

# Interaction Using the Projector Screen and Spot-light from a Laser Pointer: Handling Some Fundamentals Requirements

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## 1 Interaction Using the Projector Screen and Spot-light from a Laser Pointer: Handling Some Fundamentals Requirements

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**Abstract:** This paper presents one of the interaction models between humans and machines using a camera, the projector, and the spot-light from a laser pointer device. A camera was attached on the top of the projector, and the projector directed a direction screen display on the wall, while the user pointed a laser pointer to the desired location on the direction screen display. It is confirmed that this system can handle some distortion conditions of the direction screen display, such as an oblique rectangle, horizontal trapezoid distortion, and vertical trapezoid distortion as well as some surface illuminance - 127, 425, 630, and 1100 lux; and the system is designed to be used for static and moving objects. The coordinates that were obtained from the distorted screen can be used to give commands to a specific machine, robot, and application.

**Keywords:** Projector screen, spot-light, distorted screen, moving objects

### 1. INTRODUCTION

This paper<sup>1</sup> proposes an interface between humans and machines. A projector projects and displays a direction<sup>1</sup> screen on the wall or a floor and a user pointing a spot-light from a laser pointer while a camera capture frames of the direction screen. Coordinates obtained from the direction screen can be used as a command's coordinates for a machine or robot. The system is designed to be used for static and dynamic objects; to be used for fluctuation and instability of the illuminance<sup>1</sup> of the environment as well as for some distorted screen display, such as oblique rectangle, horizontal trapezoid distortion, and vertical trapezoid distortion.

The use of a projector as a medium between robots and humans has many benefits [1]. Several types of interfaces have been developed using projected images such as Robot Guidance on the projected display, this robot is equipped with LRF (laser range finder) and a camera to identify the nearest visitor [2]. Machino et al. used a projector and a camera on the robot as an assistant for on-site workers which the images was displayed to the wall came from the remote-supporter [3]. Both use the projector only as an information-projecting device and not as a feedback or interface apparatus. J. Park [4] proposed an indirect method of human-robot interaction by using the projected display for multi-users by using various methods such as UMPCs (ultra-mobile PCs) and a laser pointer. However, using multiple displays means the robot specific functions and tasks do not work well.

3 Some researchers have already examined the use of a laser pointer as a substitute for a PC mouse [5-8, 14]. However, it still required hardware other than the laser pointer and the camera itself, and the application was desktop-based.

Another laser pointer application is in development the depth estimation of a working piece material [9] and spot-light from a laser pointer as a target movement of a

robot arm [10]. Laser pointers are also used as tools to deliver messages to the equipment for medical purposes such as a pointing the direction of a wheelchair's movement [11]. However it has been performed only in a simulated computer<sup>16</sup> gram. Another medical application for the laser pointer is as a robot-manipulator pointing device that serves the needs of the bedridden [12] in which the laser pointer is controlled indirectly through a special lever system.

The proposed system offers another option for human interface. Coordinates obtained from the distorted screen can be used as a command's coordinates for a machine or robot. In addition, the system is designed to be used for static and dynamic objects; to be used for fluctuation and instability of the illuminance of the environment; otherwise to be used for some distorted screen display -oblique rectangle, horizontal trapezoid, and vertical trapezoid respectively.

Section 2 discusses the system specifications. Section 3 discusses the operation of the proposed system, software design phases, testing of two methods for the spot-light detection process, and testing of the transformation matrix and some distortion conditions. Section 4 presents the conclusion.

### 2. SPOT LIGHT-BASED INTERACTION SYSTEM

#### 2.1 Interface principle

The projector used to display the screen direction was pointed onto the floor or wall. Users only need to point the laser pointer to the desired place within the direction screen. A camera is ready to capture the spot-light and a computer processes it in advance. This system is expected to represent one of the interactions between humans and machines with a high mobility, safe distances between humans and robots, and a higher efficiency and practicality. One example of an application is a robot used to accompany the

guide/presenter that can point the laser spot-light directly on the direction screen in order to command the robot to perform tasks.

### 2.2 System configuration

At the beginning of its design, the system consists of a projector, USB camera, laser pointer, and computer, as shown in Fig 1.

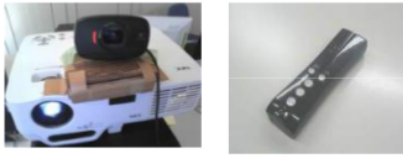


Fig. 1 Equipment in this system.

