Moving Target Position Detecting System using Dual Line CCD and Photometric Interpolation

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Abstract — A realization for an accurate position detecting system of a moving target in two dimensional plane using dual line CCDs and photometric interpolation is presented. The system is realized that the infrared LEDs are utilized for lighting source, a target size is recognized by the scanned data from CCD owing to blocking the radiated light path by placing the target between CCD and lighting source, a coordinate on the plane is found by plane trigonometry formed by the moving target and two CCD sensors, and the former scan data is used for the coordinate iteratively and the photometric interpolation is applied to sub-pixel of scanned image. The experimental results show that the experiment results in a success rate about 3 different size targets, 3, 5 and 7mmm on the test plane 210x373mm. The moving target positioning detected success rate is 93% in 3mm target, 5mm is 95.3%, and 7mm is 95.8% respectively. The photometric interpolation is enhanced to 1.5% in comparison to be unused.

Index Terms — Moving target, Positioning detection, Dual line CCD, Photometric interpolation.

I. INTRODUCTION

A most input device of the computer is equipped with keyboard, mouse and graphic tablet. A mouse is developed with various displacement detecting sensor; capacitive, derivative, magnetic, ultrasound and photo sensing. Those are not appropriate to utilize in an outdoor system such as big size monitor and displayer at kiosk. A computerizing automatic machine is also required to input a data and instructions intuitively. This needs a touch inputting function to correspond to the absolute coordinates on the monitor as matter of convenience.[1,2,4] The absolute coordination methods enable touch screen to be classified by using the capacitive, ultrasound and infrared sensor.[4] The touch screen is required to cover the touch film up on the monitor or tablet. That leads merits to recognize an accurate coordinates and to input in a pen, finger and other things. Whereas the covering film on the full monitor or tablet plane causes to be increased the manufacturing cost and get damaged by shock in external impact. The ultrasound has a merit to construct an inexpensive system except adhesive ultrasound emitter to delicate pen for recognizing the coordinates. The infrared sensing method is composed of an infrared LED transmitter and receiver results in low resolution to be decreased touch accuracy in depending on the gap of sensors.[3,5,6]

Line-scan CCD camera is mainly used for applications that a precise measurement is required. These sensors lead to a high resolution e.g. 2048 or 4096 pixels per line. However the system has a quite complex in system design and the number of processing data is increased relatively. A monochrome line CCD supports a good resolution with a small pixel size which makes them suitable for an accurate measurement. Whereas it is difficult to find out a primary position from one line data at one time, that is required to make sub-processing.[7,8]

Thus, the coordinate detecting system with dual line monochrome CCDs in 2D plane is realized in this paper. The system is implemented that the infrared LEDs are utilized for lighting sources, a target size is recognized by the scanned data from CCDs owing to blocking the radiated light path by placing the target between CCDs and lighting source and reduce the noise with the moving average filter, a coordinate on the plane is found by plane trigonometry formed by the moving target and two CCD sensors, and the former scan data is used for the coordinate iteratively and the photometric interpolation is applied to sub-pixel of scanned image. The evaluation of the system comes from comparing to the coordinate error between accuracy and preference by using the stepping motor to move the target on the test plane.

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II. SYSTEM REALIZATION

2.1. System configuration

The moving target detecting system is composed of 3 blocks; analog block, control block and display block as shown in Fig. 1. The analog block acquires input data from 2 CCDs for sensing the target existence on the plane. The light source gives them control signal to handshake in the control block. The control block has ADC to convert to digital data. The data is processed to filter, peak detection and coordinates conversion. The display block indicates the moving target coordinates through the USB interfacing. One line CCD enables to search out the target over 90 angles with constant illuminating condition. Fig. 2 shows the arrangement between 2 CCDs and the light sources.

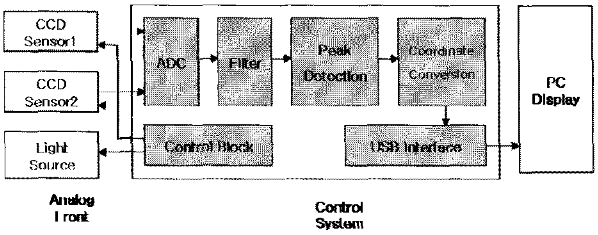


Fig. 1 System Configuration

At the system blocks, one CCD is searching for the target based on the upper and lowest end light sources, and the other source on the left and below sources. The lighting source, infrared LED has high frequency bandwidth than visible light. That makes an error reduce due to different wavelength each other.

