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A Two-Dimensional Positioning System by use of Rotation-free Mark Pattern

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Abstract: The authors proposed a new two-dimensional(2D) positioning system by use of M-array and correlation technique which is suitable for noisy environment in '88KACC and its revised versions in '89KACC and '90KACC. This system uses the property of M-array that the autocorrelation function of the M-array has a sharp peak at its origin. In this paper, a new mark pattern is developed, instead of M-array, with which the two-dimensional positioning system becomes robust to rotation error of TV camera. The property of the rotation-free pattern is checked under various conditions, and it is shown that, by use of this rotation-free pattern,the positioning system can be used not only in a noisy environment but also in a roughly aligned set up of the TV camera.

1. Introduction

A two-dimensional (2D) positioning technique is one of the most important technique in industrial processes such as automatic build-up system, automatic insertion process of IC chips, capacitors or registers on to a board etc. The authors proposed a new 2D positioning system by use of M-array [3]. 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,even when there is some noise on the M-array. This system was improved by use of a vague M-array [2], and by use of a vector-signal processor [1] and the system can control the positioning within several seconds.

However, one problem is that the M-array pattern has the shape of a square, so the X-Y direction of the M-array must be equal to the XY direction of the XY table or TV camera in oder for the crosscorrelation function to be high enough when the X-Y position of the M-array is in the right position. We have shown in reference [1] that when the XY direction of the TV camera is mismatched by over 8 degrees from the right position, the system would lose its direction of control.

In this paper, we have developed a new pattern, instead of M-array, with which the system is robust to rotation or mismatch of the rotation angle of the TV camera. The performance of the system is checked for various condition. And it is shown that by use of such pattern, the system is not only robust to noise but also rotation-free of the TV camera.

2. Principle of the method

The basic diagram of the 2D positioning system is shown in Fig.1. A pattern made from M-array is attached on an object to be 2D positioned. The pattern is observed by a TV camera, and the image data are fed to a personal computer.The observed image data of the M-array are then crosscorrelated with a reference M-array stored in the personal computer. Then a X-Y servo positioning system is controlled so as for the crosscorrelation function to become maximum. In this system, an electrically cntrolled zoom lense is used for TV camera to observe the pattern to get the effect of the added M-array.

3. A rotation-free mark pattern

The rotation-free mark pattern is basically made from 8 M-arrays, each of which is rotationally apart by 45 degrees with respect to somr rotation center. For overlapped part of the two M-arrays, only one of the M-array is used. Fig.2 shows an original M-array pattern of 6 degrees

(7x9 cells). When this pattern is rotated by 45 degrees to make the rotation-free mark pattern,we can get the mark pattern as shown in Fig.3.

Fig.4 shows the variation of the peak of the mainlobe, and the maximum of the sidelobe of the crosscorrelation functoin between the observed M-array and the reference, when the angle of each mark is changed from 0 to 90 degrees. From Fig.4, we see that in case of the M-array, we can not distinguish the peak of the mainlobe and the sidelope when the angle θ becomes larger than 8 degrees.

Fig.5 shows the variation of the peak of the mainlobe and the sidelope for the rotation-free mark pattern, when the angle is changed. Here we see that we can always distinguish the main- and sidelobe, meaning that we can always control the XY table whatever the rotation angle of the TV camera is.

Fig.6 shows how noise is increased due to the misalignment of TV camera, where the noise is defined as the percentage of non-overlapping area when the M-array and the rotated M-array is overlapped. When the noise exceeds 45%, the peak of the mainlobe and sidelobe can not be distinguished. So we see also here that when the misalignment of over 8 degrees occurs, the positioning system would lose its direction of control.

Fig.7 shows the relationship between the noise and the misalignment angle, in case of rotation-free mark pattern. Here we see that the noise does not exceeds 40%, enabling us to control the system.

Fig.8 shows the crosscorrelation function when no misalignment occurs by use of the rotation-free mark pattern. Fig.9 shows the crosscorrelation function when the misalignment of 70 degrees occurs. Here we see we can find the peak of the mainlobe (right position) even when 70 degrees misalignment occurs.

4. Experimental result of positioning

The rotation-free mark pattern is attached on an object to be XY positioned.The pattern is observed with a TV camera, at first with out of focus condition, so as to get the effect of added M-array. The observed image data are then fed to a personal computer to calculate the crosscorrelation function between the observed and the reference. In the first stage of the positioning control, the crosscorrelation function is carried out by use of 2D Fast Fourier Transform(FFT) algorithm, and its peak is sought with the XY positioning servo. The second stage of the positioning control is the precise positioning in the vicinity of the peak of the crosscorrelation function. In this second stage, the focus of the TV camera is controlled with an electrically controlled zoom lence, so as for the TV camera to be focused well when the positioning come close to the vicinity of the true peak.

