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Determination of Object Position and Orientation Using Image Processing Technique

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Abstract
A method for measuring position and orientation of an object was determined by making use of image processing technique. The position of light sources gives a geometrical constraint between them. Three light sources was designed and constructed at appropriate positions with respect to camera (webcam), the processed/programmed images directly give the coordinate values (x and y) of each of the light spot which were used in calculating their distances apart using square root of the both coordinates. The approach is based on measuring/calculating distances and determining the object orientation. The proposed research (position-orientation masking x, y,ϴ) would be useful, in-real world for robotic applications such as navigation of indoor mobile robots and machine vision. The results show that when hand moved to 30° right to the webcam, it was seen that the orientation obtained from the tracking was 30.9°, as the hand moved in the other direction (left). The experimental result shows the direction that an object moved in degrees of angle which compared with the calculated results in order to determine the orientation (ϴ). Based on this result on the error of measurement, it shows that image processing technique is sufficient for such purposes.

Keywords: *Computer control, image processing, object position*

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INTRODUCTION

From the viewpoint of robotic applications such as the navigation of indoor mobile robots, the key for robot vision is to determine the distances and orientations of planar object surfaces such as walls, doors and other man-made objects. Considerable effort has been devoted to the development of various methods of extracting such geometrical information from scenes [1, 2]. Image processing is an important technique and long standing image understanding problem. Object detection is often based on salient image features such as edge pixels, and image conversion. Use of such features has the benefit of reducing the amount of data to be processed by the object detector. In certain applications, such as object detection in high altitude aerial images, image scale can be deduced from the image acquisition parameters but the objects can occur at arbitrary position (x, y) and orientationϴ [3]. In this paper, a fast and reliable method for two-dimensional measurement was proposed and implemented. The determination of orientation was becoming progressively more important in a huge array of application. Modern digital technology has made it possible to manipulate multi-dimensional signals with systems that range from simple digital circuits to advanced parallel computers [4, 5]. Image processing technique was clearly a method for accurate, real-time distance measurement and object detection. This technique was superior to classic measurement methods, which was especially suited for use in automation, automobiles, robotics, security technology and 3-dimensional scanning purposes. Image processing allows extracting various parameters in measurements such as position/location, while simultaneously offering the highest level of precision and uncomplicated use [4–6]. This perception has been used in this paper to process an image (image analysis, image understanding, and image processing) [7]. This was to determine the geometrical information of an object using light spots' location, in order to measure the hand orientation. The measurement system consists of a camera and three ordinary lamps (light sources) [8].

Three light sources are arranged at appropriate positions on a hand glove with respect to the camera; the processed image will enable us to determine location of each light spot using their coordinates which can be used to obtain their distances apart by the use of distance formula. The equipment setup is very simple; lighting is not assumed to be special but to approximate a point source, which can be viewed at different angles. The image processing to extract the peak positions is not computationally intensive, and the system is both practical and acceptable for robot vision [6]. Image processing satisfies the requirement of machine vision system which would be applicable in robotic applications such as identifying object, determining shape and direction of an object [9]. This was to determine the geometrical information (position and orientation) of the hand through light spots' location, in order to measure the hand orientation. The human hand was a flexible system with 25° of freedom [8]. This research was to determine the geometrical information from designed glove with light sources, which can enable the determination/measurement of hand orientation (Figure 1). A system was to be developed for determining geometrical parameters (position and orientation) of a light spots by using image processing technique. Position and orientation were the key points in most of the vision applications such as machine vision and navigation of indoor mobile robots [10].

APPARATUS AND PROCEDURE

The following accessories were used in this research:

1. Light sources (LEDs),
2. Webcam,
3. MATLAB package,
4. Microcontroller (PIC 18F1320) based system,
5. RS232 to USB converter,
6. Meter rule,
7. Hand glove,
8. PIC C compiler, and
9. ICD2 debugger.

Computer Controlled Light Sources

A network of computer controlled circuit made with a PCB consists of LEDs, resistors, and a transistor was designed and constructed on hand glove. A transistor was used to switch/amplify the signal in order to match the lamps' operating current with sink/source current of microcontroller, and current limiting resistor was also included. Three light sources were designed on hand glove (L_1, L_2, and L3) with defined distances between them, (|L1L2|=3 cm, |L2L3|=4 cm, and |L1L3|=5 cm. A camera (webcam) was fixed on a stand, the height of the camera was 30 cm to the hand glove and its optical axis was perpendicular to the floor/hand. The light sources were white LEDs which were bright and with less power consumption. These light sources were controlled by the computer by using a microcontroller. The program that initialized all the lamps connected to the controller output had to be written in such a way that the controller received commands from computer package (MATLAB) and sent signal to the LEDs. A microcontroller based PCB was designed to interface the light sources circuit, obtain the data, process it and send it to the LEDs from the computer. PIC 16F1320 Development System was used for the purpose since it was readily available (Figures 2–4).

