Memoirs of the Faculty of Engineering, Okayama University, Vol. 33, No.1, pp. 53-57, November 1998

A Method for Designing an Automatic Monitoring System for Unmanned Rooms

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(Received October 9 , 1998)

A method for designing a monitoring system with multiple cameras is proposed in order to supervise and recognize the progress of wide work area. First, a wide view camera is developed by combining several usual cameras so that its visual angle could cover more than $\pi/2$. Secondly, A method for determining the number and location points of cameras is proposed by considering the shape of monitored area and the installation cost of cameras. The monitored area is divided into three kinds of basic shape (rectangular form, L form and convex form). For every basic shape area, the camera is located at the vertex position, so that the whole area can be monitored by the camera.

1. INTRODUCTION

Recently, unmanned rooms are increasing to correspond to high accuracy, such as in FA factories, clean rooms, nuclear power stations and so on. Once an accident occurs in an unmanned room, the state will become seriously and dangerously. So the monitoring system is very important not only for worker but also to assure the safety. Many studies on monitoring system have been reported [1]. But most of them can only monitor a specific area. For a wide area, a monitoring method has been presented to recognize the moving object by many cameras [2]. But it is supposed that there are no machines and materials which disturb the sight of the cameras in the monitored areas. For a wide area with many obstacles like in a factory, it is necessary to divide the monitored area into some small areas in which there are no obstacles. The number and the location of cameras are also very important to monitor all area. For this problem, the shadow area of the obstacle is calculated by using CAD layout figure [3].

In this paper, we propose a automatic monitoring system using many wide view cameras. Firstly, we develop the camera whose visual angle is greater than $\pi/2$. Secondly, we propose a method to determine the number and the location of the wide view cameras by dividing all area into rectangular, L-form and convex areas which can be monitored by a wide view camera.

2. PROPOSED METHOD

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In this paper, first we develop the wide view camera whose visual angle is greater than $\pi/2$ by combining some usual cameras. Secondly we propose the method to determine the watching area and position of cameras in the monitored area.

2.1 Development of a Wide View Camera

As the visual angle (β) of a usual camera is less than $\pi/2$, many cameras are required to monitor all area and it is very difficult to design the monitored area. So we develop the camera whose visual angle (α) is greater than $\pi/2$ by combining the usual cameras. The number of cameras is given as follows.

$$[\ \alpha/\beta\ ]+1$$

Numbers ($[\alpha/\beta]+1$) of cameras are set at the center of visual point in Fig.1. And the switching unit is used to select and change the images from combined cameras. This camera is called as the wide view camera whose visual angle (α) is put as $\pi/2$ in the later.

2.2 Determination of Number and Location of Cameras

2.2.1 Assumption

(1) The wide view camera's visual angle is set as $\pi/2$.

(2) The wide view camera can monitor the object in a range of distance from 0.30m to LD m in front of the camera.

(3) The monitored area is divided into small areas. The small area can be monitored by one wide view camera. The dividing method is proposed in the later.

(4) The factory layout is shown by 2D CAD figure. In this figure, the areas of obstacles are shown by the shadowed portion in Fig.2. The blank area should be monitored.

(5) The cameras are set at the surrounding wall or contour line of obstacles.

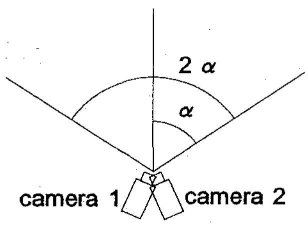

Fig.1. A wide view camera by using two usual cameras

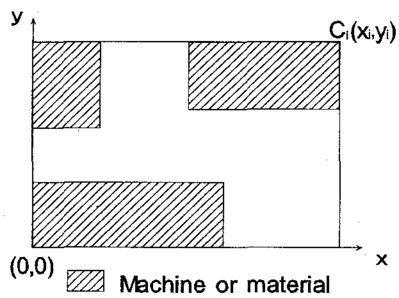

Fig.2. 2D CAD figure of a factory

2.2.2 Basic shape of divided area

The divided area takes a rectangular form, L form or convex form to be monitored by one camera.

(1) In the rectangular form, the camera is set at one vertex as shown in Fig.3 (a). And the direction of the camera is set as $\pi/4$ from the contour line. The rectangular area is contained in the circle whose radius is equal to LD.

(2) In the L-form, the camera is set at the corner of L character in Fig.3 (b).