Fig.10 shows an example of the positioning process when the misalignment angle between the TV camera and the mark is 20 degrees. The "added area" means the equivalent added region on the mark due to the defocusing of TV camera. "The added area=11"means the 11 elements of the M-array is equivalently added together by defocusing. "The added area=1" means that there is no addition on the mark pattern, meaning the TV lense is well focused. From Fig.10, we see the positioning control is accurately carried out by use of the rotation free mark pattern, even when the misalignment between the TV camera and the direction of the mark pattern is 20 degrees.

5. Conclusion

The two-dimensional positioning system by use of M-array and correlation technique which was proposed by the authors has a property that it can be used under noisy circumstances.

However, there was one defect in that the M-array is a square having XY direction, causing the system to be rotational error sensitive of TV camera; when the misalignment angle between the TV camera and the M-array is over 8 degees, the system loses the direction of control.

So a new mark pattern made from M-array is developed which has a rotation-free property. This mark pattern is made from 8 M-arrays, each of which is 45 degrees apart with respect to a rotation center. The crosscorrelation functions between the mark pattern and its rotated version for various rotation angles are calculated. And it is shown that this mark pattern is rotation-free, meaning whatever the misalignment of TV camera is, the system can control the XY position accurately. The performance of the positioning system is checked under various conditions. And it is shown that this positioning system can be used not only in a noisy environment but also in a roughly aligned set up of the TV camera.

References

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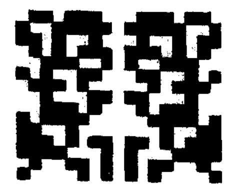

Fig.2 An Original M-array pattern

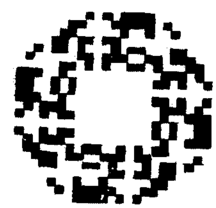

Fig.3 Rotation-free Mark Pattern

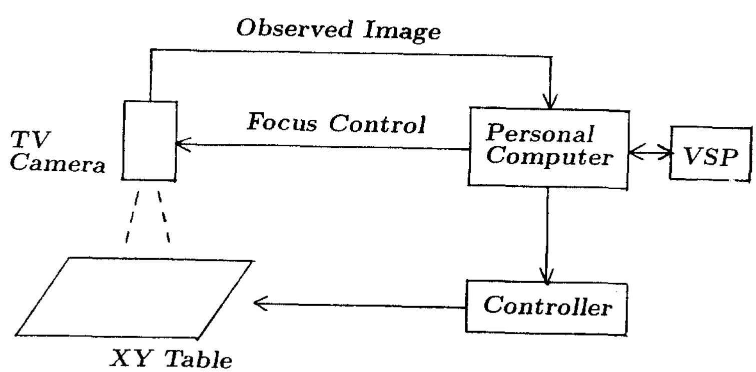

Fig.1 Basic diagram of the 2D positioning system

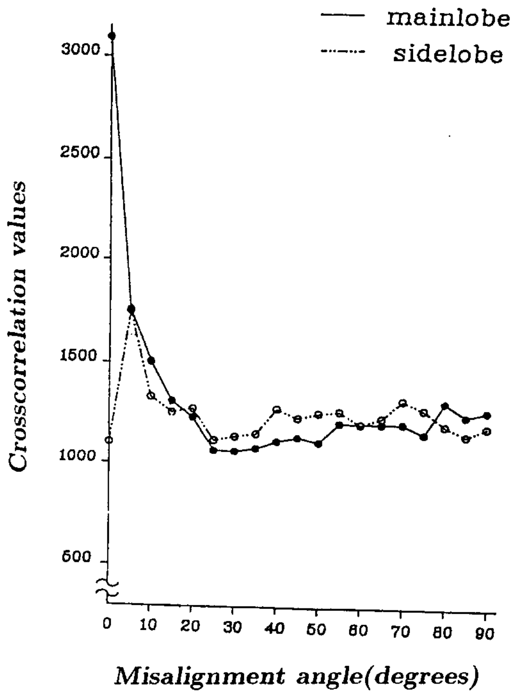

Fig.4 Crosscorrelation values vs. misalignment angle, in case where the original M-array is used.

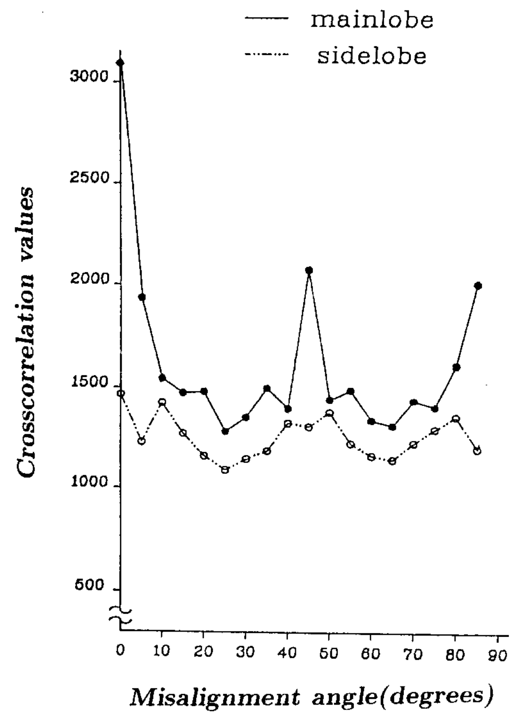

Fig.5 Crosscorrelation values vs. misalignment angle, in case where the rotation-free mark pattern is used.