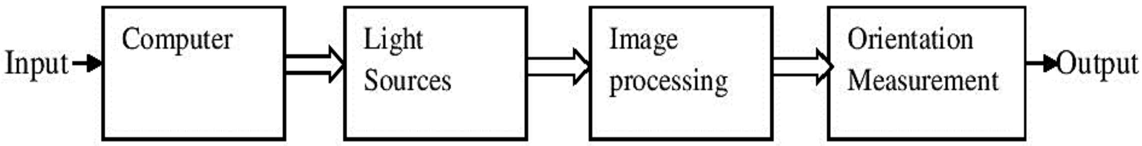

Fig. 1: *System Block Diagram.*

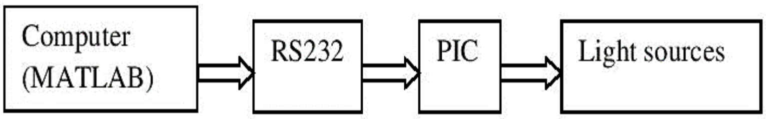

Fig. 2: *Computer Controlled Light Bock Diagram.*

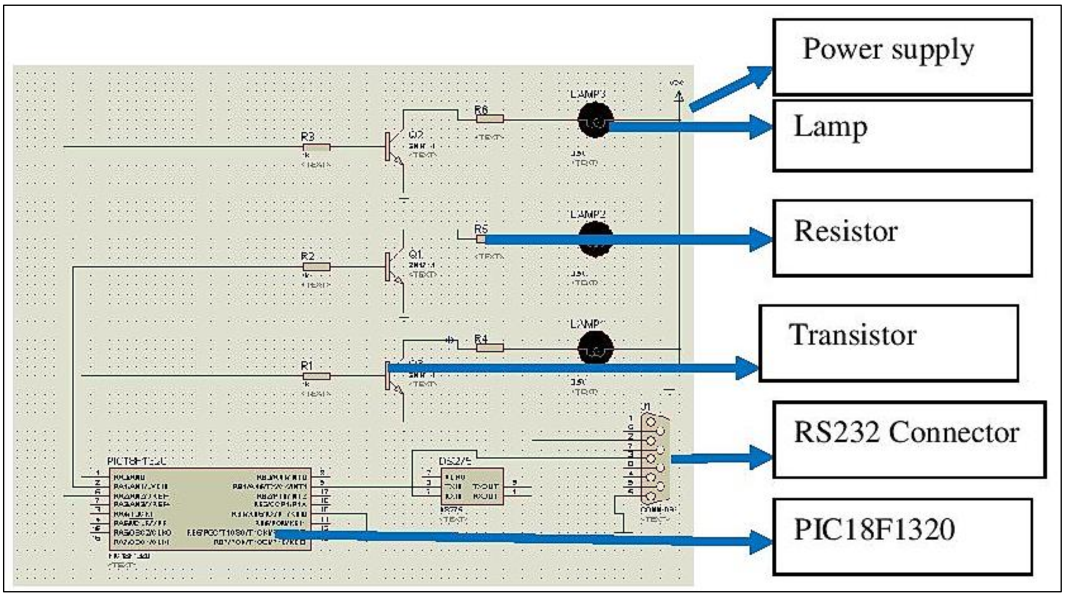

Fig. 3: *Computer Controlled Light Circuit Diagram.*

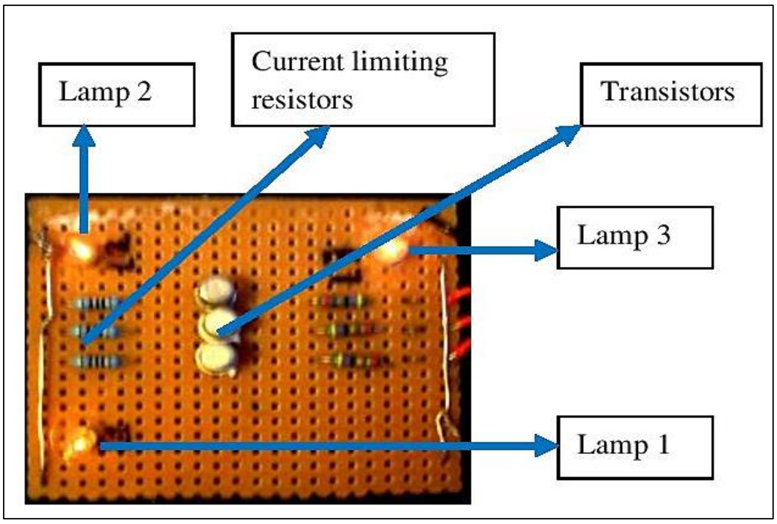

Fig. 4: *Constructed Light Sources on the Glove.*

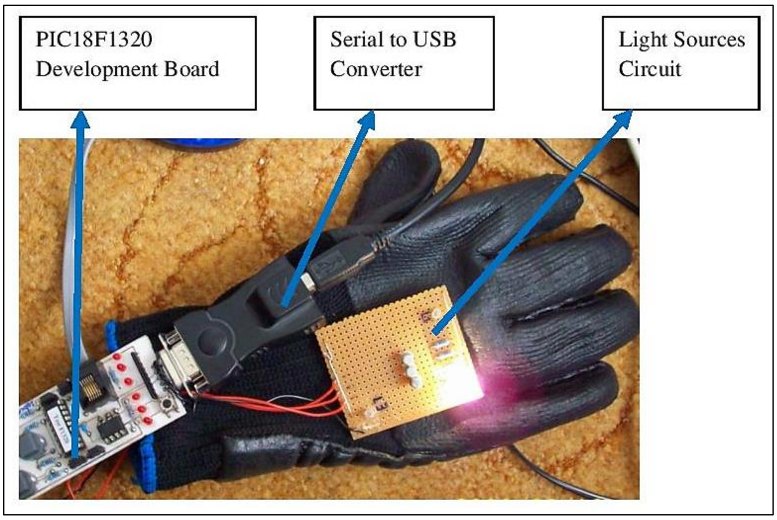

Fig. 5: *Designed Light Sources on the Glove.*

Lamp1 stands for LED 1, Lamp2 for LED 2, and Lamp3 for LED 3. The distances between these light sources was used as (|L1L2|=3 cm, |L2L3|=4 cm, and |L1L3| would be calculated as the hypotenuse of this triangle).

Microcontroller

A microcontroller based PCB was constructed to interface the light sources; circuit obtains the data, processes it and sends it to the LEDs. The PIC18F1320 can operate at a maximum clock frequency of 8 MHz and this would give a considerable speed of operation for the system. The port B of the microcontroller allows the serial data communication and this could be used to interface with the computer. RB1 of the PIC 18F1320 would serve for the transmitting serial data and RB4 could serve for serial data reception with the baud rate of 9600. MATLAB could be used to manipulate the incoming data and to be processed in the microcontroller. The data from the PIC had to be encoded for proper interface with the software on computer. RS232 was used as communication protocol between computer and microcontroller. The models were low cost and readily available in the PIC18F1320 development system used. The connection to the computer would make use of DS275 IC to convert the TTL voltage levels to +12 or –12 V, alternatively MAX232.

