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A Two-Dimensional Positioning System Suitable for Noisy Environment

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Abstract: The authors proposed a new two-dimensional(2D) positioning system by use of M-array suitable for noisy environment in '88KACC and its revised version in '89KACC. This 2D positioning system is further improved to be used in practice; the computation time is improved by use of vector signal processor and the focussing process is improved by use of an electrically controlled zoom lense. It is shown that this system is robust to noise and also to misalignment of devices.

1. Introduction

A two-dimensional (2D) positioning technique is one of the most important technique in industrial processes such as automatic build-up system, insertion process of capacitors or registers on to a board and so on. The authors proposed a new 2D positioning system by use of M-array in '88KACC [2]. In this system, the property of M-array is used in that the 2D autocorrelation of M-array has a very sharp peak at its origin. However, since it sometimes ocurrs the case where the autocorrelation of M-array is too sharp for servo-controlloing the two-dimensional position, the system was improved by use of autocorrelation of vague M-array which was observed with a TV camera in out-of-focus condition('89KACC) [1].

This two-dimensional positioning system is further improved to be used in practice; the computation time is improved by use of vector signal processor(VSP) and the focussing process is improved by use of an electrically controlled zoom lense. An M-array pattern is attached on an object(xy-table in this case) which is to be XY-positioned. The object is observed with a TV camera which is at first in out-of-focus condition. Then the observed image data including the vague M-array is crosscorrelated with the reference M-array in a computer. Since it is known that the autocorrelation of the vague M-array has a larger width in the vicinity of its origin than that of pure M-array, the vague M-array gives wider error signal for XY servo system, so it is more suited to be used for servo controlled positioning in an early stage. When the XY-table come close to the aimed point, the focus of the lense is servo-controlled to be in a focused condition, so as for the autocorrelation of the vague M-array becomes sharp. Thus the positioning accuracy becomes high.

The performance of the system is checked for various conditions. The effect of mismatch of the XY direction of the TV camera is checked. The results of the experiment show that the follow up speed is much improved by the use of vector signal processor and the focussing process is improved by use of a servo-controlled zoom lense. It is shown that this positioning system is robust to noise and is very suited to be used in a noisy environment.

2. Principle of the method

The basic diagram of the 2D positioning is shown in Fig.1. An M-array pattern as shown in Fig.2, black and white pattern in this case, is attached on an object to be 2D positioned. The M-array pattern is observed by a TV camera, and the image data are fed to a personal computer through an interface. Here the focus of TV camera is at first set to out-of-focus condition so that the image data from TV camera plays a role of the added M-array(Kashiwagi *et.al.*,1987). The added M-array is very useful in following up the peak of correlation function since the correlation function of the added M-array has enough width which enables us to get information about the direction of control even when the displacement of the object from the right position is large. The observed image data of the M-array are then crosscorrelated with a reference M-array stored in the personal computer. The 2D crosscorrelation function is first calculated with a vector signal processor by use of 2D Fast Fourier Transform(FFT) algorithm, and the peak of the crosscorrelation function is 2D sought roughly by use of X-Y positioning servo. This rough positioning is called here the first stage of the positioning. Then the system proceeds to the second stage, fine and precise positioning in the vicinity of the peak of the crosscorrelation function. In this stage, the focus of the TV camera is controlled with an electrically controlled zoom lense so that when the X-Y positioning come close to the vicinity of the true peak, TV camera is focused well,and when the positioning is apart from the peak, TV camera is in out-of-focus condition. The signal processing in this 2D positioning system is shown in Fig.3.

3. An M-array Pattern

The M-array pattern used here is of 8 order(15×17 elements, 30mm×34mm in real size) as shown in Fig.2. Here one element of the M-array is a square of 2mm×2mm, which is taken into the personal computer as 4×4 pixels. That is to say, one pixel in the image data corresponds to 0.5mm in real size. It is quite easy task to make this correspondence as precise as you want. Although an optical M-array pattern of black and white is used in this system, we can also use a magnetic pattern, if necessary. In our TV camera system, 240×150 pixels of image data are fed to a personal computer. Out of these data, 128×128 pixels are taken out for image processing. The 128×128 pixel image including M-array is crosscorrelated with a reference M-array stored in the computer by use of 2D FFT and inverse FFT.