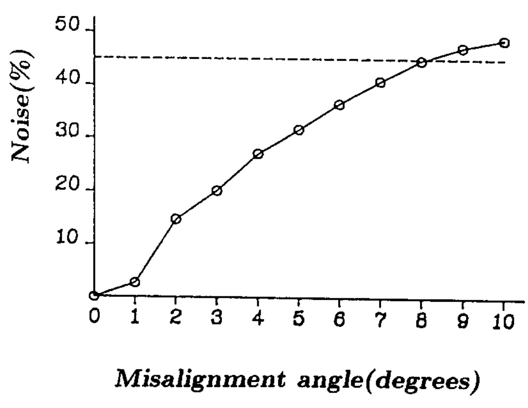

Fig.6 Percentage of noise vs. misalignment angle, when the original M-array is used.

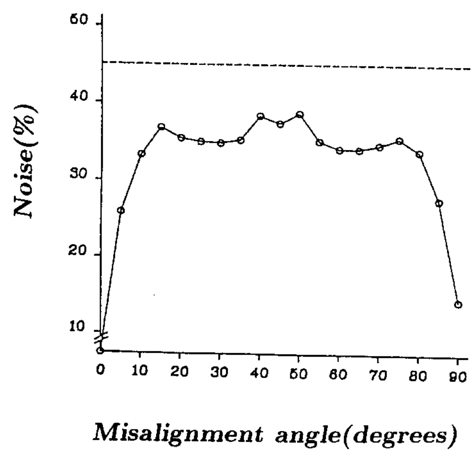

Fig.7 Percentage of noise vs. misalignment angle, when the rotation-free mark pattern is used.

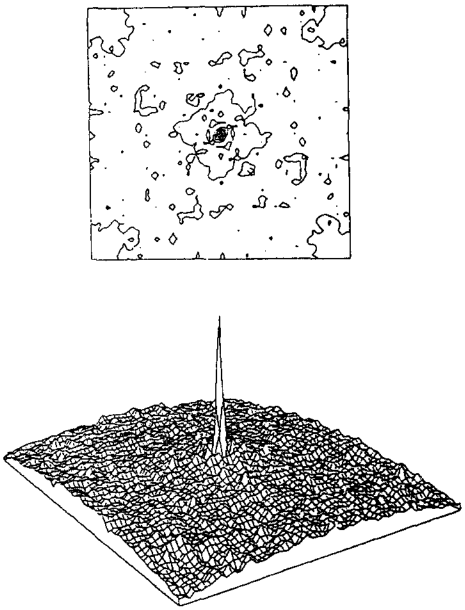

Fig.8 Crosscorrelation function when no misalignment occurred.

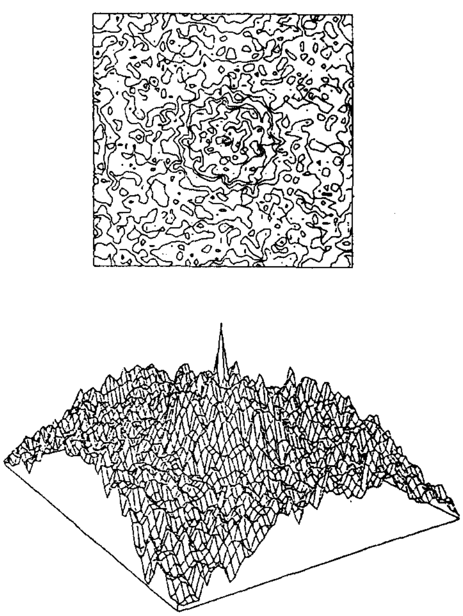

Fig.9 Crosscorrelation function when the misalignment of 70 degrees occurred.

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Preliminary alignment
        Peak (i, j):  1570 (49, 63)
        deviation x, y:  +5.95, -0.40  in mm
```

Precise alignment - 1(added area 11)

y

	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	147	162	161	0	0	0
	0	0	0	149	166	166	0	0	0
x	0	0	0	121	118	140	0	0	0
	0	0	0	118	115	124	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0

```
Peak (i, j):  166 (63, 64)
deviation x, y:  +0.40, +0.00  in mm
```

Precise alignment - 2(added area 0)

y

	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	951	955	966	1539	0	0
x	0	0	0	1018	1020	3918	974	0	0
	0	0	0	1074	1080	474	1035	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0

```
Peak (i, j):  3918 (64, 65)
deviation x, y:  +0.00, +0.40  in mm
```

Precise alignment - 3(added area 0)

y

	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	978	982	381	0	0	0
x	0	0	0	1042	3074	994	0	0	0
	0	0	0	1096	1661	1053	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0

```
Peak (i, j):  3074 (64, 64)
deviation x, y:  +0.00, +0.00  in mm
```

Fig.10 An example of positioning process.