- PIC18F1320 Development Board was connected to light sources' circuit. This was where the program was loaded, which executed to operate the light sources. This served as the kernel of this control system.
- Serial to USB converter was used as the communication link between computer and PIC. Specifically, this was used in order to use laptop computer (without rs232 connector).
- Light sources' circuit was the hardware design of the system which consists of lamps, transistor, and resistors (Figure 5).

IMAGE PROCESSING TECHNIQUE

The image of three constructed LEDs was captured and processed in MATLAB computer package (Figure 6). The following steps were being followed from the configuring of image acquisition device (webcam) up to the determining the light spots' location.

Step 1: Installing and configuring a webcam (image acquisition device): The webcam was fixed on the clipboard at 25 cm top to the hand.
Step 2: Checking the device (webcam) information: This was to retrieve several pieces of information such as device name and ID. The following command was used to retrieve that information.

```
>> imaqhwinfo
```

```
ans =

InstalledAdaptors: {'coreco'
'winvideo'}

MATLABVersion: '7.5 (R2007b)'

ToolboxName: 'Image Acquisition
Toolbox'

ToolboxVersion: '3.0 (R2007b)'
```

```
>>info=imaqhwinf
o('coreco')
```

```
info =

 AdaptorDllName: [1x79 char]

 AdaptorDllVersion: '3.0
(R2007b)'

 AdaptorName: 'coreco'

 DeviceIDs: {1x0 cell}
```