A NEC projector, Type NP41J, that uses a DLP chip, auto-focus on a range of 1.5-5.5 m, 2300 lumens brightness is used to display a direction screen. A Logicoool Webcam USB camera, Type c525, 640 x 480 resolution, 24-bit color depth, frame rate up to 30 fps, and USB 2.0 standard is used to accept input frames from the spot-light and screen direction. A red laser pointer with a wavelength of 650 nm and operation distance up to 15 meters is used to point a spot-light to the direction screen display. And a digital luminometer, Type TONDAJ LX-1010B is used to measure the surface illuminance.

### 2.3 Direction screen display

On the direction screen, there are five simulated-commands button as shown in Fig 2. These commands represented the basic movement of common machinery or the mobile robot. The five symbols are: turn left, straight forward, stop, reverse, and turn right. The empty space at the bottom of screen will be used for further system development. The screen resolution is 640 x 480, the background color is gray-obtained from 50 percent composition of each RGB color- and the signs are blue.

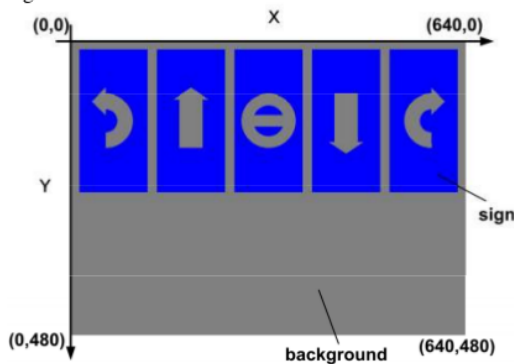


Fig. 2 Direction screen display and its coordinate system

## 3. SYSTEM DESIGN AND OPERATION

The system starts by turning on the computer and projector then setting the direction screen display to the desired location. The following session explains the software design procedure with multiple testing. A 20-millisecond timer is activated to control spot-light detection, draw the cursor on the monitor, run the foreground extraction process, and calculate the coordinates of the spot-light. However, the real speed depends on the specifications of the computer's hardware. There are three major routines in the program: detecting the spot-light, calculating the coordinate, and recognizing the area for coordinate transformation; as described in Fig 3.

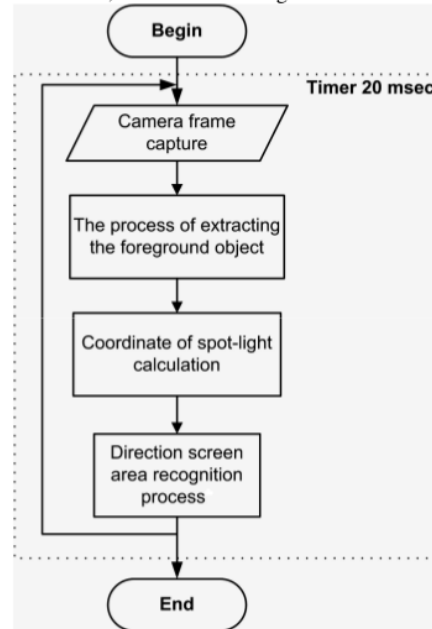


Fig. 3 Schema of software design.

The process of the direction screen area recognition was described in Fig. 4.

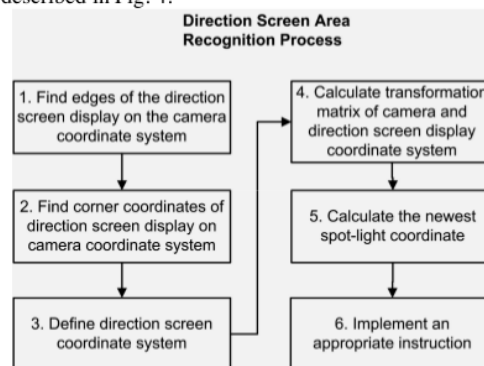


Fig. 4 Direction screen area recognition process.

The following session will explain Fig.3 and Fig.4 in more detail.

### 3.1 The process of extracting the foreground object

Two methods of the extraction process have been tried in this study: the foreground-background extraction method and the color threshold method. These methods are to separate the spot-light from the background of the direction screen display. The separated spot-light will be introduced as “foreground” in the next discussion.

#### 3.1.1 Foreground-Background Extraction Method (GM)

Foreground extraction is used to separate the spot-light from the screen background. There are many methods of foreground extraction processes but this experiment used the Gaussian mixture-based background/foreground segmentation algorithm (GM) [13]. This method is used to extract the moving object (foreground) from its background, like in a surveillance system. In this research there are two conditions of the screen –static and dynamic screen or disturbed screen. A dynamic screen occurs by shaking the screen by hand, moving the screen in and out from the projector, or by changing the sign picture.