4. Focusing of TV camera

The focusing of TV camera is performed with an electrically controlled zoom lense. As a prototype experiment, we use two stage focusing;one in the focused condition, and the other in the out-of-focus condition. When the displacement of XY table is large, the focus is in out-of-focus condition in order to get wide error signal(about 2.5 times larger than the focused case). The out-of-focus condition of TV camera plays a role of addition within a circle optically. Thus the added M-array can be obtained optically without calculating it in a computer.

5. Experimental result of positioning

Fig.4 shows one example of the obtained crosscorrelation functions. We see the sharp peak at the right phase of the observed M-array. The X-Y table is controlled by 2D servo systems so as for the crosscorrelation to be a maximum(The first stage). Then, several crosscorrelation values of the vicinity of its peak are calculated. From these crosscorrelation values, the precise adjustment of the peak following system is carried out(The second stage)by use of the steepest ascent method. Note that the control of the focus is also carried out at the same time X-Y servo controls the X-Y axes. Even when the object to be positioned is moved to some place, the positioning system follows up the right position repeating the first and second stages.

6. Improvement of Positioning speed

The positioning speed is much improved compared with the previous system, mainly due to the use of vector signal processor(VSP) for computing 2D FFT. The image data taken from the TV camera are at first of 128×128 pixels. These data are fed to VSP for computing the crosscorrelation fucntion between the image data and the reference data via 2D FFT. In the previous system, the image data are sampled with sampling interval of 2 to be 64×64 pixels in order to reduce the calculation time. Nevertheless,it took 11 seconds in the first stage(rough positioning). The present system takes only 3 seconds for 128×128 pixels in the first stage. Thus we see much improvement in the positioning speed by use of vector signal processor.

7. Effect of Rotation of TV camera

The M-array pattern has the shape of a square as shown in Fig.2. So the XY direction of the M-array must be equal to the XY direction of the XY table or TV camera in order for the crosscorrelation function to be high enough when the XY position of the M-array is in the right position. However, there occurs the case in practice where the alignment of TV camera is a little bit mismatched to the XY direction of XY table. The authors have checked this effect of mismatch of XY direction by rotating TV camera. Fig.4 shows the crosscorrrelation function when no mismatch occurred. Fig.5 shows the case where TV camera is rotated by 5 and 9 degrees, respectively. From these figures, we see that we can get enough crosscorrelation value even when the XY direction of TV camera is mismatched by 9 degrees from the right direction.

8. Conclusion

The two-dimensional positioning system by use of M-array proposed by the authers in '88KACC and '89KACC is much improved by use of vector signal processor and electrically controlled zoom lense. At first, TV camera has a focus of out-of-focus condition. Thus obtained vague M-array essentially plays a role of added M-array without calculating the addition of M-array[1]. Therefore, by use of the vague M-array, the positioning process becomes much faster than in case of added M-array. In addition, the use of vector signal processor has shortened the calculation time for 2D FFT very much. The positioning speed is shown to be within 3 seconds in the first stage(rough positioning) and within 2 seconds in the second stage and after(precise positioning).

In this paper, a black and white M-array pattern and TV camera was used. However, we can use a magnetically marked M-array pattern and a magnetic pick up instead, when a small mark is needed. The effect of mismatch of XY direction of TV camera is also investigated. And it is shown that even when the alignment mismatch of XY direction of the TV camera is 9 degrees, the system has a good performance.

It is shown that in addition to the robustness of this system to noise, the system is also robust to misalignment of the TV camera to some extent. Therefore this method of 2D positioning is suitable for being used widely in the field of various industries even in noisy environment and in a rough alignment of the devices.