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Step 3: Determining the Supported Video Formats.

```
>> vid=videoinput('coreco',1)

>> vid = videoinput('winvideo',1,'RGB24_320x240')

>> preview(vid);
```

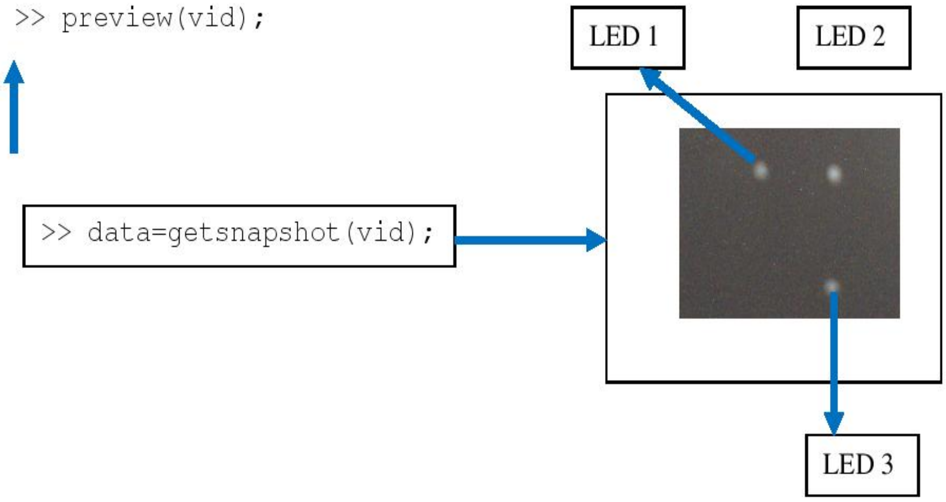

Fig. 6: *RGB Image of the Three Light Spots.*

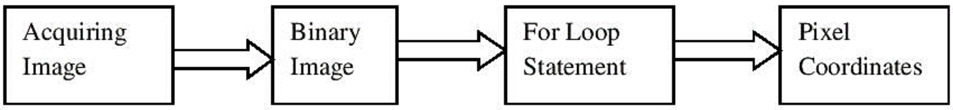

Fig. 7: *Image Processing Technique Block Diagram.*

The sequence of possible solution that would be implemented to achieve this goal was represented in the Figure 7:

- *Acquiring Image:* This consists of configuring image acquisition device (webcam), previewing video, capturing and saving the image. The image would be saved in .jpg format.
- *Binary Image:* This was to convert the obtained RGB image to black and white image with only two possible pixel values (0's and 1's).
- *For Loop:* This was designing a MATLAB program using "for loop" statement to scan the required pixel value of the converted binary image.

Position and Orientation Determination

The position and orientation was determined using light spots' images captured by finding their distances apart. This was done by having separate image of each light spot to obtain their pixel coordinates (x, y), which enables to calculate their relative change in distance as each light spot was tracked. The possible ways of determine position based on these techniques is detailed below:

- ***Distance between Two Points***

The distances between two points P_1, and P_2, would be expressed/determined in terms of their coordinates (x_1, y_1), and (x_2, y_2) using Pythagoras theorem: "In a right triangle, the square of length of the hypotenuse is equal to the sum of the square of length of the other two sides".

Mathematically:
If $P_1=(x_1, y_1)$, and $P_2=(x_2, y_2)$.
Therefore Eq. (1) was used to find the distance between these two points (P_1, and P_2). Since the image pixels was used instead of measured distance in centimetre.

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}\text{-} \qquad (1)$$

- ***Measured Distances from Three Constructed Light Sources (M_l)***

Distance between LED 1 and LED 2=3 cm
Distance between LED 2 and LED 3=4 cm
Distance between LED 1 and LED 3=5 cm (using Pythagoras theorem)

- ***Calculating Distances between Three Light Sources (K_l)***

Distance between LED 1 and LED 2: This would be calculated using Eq. (1). This was implemented after obtaining their pixel coordinates, similarly distance between |LED2 LED3|and |LED3 LED1| was calculated using the same Eq. (1).

The hand was moved in six possible locations in other to calculate the position and orientation for each position moved. The following pixel coordinates were used to calculate the distances between each LED (Table 1).