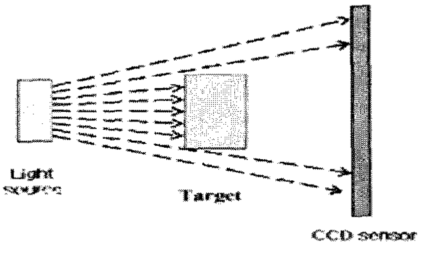


Fig. 2 Target detecting arrangement

2.2. Position detecting algorithm

Dual line CCDs are placed at the left and right upper side corners for the coordinate detection on the plane. The light sources are arrayed at the lowest end on the plane. If the length l between the two sensor is defined, the angle θ_1 and θ_2 between sensor and target is defined, then the $f(x,y)$ coordinates from the light source is given by equation (1).

$$f(x,y)=\left(l\frac{\tan\theta_2}{\tan\theta_1+\tan\theta_2},l\frac{\tan\theta_1\tan\theta_2}{\tan\theta_1+\tan\theta_2}\right) \tag{1}$$

The angle between sensor and detect target is produced by using a pixel position from sensor output. If a target is detected in the pixel data, the equation for the angle yields equation (2) Where 45 degree means the fixed CCD slope placed, n is the pixel that the target position is detected, and N is the number of total pixel.

$$\theta=45^\circ+\tan^{-1}(\frac{N-2n}{2n}) \tag{2}$$

Substituting Eq. (2) into Eq. (1) results in Eq. (3) and Eq. (4). Where n_1 and n_2 denote the pixel number to be detected by 2 sensors respectively. Eq. (3) and (4) $f(x,y)$ are used to make coordinate conversion algorithm for the moving target position detecting.

$$\frac{x}{l}=\frac{n_2(N-n_1)}{n_1(N-n_2)+n_2(N-n_1)} \tag{3}$$

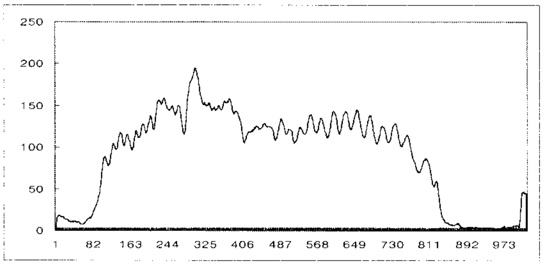
$$\frac{y}{l}=\frac{n_1n_2}{n_1(N-n_2)+n_2(N-n_1)} \tag{4}$$

2.4. Noise reduction

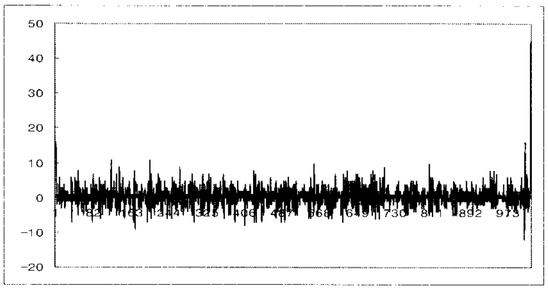
The data of line CCD sensor has big deviation in depending on brightness of light and gap of infrared LEDs, and is also affected by illumination outside. This is required to take filter to separate the target signal from noise. The moving average filter is simple in digital signal processing. The function keeps a sharp step impulse and reduces a random noise. The filter is operated by averaging and adding to a few point data produced at each point like Eq. (5).

$$y[i]=\frac{1}{M}\sum_{j=0}^{M-1}x[i+j] \tag{5}$$

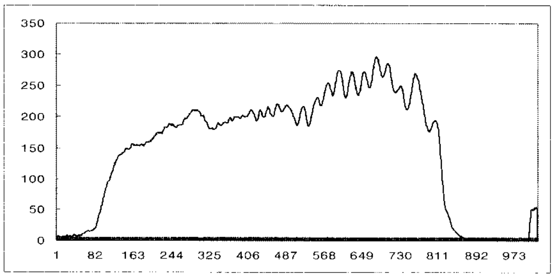
Where x is input data, M is the moving average point number, and y is the filtered output data. The number of the moving average points takes 5 to make simple calculation. The processing is shown in Fig. 3: (a) shows the filtered moving average signal from AD converted signal of CCD1, (b) indicates the noise signal of CCD1, and (c) and (d) shows CCD2 signals respectively. The x-axis is the pixel number, and y-axis means amplitude of signal and noise.