The vertex of L-form is put as P_i (x_i, y_i), i=1, 2, ･･･,6.

(a) The condition that $x_3 \leqq x_4$ and $y_4 \geqq y_5$

As this condition is satisfied, the monitored area can be monitored by the camera set at point P_1.

(b) The condition that $x_3 \geqq x_4$ and $y_4 \leqq y_5$

As the point P_4 is located in the area between the line through P_1 to P_5 and that through P_1 to P_3, the monitored area of L-form can be monitored from P_1.

(3) In the convex form, the vertex points are shown as P_i, i=1, 2,$\cdots$, n. And the other points except for one point (P_{i0}) can be seen from point P_{i0} (Fig.3 (c)). As the visual angle at P_{i0} is less than $\pi/2$, the camera is set at point P_{i0}.

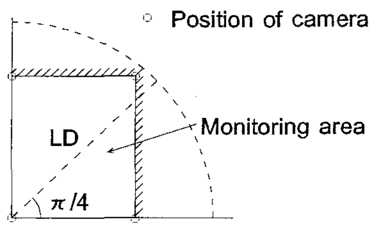

Fig.3. (a) Rectangular form

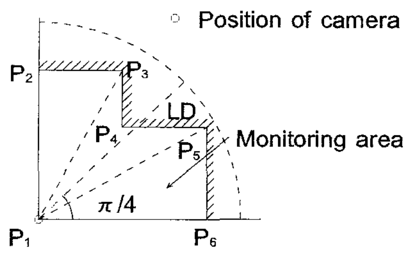

Fig.3. (b) L-form

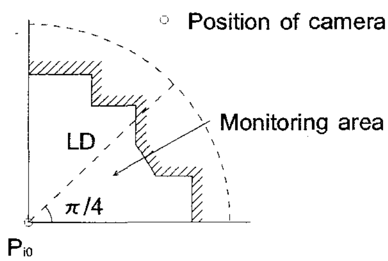

Fig.3. (c) Convex form

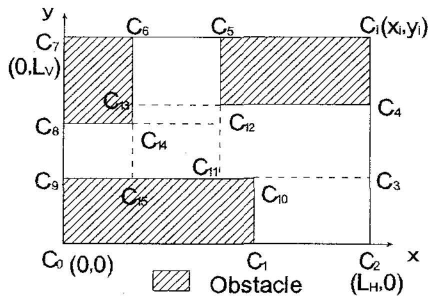

Fig.4. Dividing method (rectangular obstacle)

2.2.3 Allocation method of camera in monitored area

(1) As the monitored area is so large, firstly, it is divided into same square areas in two dimension that the length of the side is equal to $LD/\sqrt{2}$. Secondly the camera allocation is determined in each square area as follows.

(2) Allocation method

(a) The case that the area of obstacles are all rectangular form

(i) Dividing monitored area into small rectangular area

The contour lines of the area of obstacle are extended to the nearest line of surrounding wall, the contour line of other obstacle or the extended line of other obstacle as shown in Fig.4.

(ii) Combining method

We combine some divided areas into rectangular form, L-form or convex form. As two adjacent divided areas are combined, a rectangular form or a L-form will be formed. Further as this combining procedure is continued, the combined area will become a rectangular, a L or a convex form.

As the area becomes a L-form or a convex form, we should examine whether the area can be monitored or not by one camera. If the area of L-form or convex one can be monitored by one camera, the combining procedure can be continued. But if it can not be monitored, the combining procedure should be stopped.

(iii) The criteria for exclusive monitored area

The monitored area is divided into some exclusive areas by the combing method.

The number and the square measure of the exclusive areas are different for different combining order. So the two criteria are determined as follows.

NE_l : number of exclusive areas by l-th combining order (l=1, 2,$\cdots$,ND)

AD_{lq} : Square measure of q-th exclusive area

(q =1, 2,・・・,NE_l)

① Criterion of minimum number of camera.

$$NE_{l_0} = \min_{1 \leqq l \leqq ND} NE_l \quad (1)$$

The number of cameras becomes minimum at l_0-th combining order.

② Criterion of minimum difference among square measure.

$$AD_{l_0} = \min_{1 \leqq l \leqq ND} \{\max_{1 \leqq q \leqq NE_l} AD_{lq} - \min_{1 \leqq q \leqq NE_l} AD_{lq}\} \quad (2)$$

The number of camera and its position is determined by these criteria.