#### 3.1.2 Color Threshold Method

The color of spot-light is identified by using the HSV color space and by using an appropriate threshold in the recognition process. Table 1 describes the result of these two methods.

Table 1. The comparison between Method 1 and Method 2.

Condition	GM method	Color threshold method
Laser spot-light color	Any color	Specific color
Background and sign color	Any color	Any color, but should be different from spot-light color
Static background and sign	Normal operation	Normal operation
Dynamic background and sign	Affected, need time to recalculate the extraction process.	Not affected as long as the color of the background and sign are different from the spot-light color.
Average response time (100 samples)	0.0373 us	0.006 us

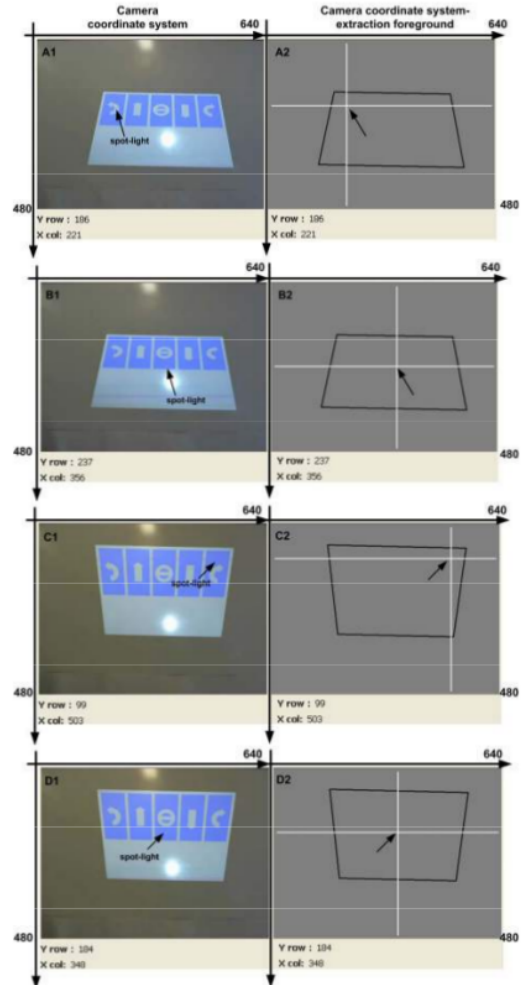
In this study, the GM method is only appropriate for static backgrounds and signs even though the response

time is greater than the color threshold method. If the background is dynamic, the GM method takes 3-6 seconds to achieve stability, depending on what learning rate is used. Some advantages of this method are that the user can use any color of laser spot-light, sign or background -it is color independent.

The color threshold method is an appropriate choice in a situation where the direction screen always changes or is dynamic. Table 1 shows that this method is faster than the GM method, but it requires a spot-light color consistency, larger spot-light size, while the color of the signs and background should be different from the spot-light.

### 3.2 Coordinate of spot-light calculation

The coordinate of the spot-light can be calculated using the mass center coordinates of the frame. The result of this process is the Cartesian coordinate system, with ranges from (0,0) to (640,480). Fig. 5 (A to F) describes the result of the foreground extraction and the coordinate calculation processes.



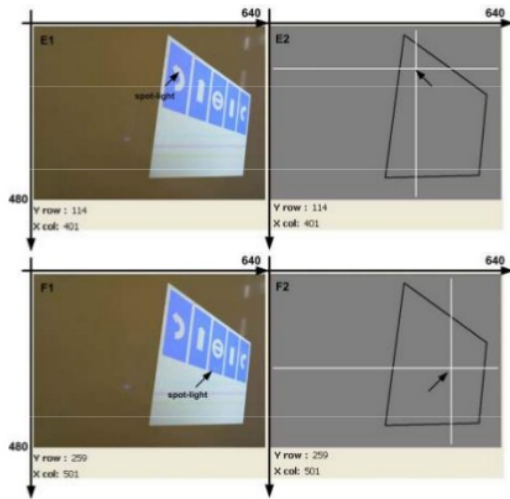


Fig. 5 Extraction foreground and coordinates of the laser spot-light calculation.

### 3.3 Direction screen area recognition process

The length and width of a directional screen display may change due to changes in the distance between the camera and the screen display. Similarly, a perspective distortion may occur because the camera and display screen were not orthogonal to each other. This process is to calculate and implement a transformation matrix from the camera coordinate system to the direction screen coordinate system.