Table 1: *LEDs Pixel Coordinates Values.*

Hand Direction (°)	LED 1	LED 2	LED 3
30° Right	(11, 7)	(14, 9)	(15, 2)
60° Right	(8, 9)	(9, 5)	(7, 6)
90° Right	(17, 9)	(21, 10)	(2, 7)
30° Left	(6, 8)	(7, 13)	(9, 7)
60° Left	(4, 7)	(9, 5)	(5, 3)
90° Left	(31, 23)	(15, 12)	(33, 5)

- ***Position and Orientation as Hand Moved at 30° Right***

The distances between the light sources would be computed using the pixel coordinates obtained from their respective images.

Distance between LED 1 and LED 2 when Hand Moved at 30° Right:

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$
$$d = \sqrt{(11 - 14)^2 + (7 - 9)^2}$$
$$d = \sqrt{-13} = 3.6 \text{ cm}$$

Distance between LED 1 and LED 3 when Hand Moved at 30° Right:

$$d = \sqrt{(x_1 - x_3)^2 + (y_1 - y_3)^2}$$
$$d = \sqrt{(11 - 15)^2 + (7 - 2)^2}$$
$$d = \sqrt{-100} = 10 \text{ cm}$$

Distance between LED 2 and LED 3 when Hand Moved at 30° Right:

$$d = \sqrt{(x_2 - x_3)^2 + (y_2 - y_3)^2}$$
$$d = \sqrt{(14 - 15)^2 + (9 - 2)^2}$$
$$d = \sqrt{48} = 6.9 \text{ cm}$$

Therefore the calculated and measured distances between light sources were:

- Calculated distances =3.6+10+6.9=20.5 cm (k_l)
- Measured distances =3+4+5=12 cm (m_l)
- Angle Θ, which will give the orientation.

$$\Theta = tan^{-1}\left(\frac{m_l}{k_l}\right)$$
$$\Theta = tan^{-1}\left(\frac{12}{20.5}\right)$$
$$\Theta = 30.9°$$

Similar procedure for calculating the distances apart and comparing it with measured distances in order to obtain orientation of the hand was followed throughout the remaining five directions of the hand.

RESULTS AND DISCUSSION

Calculated Distances

The Table 2 below shows the comparison between the calculated and measured distances of the light sources designed on the glove.

Table 2: *Measured and Calculated Distances.*

Hand Direction (°)	Calculated Distances (cm)	Measured Distances (cm)
30° Right	20.5 cm	12 cm
60° Right	9.1 cm	12 cm
90° Right	14.11 cm	12 cm
30° Left	12.08 cm	12 cm
60° Left	18.46 cm	12 cm
90° Left	16.21 cm	12 cm

Measured Orientation

Feasibility of the proposed approach was demonstrated by comparing the distances to obtain orientation. Three light sources were chosen to calculate their distances apart using image processing.

Table 3: *Hand Orientation Comparison.*

Hand Direction (°)	Orientation Determined
30° Right	Θ(x, y)=30.9°
60° Right	Θ(x, y)=52.43°
90° Right	Θ(x, y)=86.1°
30° Left	Θ(x, y)=26.71°
60° Left	Θ(x, y)=17.22°
90° Left	Θ(x, y)=10.76°

Discussion of Results

Orientations obtained in Table 3 indicate that the values obtained using image processing by pixel coordinates in an image tend to be slightly different with the measured distances obtained using standard measurement methods during design. This was probably partly due to an effect of having various spots on the image background, which would be scanned instead of the required light spot. This would lead to obtain a wrong pixel value in an image.

The orientation of the hand determined shows that some point sources of light on the glove were tracked as predicted, but some were not. This was obtained through the calculated distances; as some calculated values coincide with the measured values, clearly showed that these spots were tracked correctly. This was possible due to proper processing of these images by applying accurate filters to the image that would filter out the unwanted spots in the image.

By analysing the above orientation, it shows that as hand moved to 30° right to the webcam, it was seen that the orientation obtained from the tracking was 30.9°, when the hand moved in the other direction (left). Also, that the image processing technique was an accurate method in determining a location/position.

CONCLUSION

In this research, image processing technique as a method of determining/detecting object was illustrated and confirmed. Image processing has been used to determine the position of a light spot by detecting the location of this light spot in an image. This enables to obtain the pixel coordinates (x, y) from the non-RGB image. These coordinates were used in hand orientation determination. Three different images of different positions were acquired using image acquisition device. A hand orientation determination method was presented using landmarks location. The experimental results show that two-dimensional (2D) image processing technique was a method of producing accurate geometrical information of an object. Another approach here was computer control, where the control through a microcontroller was presented. Both the results obtained show that both the two approaches satisfy the requirements.

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