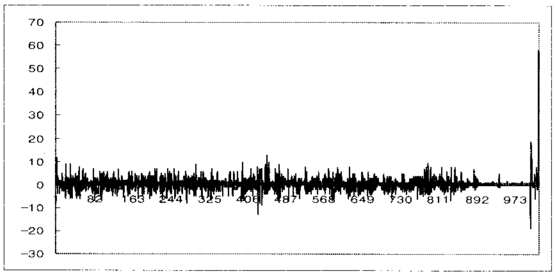
(a)CCD1 Filtered signal



(b)CCD1 Noise



(c)CCD2 Filtered signal



(d)CCD2 Noise

Fig. 3 CCD1, CCD2 Filtered signal and noise

2.3. Photometric Interpolation

The photometric interpolation designed with minimal requirements for processing time is not optimal. The peak height depends on the edge slope and the comparison level must be carefully selected. In case of the reference level intersection is used for the coarse edge localization, the edges enable to be located on the way to read out the line. Only a few pixels around the edge can be stored in the internal memory of processor and used for the photometric interpolation. To increase the reliability of this method, the reference level should be derived from the minimal and maximal value of the signal.

The simplest interpolation method used to improve the edge position estimation is the linear inter interpolation. Only two points around the reference level intersection are required. The principle of this well-known method is shown in Fig. 4. The correct edge position is calculated by Eq. (6).

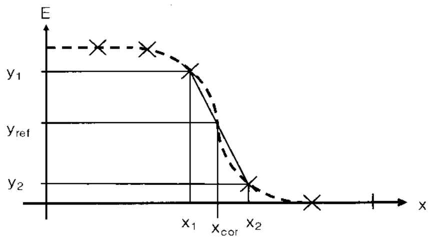


Fig. 4 Photometric interpolation

$$x_{cor} = x_1 + \frac{y_{ref} - y_1}{y_2 - y_1} \cdot (x_2 - x_1) \tag{6}$$

The interpolation method used in this paper is implemented in wider surrounding of the reference level. The basic idea is that the real edge curve is arrayed to be the same area as shown in Fig. 5.

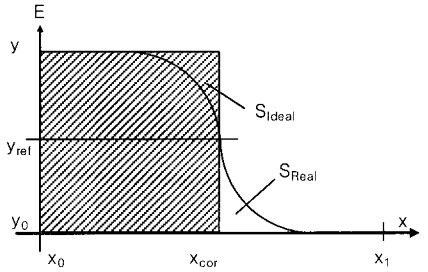


Fig. 5 Photometric interpolation

The correct edge position can be calculated by the following equation (7).

$$(x_{cor} - x_0)(y_1 - y_0) = \int_{x_0}^{x_1} (y(x) - y_0)dx \tag{7}$$

In fact the intensity profile along the edge neighborhood is sampled with a constant step size Δx. The integral can be replaced by a sum. The correct edge position is given by Eq. (8).

$$x_{cor} = x_0 + \Delta x \frac{\sum_{n=x_0}^{x_1} (y[n] - y_0)}{y_1 - y_0} \tag{8}$$

This is an integral summation. Thus local pixel inhomogeneity is less sensitive to additive noise. The main limiting factor is the determination of the upper and lower limits. The edge outside of the acquired signal is not flat and contains also some additive noise, and the limits should be calculated an average of several points around the beginning and end points (x_0 and x_1). These points need to be symmetrical around the reference level and crossing point. The distance and the average of the amount of pixels must be carefully chosen in depending on the application.

Ⅲ. EXPERIMENT AND RESULT

The experimental flat board 210x373mm is composed of 1024 pixels dual line monochrome CCDs and the arrayed infrared LEDs light sources along the board edge as shown in Fig. 6 with 32 bits microprocessor for the moving target position detecting algorithm. The experimental conditions are that the targets size are changed to 3, 5 and 7mm, and moved by driving a stepping motor to keep a constant step angle to clockwise and a constant speed for reliability. The moving path of the target orbits along a diameter 120mm of the center on the plane. The detected coordinates is compared to the simulation coordinates.

Fig. 4 shows an arrangement for the experiment system in detail. The CCD sensor is placed to upper corner of the test plane with slope angle 45 degree. The infrared LEDs are mounted at the lowest end, left and right side of the test plane. The LED is off in the idling, and turns on at scanning to get luminance for CCD. The step motor in order to rotate the test target and a mounting frame are installed at the center of the test plane.

The target width in detecting from the sensor is changed by size and position of the target respectively. The detecting target size and position enable to be discriminated. Fig. 6 shows the CCD sensor signals in putting the different size target on the plane.