#### 3.3.1 Find edges of the direction screen display on the camera coordinate system

Edge detection is the critical step that determines the subsequent processes. All edges in a directional screen should be identified perfectly. Sometimes the illuminance of the environment can cause fluctuation and instability; the threshold in this proposed system was made adaptively to avoid this problem. There are two thresholds -upper and lower- which calculated by determine the median of the image histogram periodically. However, in static threshold experiment, the threshold is defined as 130 and 70, respectively. In this research the illuminance that have been tested are: 127, 425, 630, and 1100 lux, namely condition 1, 2, 3, and 4 respectively. Table 2 and Fig. 6 display the comparison between static and adaptive threshold in the edge recognizing process.

Table 2. The performance comparison between static and dynamic threshold in recognizing all edges

Experiment condition	Illuminance (lux)	Static threshold	Adaptive threshold
1	127	100%	100%
2	425	100%	100%
3	630	50%	100%
4	1100	10%	90%

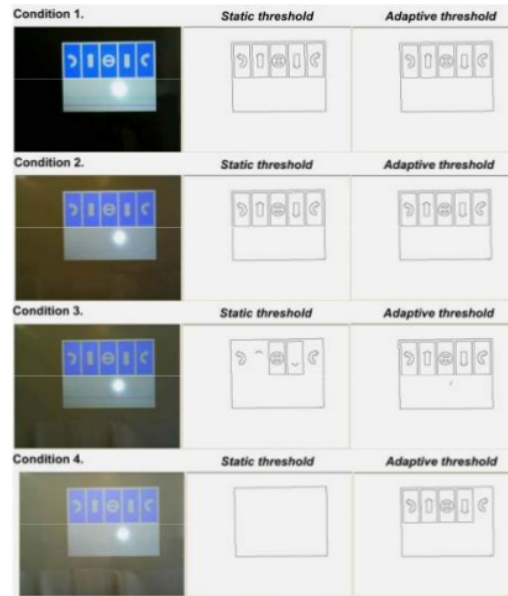


Fig. 6 Edge detection results process.

In condition 1 and 2, all edges were detected as well as for static and adaptive threshold. However the performance result of static threshold starts to decline with increasing illuminance, starts from 100%, 50% and finally only 10% of edges was recognized.

#### 3.3.2 Find corner coordinates of direction screen display on camera coordinate system

The corner coordinates were used to determine the area of the direction screen and to calculate the transformation matrix. The coordinates can be found by calculating the distance between the end-points of every polygonal approximation and the coordinates of the top-left (dist a), top-right (dist b), bottom-right (dist c), and bottom-left (dist d) respectively. (X,Y) is the end-point coordinate of every polygonal approximation.

$$\text{dist a} = \sqrt{X^2 + Y^2} \quad (1)$$

$$\text{dist b} = \sqrt{(640 - X^2) + Y^2} \quad (2)$$

$$\text{dist c} = \sqrt{(640 - X^2) + (480 - Y^2)} \quad (3)$$

$$\text{dist d} = \sqrt{X^2 + (480 - Y^2)} \quad (4)$$

Corner coordinates are the minimum value in each calculation of Eqs. (1) ~ (4).

#### 3.3.3 Define direction screen coordinate system

The coordinates' destination is the maximum coordinates that will be used for conversion. In this system, the resolution of the direction screen is 640 x 480; this value will be the maximum coordinate of this system. Therefore, the rectangle corner coordinates (column,row) are:

Top-left : 0,0  
 Top-right : 640,0  
 Bottom-right : 640,480  
 Bottom-left : 0,480

3.3.4 Calculate transformation matrix

A camera frame display can have linear and perspective distortion. Fig. 7 shows some forms of distortion that may occur in the proposed system –oblique rectangle, horizontal trapezoid, and vertical trapezoid, respectively.

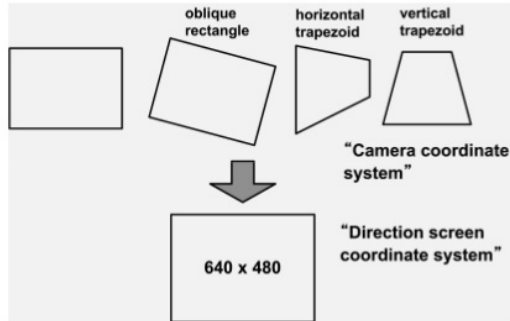


Fig. 7 Various forms of distortion.