References

(1) H.Kashiwagi, M.Sakata and A.Ohtomo, "A Two-Dimensional Positioning System by Use of Vague M-array", *Proc. of 1989 KACC held in Seoul, Korea,* pp.1059-1062(1989)

(2) H.Kashiwagi, M.Sakata and A. Ohtomo, "A two-dimensional Positioning System by use of M-array", *Proc. of 1988 KACC held in Seoul, Korea*, pp.782-785(1988)

(3) H.Kashiwagi, H.Harada, S.Honda and T.Takahashi, "A random signal suitable for delay-lock tracking servo systems", *Proc. of 1987 KACC held in Taejon, Korea*, pp.823-826(1987)

(4) F.J.Mcwilliams and N.J. Sloane, "Pseudo-Random Sequences and Arrays," *Proc. IEEE*, Vol.64, No.12, pp.1715-1729(1976)

(5) S.W.Golomb, "*Shift Register Sequences*", Holden Day (1967)

(6) H.Kashiwagi, "Recent Topics on M-sequence", (in Japanese), *J.SICE*, Vol.20, No.2, pp.236-245(1981)

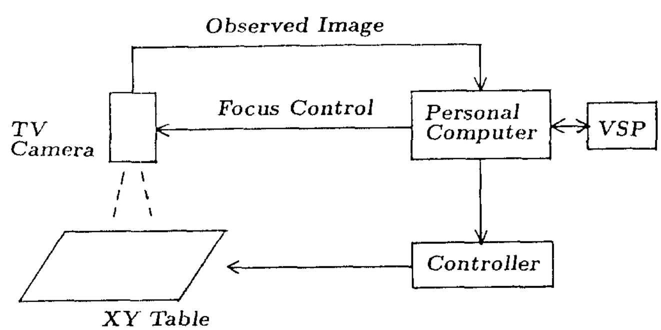

Fig.1 Basic diagram of the 2D positioning system

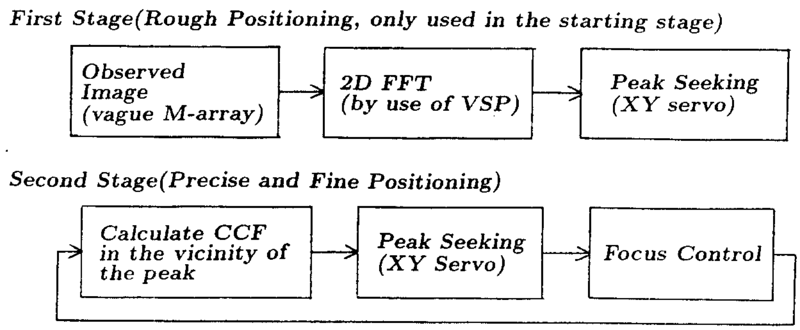

Fig.3 Signal processing in the system

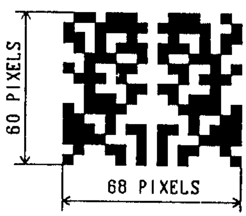

Fig.2 An M-array pattern

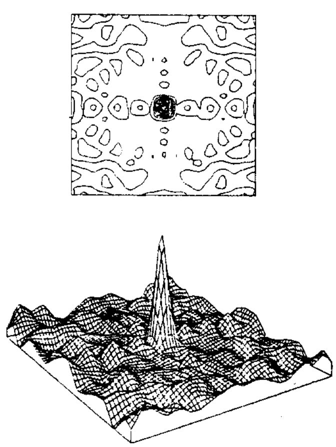

Fig.4 Crosscorrelation function in case where no misalignment in TV camera occurred.

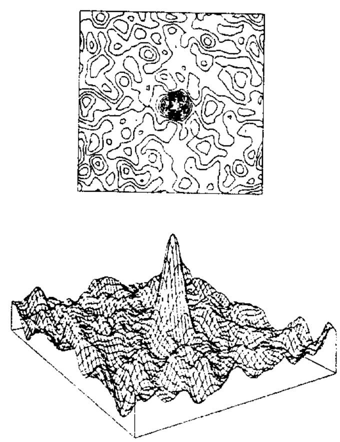

Fig.5(a) Crosscorrelation function in case where misalignment of 5 dgrees occurred.

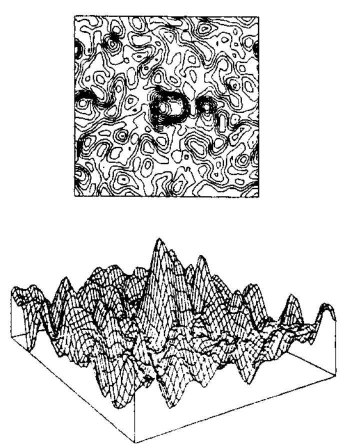

Fig.5(b) Crosscorrrelation function in case where misalignment of 9 degrees occurred.