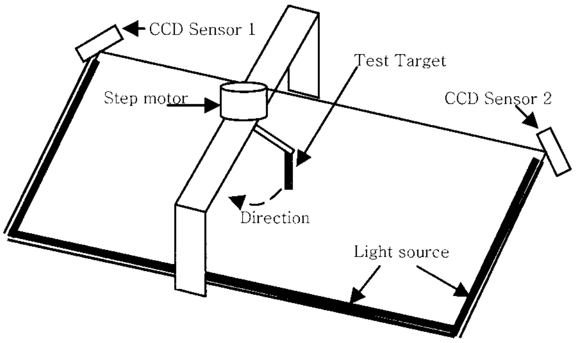


Fig. 6 System testing board

The peak detection value of CCD to the target size 5mm comes out 104, and 3mm is 70. In Fig.7 x-axis is the pixel number of sensor and y-axis indicates magnitude of signal. The range is 0 to 255. The peek wave width enables to discriminate a different target size at the same location.

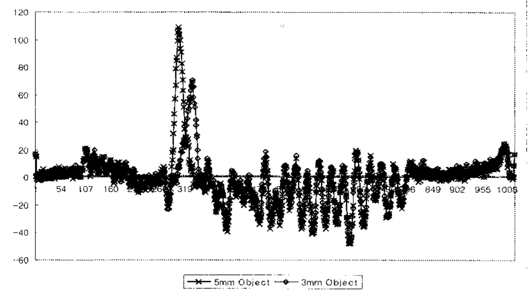


Fig. 7 CCD signal of the target size 3 and 5mm

Fig. 8 shows signal levels at no target and blank space. One of the CCDs, #1 is lamp ON, and #2 is OFF. These are the reference levels for detecting target. If lamp is OFF, then CCD sensing level is around 500 mostly not to be varied. If ON, sensing ADC level is 400 to 300. This high difference between #1 and #2 makes high threshold level. It is easy to detect a target. The nonlinear signal levels depend on lamp distance and illumination.

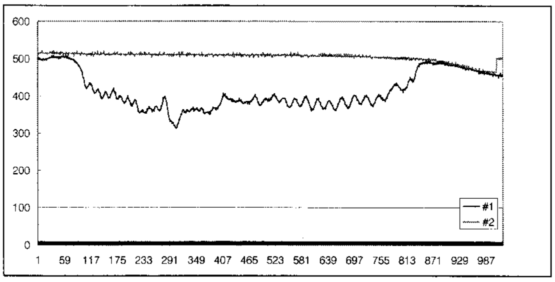


Fig. 8 Lamp ON/OFF CCD reference signal

On putting a target on the test board, one of the CCDS makes normalized signal #3 as shown in Fig. 9 included a harmonic noise. The noise is filtered by the five points moving average filter, and then #4 is compared to the reference signal #1. The peek wave of difference signal #5 shows the target detecting position. The peek with threshold and width is corresponded to a pixel number. This is allocated to a physical coordinates.

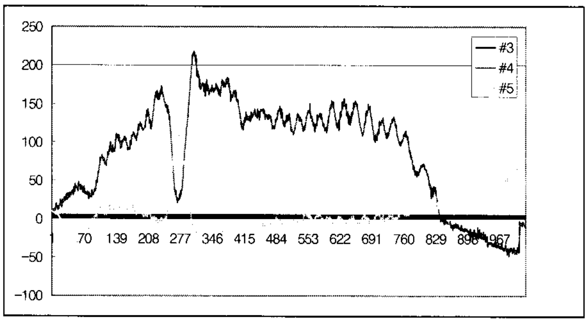


Fig. 9 Filtered and compared signals

When the target is moved the test plane, the signal is changed continuously as shown in Fig. 10 and the pixel position is changed from #1 to #2. The width and peek signal is varied by detecting position.

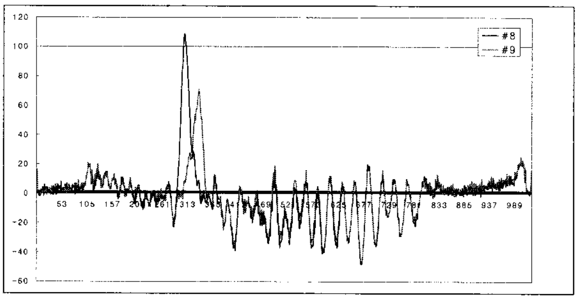


Fig. 10 Moving target signal

At no target the dual CCDs signals normalized has symmetrical pattern between left and right as shown in Fig. 11.These are the dual reference signals.