3.3.5 Calculate the newest spot-light coordinate

The result of the transformation matrix is used to

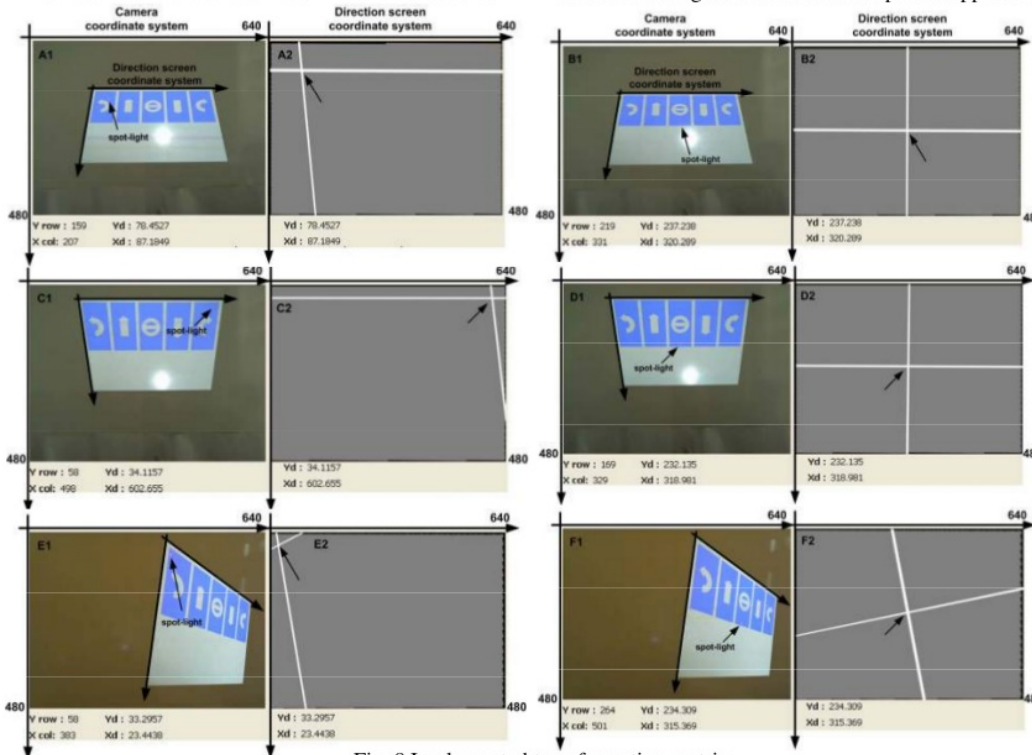


Fig. 8 Implemented transformation matrix.

calculate the final coordinates of the spot-light on the direction screen (640 x 480). Fig 8 shows pictures of the transformation of the coordinates, the white lines are the auxiliary lines that the intersection is the final coordinate; while Table 3 shows the final coordinate of the spot-light in the camera and direction screen coordinate system respectively.

Table 3. Spot-light coordinates

Camera coordinates system	Direction screen coordinates system
A1 (207,159)	A2 (87.18, 78.45)
B1 (331, 219)	B2 (320.29, 237.24)
C1 (498, 58)	C2 (602.66, 34.12)
D1 (329, 169)	D2 (318.98, 232.13)
E1 (383, 58)	E2 (23.44, 33.3)
F1 (501, 264)	F2 (315.37, 234.31)

3.3.6 Implement an appropriate instruction

The spot light coordinate in the direction screen display in Fig. 8 (A2, B2, C2, D2, E2, and F2) can be customized to the coordinate of the sign. Therefore the command or instruction could be inserted into the program regarding those signs' coordinates. We are working to improve this system and implement these coordinates to give commands to a specific application.

#### 4. CONCLUSION

This paper proposed a basis for an interface between humans and machines using a spot-light from a laser pointer, a camera, and a projector. This proposed system has obtained the stable conditions of spot-light detection as shown in Fig. 5, while in some distorted screen area –oblique rectangle, horizontal trapezoid distortion, and vertical trapezoid distortion respectively as shown in Fig. 8 and Table 3. Various lighting environments is the critical factor in the edge detection step, in this experiment we were used 127, 425, 630, and 1100 lux surface illuminance in testing our system, therefore the adaptive threshold mechanism in detecting the edges that was applied in this system is the other advantage, as described in Table 2 and Fig. 6.

Although the current system can result the coordinate of laser spot-light in screen distortion, we are working to improve this system's ability to calibrate for another kind of direction screen distortion, implementation on a single PC, and implement the system to give commands to a specific machine, robot, or application.

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