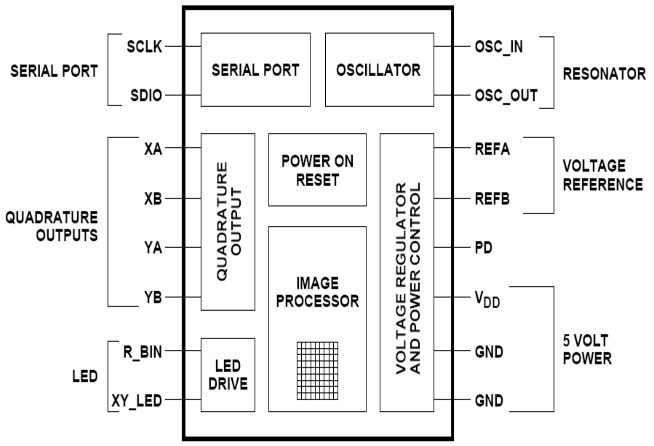


Fig. 1 Block diagram of optical sensor ADNS 2051 [10]

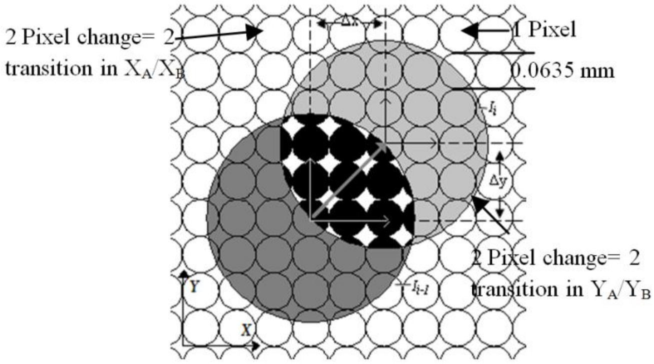


Fig. 2 Two consecutive images of optical sensor

2. Sensor Working Principle

The optical sensor consists of a tiny camera usually comprises of a rectangular array of 18 x 18 pixels, which is capable of capturing more than 1500 frames per seconds (fps). A digital signal processor (DSP) is also integrated in the sensor chip with the capability of 18 MIPS (million instructions per second) as shown in fig. 1. This DSP detects the change in the sequence of frames captured by the tiny camera and determine how far the mouse has moved as shown in fig. 2. DSP then sends the current coordinate to computer. The computer then moves the cursor according to the coordinates received. Fig. 3 shows the exploded view of the sensor assembly. The clip is used to hold & lock the LED in 90 degree position. The lens is design in such a way that it collects the maximum light from the LED and transmits it to the surface, then collect maximum reflected light to the lens of the optical sensor. The optical sensor and LED are placed very close to the surface to detect the minute features. The optical sensor can work best at a distance not greater than 1.25 mm [4].

3. Experiment

The experiments was conducted using x & y translation stages which uses circular micrometer as manual actuator (as shown in fig. 4). The white diffused reference surface was used, as the transparent and reflective surfaces are unsuited for displacement measurements [4]. The optical sensor's resolution is 400 cpi (counts per inch). This is a measure of how many pixel changes the sensor can register in one inch. From this we can calculate the height and width of a single pixel in mm i.e. 1/400*25.4 = 0.0635mm. The optical sensor generates quadrature output, which is digital encoded signal of x and y movements. One transition in X_A/Y_A and X_B/Y_B represent one count in the x/y axis.

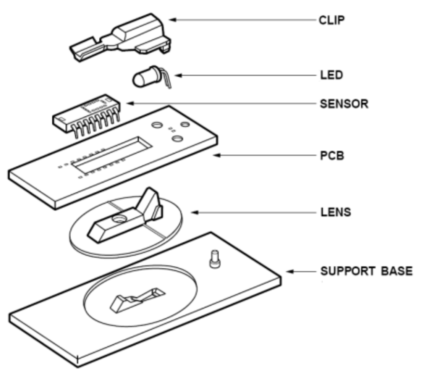


Fig. 3 Exploded view of sensor assembly [10] a) clip to lock the led, b) led, c) optical sensor IC, d) PCB, e) lens, f) support base.