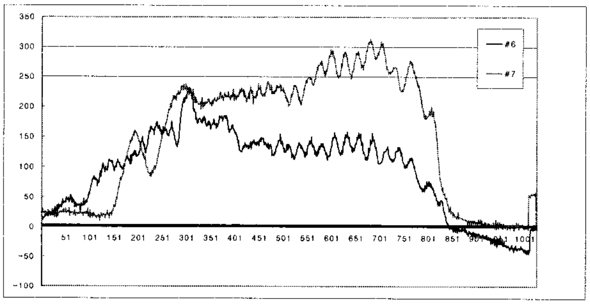


Fig. 11 Dual CCD normalized reference signals

The dual CCDs signals target are shown in Fig. 12 at a target is situated on the test board. The peek signals of CCD1 and CCD2 are located on the same position. The peek may be changed by light intensity and array.

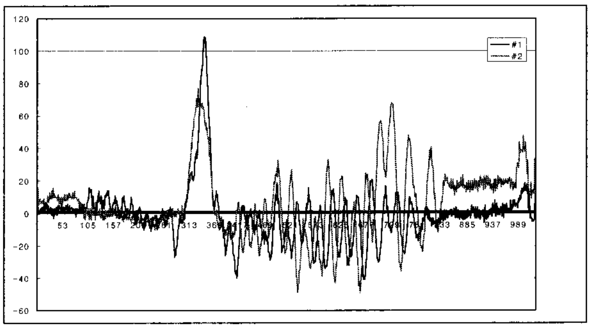


Fig. 12 Dual CCDs signals for target detection

The experiment results in a success rate about 3 different size targets as shown in Fig. 13. X-axis indicates the moving angle, and y-axis points out the count of success. The moving target positioning detection success rate is 93% in 3mm target, 5mm is 95.3%, and 7mm is 95.8% respectively as shown in Fig. 14.

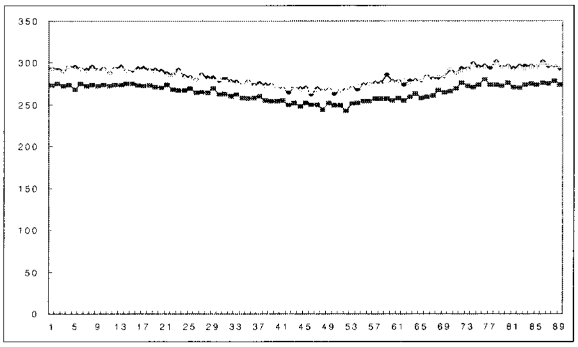


Fig. 13 Success rate of the position detection

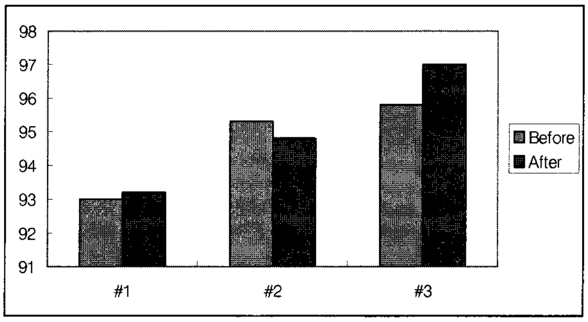


Fig. 14 Moving target position detection success before and after.

The photometric interpolation is enhanced to 0.2~1.5% in comparison to be unused. The error rate shows before and after the photometric interpolation as shown in Table 1. As this result, in case of small target with the method the correct positioning coordinates of the target is more accurate because of good details. The error causes to depend on the detected angle difference of sensor. This results from the low success rate at a part of the test plane, and the error rate is affected by the different illumination caused by a surrounding interference of the light sources.

Table 1 Error rate of the before and after photometric interpolation

Test Target	Before	After
#1	7.2	7
#2	4.2	4.7
#3	5.4	4.2

IV. CONCLUSIONS

A realization for accurate position detecting system to moving target in 2D plane using dual line CCDs and photometric interpolation is experimented. The experiment results in a success rate about 3 different size targets, 3, 5 and 7mmm on the test plane 210x373mm. The moving target positioning detected success rate is 93% in 3mm target, 5mm is 95.3%, and 7mm is 95.8% respectively. The photometric interpolation is enhanced to 1.5% in comparison to be unused. As this result, in case of small target with the method the correct positioning coordinates of the target is more accurate because of good details. The error causes to depend on the detected angle difference of sensor. This results from the low success rate at a part of the test plane, and the error rate is affected by the different illumination caused by a surrounding interference of the light source.

In the future, the study is required to reduce an error correspond to region in coordinate plane, and to increase overall moving target recognition rate with a multi-touching.

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