(b) The case that the area of obstacle is any form

The straight line is drawn from the vertex of the area of obstacle perpendicularly to the surrounding wall as shown in Fig.5. The line can be drawn one side or two or three sides at the vertex of the obstacle. And the monitored area is divided into the small areas of the rectangular form or convex form. For these small areas, the combining procedure is applied to make the exclusive area. And the number and the location of camera is determined by these exclusive areas.

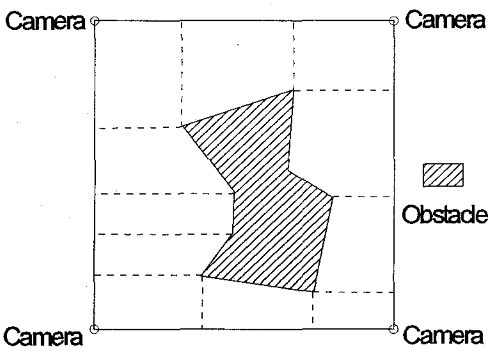

Fig.5. Any shape of obstacle

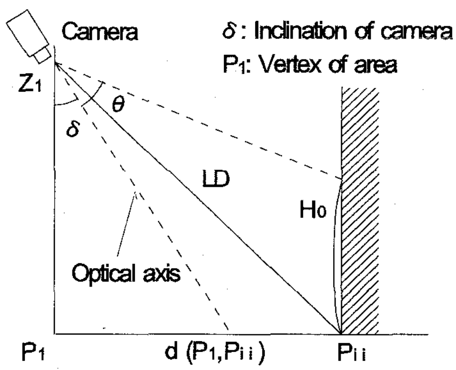

Fig.6. Height of Camera

2.2.4 Determination of height of wide view camera

As the exclusive area is monitored in three dimension, the height and the angle of inclination of the camera should be determined as follows.

(1) In one exclusive area, the vertex is shown as P_i (x_i, y_i) (i=1, 2, ⋯ NV)

It is assumed that the camera is set at (Z_1) height from P_1 as shown in Fig.6.

(2) The distance from P_1 to P_i is put as d(P_1, P_i)

As the distance d(P_1, P_i) becomes maximum, the farthest point P_{ii} from camera is determined.

$$d(P_1,P_{ii}) = \max_{2 \leqq i \leqq NV} d(P_1,P_i) \quad (3)$$

And the height of camera (Z_1) can be calculated by the following equation.

$$Z_1^2 + d(P_1,P_{ii})^2 = LD^2 \quad (4)$$

(3) It is assumed that the angle of inclination of the camera is δ and the height of the monitored object is less

than H_0. For monitoring the object at P_{ii}, the equation $\tan(\delta+\theta)=d(P_1, P_{ii})/(Z_1-H_0)$ must be satisfied. So the angle of inclination of the camera (δ) can be derived from it.

$$\delta=\left(\tan\left(\frac{d(P_1,P_{ii})}{Z_1-H_0}\right)\right)-\theta \tag{5}$$

Where, 2θ is the vertical visual angle of the camera.

2.3 Cost of Monitoring System

The determined exclusive area is shown as EA_m. (m=1, 2, ⋯ NEA). And the location point of wide view camera is done as $CP_m(x_m, y_m, z_m)$. The construction cost (TC) of the monitoring system is estimated as follows.

(1) Cost factors

CC: cost of a wide view camera

CL: cost of setting wire from camera to control system

CFC: fixed cost of control system (includes the software cost)

CVC: variable cost of control system from number of camera

(2) Total construction cost (TC)

The distance from the position of control room to the position of camera (CP_m) is put as LCP_m. Total cost is calculated by equation (6).

$$TC=CC\cdot NEA+CL\cdot\sum_{m=1}^{NEA}LCP_m+CFC+CVC\cdot NEA \tag{6}$$

(3) The construction cost using other monitoring method is calculated and compared with TC.

If TC is less than that of other method, the proposed monitoring system is adopted.

3. CONCLUSIONS

A monitoring system has been proposed to monitor the three dimension area. For this purpose, the wide view camera whose visual angle is greater than $\pi/2$ was developed by combining some usual cameras. The monitored area was divided into some small areas by three kinds of basic shape (rectangular form, L-form and convex form). Every small area was monitored by one camera. The number and the three dimensional position of camera were determined by the divided areas based on the criteria. And the construction cost was also estimated by the various cost factors.

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