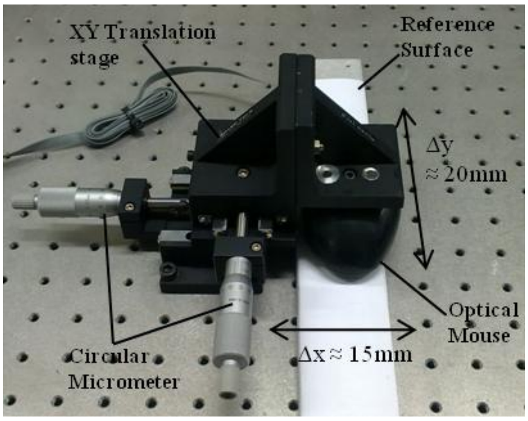
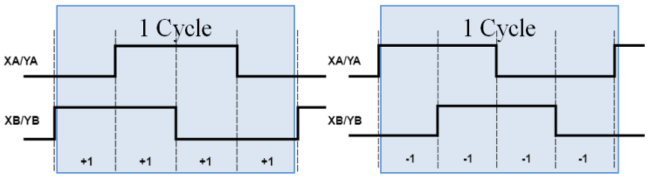


Fig. 4 Experimental setup

Therefore, one complete cycle (shown in fig. 5) is equal to 4*0.0635 = 0.254 mm. Our system is capable of measuring 15mm displacement in x and 20mm displacement in y axis. Thus the total cycles count should be 15/0.254 = 59.04 cycles in x and 20/0.254 = 78.74 cycles in y axis. The optical sensor data is acquired using DAQmax module of LabView. This LabView program is capable to display the current position with the direction of displacement.



(a) (b)

Fig. 5 Quadrature output for (a) right/up translation (b) left/bottom translation

4. Results

The experiments were conducted to check the repeatability and accuracy of optical sensor. The actual change in position was made by rotating x/y axis micrometer scales. This change in position detected by the sensor and transmitted to LabView designed software with an accuracy of 95%. The graph for position accuracy is shown in fig. 6 which is average for six consecutive experiments. The repeatability of optical sensor is also checked by measuring the number of cycles per 15 mm along x-axis and 20 mm along y-axis. The cycles registered in forward and backward direction for the same experiment were found similar after several experiments (graph shown in fig. 7).

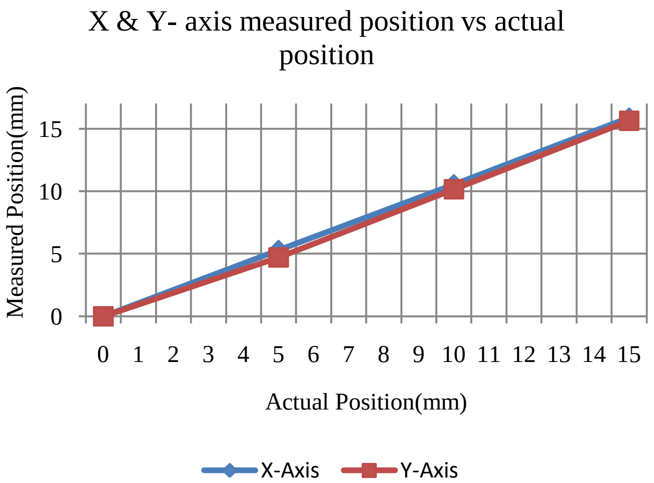


Fig. 6 x & y-axis position graph, average for 6 experiments

5. Conclusion and Future work

The optical sensor is highly sensitive sensor that can register the change of position in few tens of micrometers. This sensor shows high repeatability and accuracy for the experiment conducted to check its feasibility for the wearable robotic arm. Therefore it is concluded that optical sensor can be able to detect the slightest position change caused by the wearers arm with precision and accuracy. The purpose of investigating the precision and accuracy of optical sensor is to apply this sensing technique in the control of wearable robotic arm. The next step is to implement this technique in 3-Dimensional position control in wearable robotic arm such that it follows the slightest position change caused by the wearer's arm.

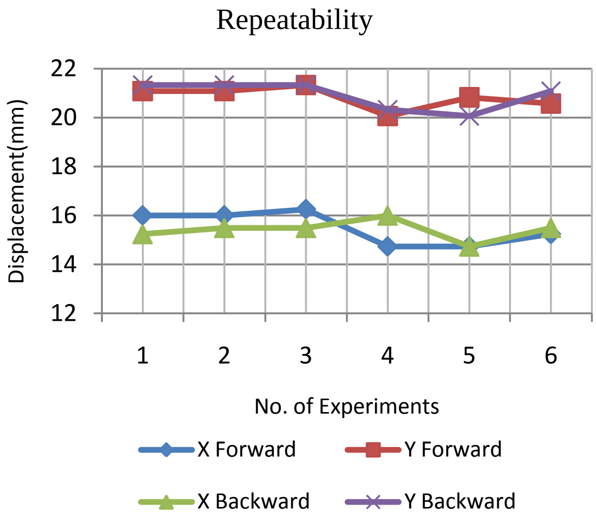


Fig. 7 Repeatability graph for x & y-axis position

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