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An Image Processing Method for Handling Subject Piled in a Container

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We propose an image processing method for part handling robot for picking up subjects piled in a container. Line laser light is projected on subjects, and its external shape is detected by many segments of a line laser, and pitch, roll, and yaw angles of subject are recognized precisely. A priority rule is settled to choose one subject that is taken out. This rule is determined by considering the grasping space, the position of a subject, the movement space of hand and so on.

1. INTRODUCTION

In the production process, parts are piled in containers that are carried to machines, and many parts feeders have been used to take out a part from the container and set them up the machine. However, each parts feeder is expensive and could handle only few kinds of parts. These conditions increase the production cost. Accordingly, installation cost of parts feeders causes the increased of fixed cost of multiproduct line companies. On the other hand, robots could cut down parts handling cost, because robots could pick up and set various kinds of subjects only by changing control programs. However, the handling robot requires image processing function for recognizing kind and posture of subjects.[1][2][3]

Therefore, in this paper, we propose the image processing method for part handling robot. Firstly, a light-section method is used to detect three-dimensional outer shapes of piled subjects. The top surface of the subject is scanned by a line laser from right to left at constant speed. The three-dimensional outer shape of subjects are represented by many segments of a line laser, and surface of subjects is recognized by grouping those segments. Secondly, the priority rules are used to choose an subject that is taken out, considering the following condition: whether or not obstacles exist on the way to an subject, space between the subject and its adjacent one for inserting a robot hand. Finally, a handling robot system is constructed by using the above-mentioned method.

2. PROPOSED METHOD

2.1 Assumption

We assume that many subjects in a container are the same kind. They are piled in a container. One line laser is

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used to recognize three-dimensional position of the subjects.[4] The brightness of line laser is the constant.

2.2 Symbols

Some key symbols are shown as follows.

(x, y, z) : A standard coordinate system. A parts handling robot moves along this coordinate system.

(ix, iy) : A coordinate system of an image processing board.

m : Serial number of scanned input images. (m = 1 ～ M)

n: Segment number of the reflected light of the line laser. (n = 1 ～ N)

2.3 Recognition of Subjects' Positions

A segment of a reflected light becomes a straight line when the plane of subject is horizontal. It curves as the subject is inclined. As the reflection light is parallel to the j-axis of the input image, the plane of objects is horizontal. (Fig.1 (a)) However, as the reflected line is not parallel to j-axis, the subject is inclined. (Fig.1 (b)) Additionally, start point and end point of a segment could be used to recognize the position of subject. Thereinbefore, the position and the posture of the subject could be recognized from the segment of line laser light. The method for analyzing the segment is explained from here after.

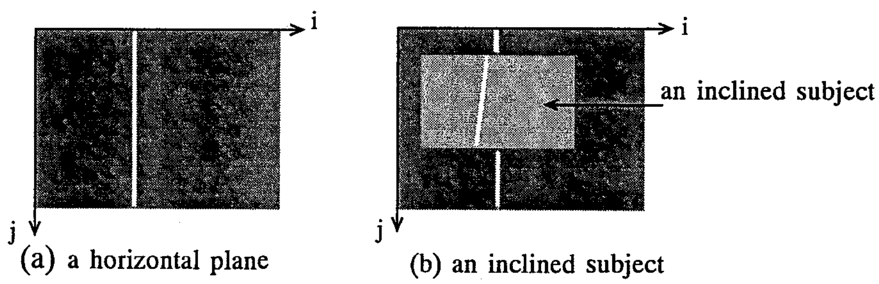


Fig.1 Reflected light of line laser

2.3.1 Position of a line laser and a camera

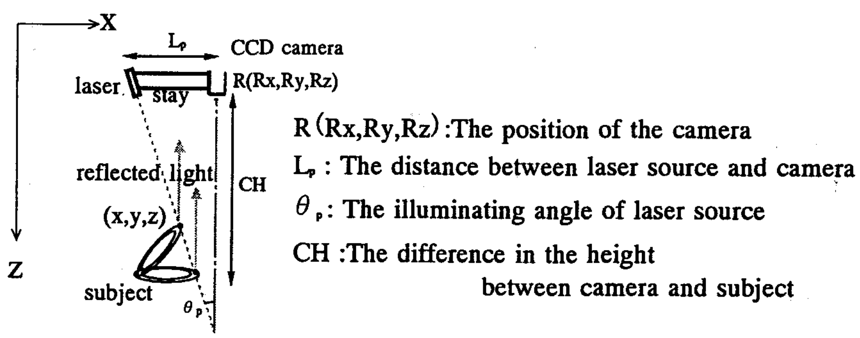


Fig.2 Configuration of camera and laser

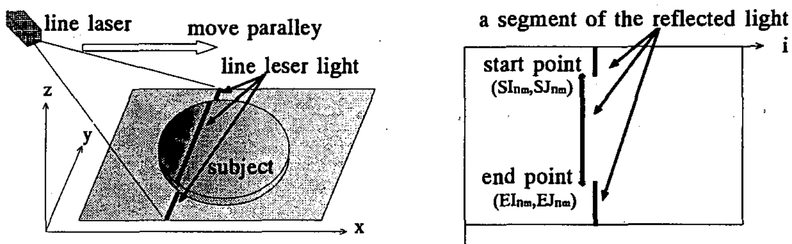
Line laser and CCD camera are fixed on a wrist of the robot arm. They are sat apart at distance L_p by using a stay. The optic axis of the camera is paralel to z-axis. The laser source is tilted so that line laser and z-axis make angle θ_p. The line laser is parallel to y-axis. (in Fig2.) Robot arm moves parallelly along x-axis at constant speed, and image is taken through CCD camera at a regular interval. The interval is set considering the shape and size of subjects.

2.3.2 Estimation of three-dimensional coordinate

The robot moves in a space of the standard coordinate system (x,y,z). The position (ix,iy) in an image processing board should be transformed to standard coordinates system to grasp a subject by the robot hand. This transformation is expressed by eq. (1). Where, a symbol CH, L_p, θ_p, and R (Rx,Ry,Rz) are shown in Fig.2. The coefficients (from a to f) are estimated by using multiple regression analysis.

$$\begin{aligned} x &= a\times ix + b\times iy + c + Rx \\ y &= d\times ix + e\times iy + f + Ry \\ z &= Rz - CH = Rz - (L_p - Y)\tan(\pi/2 - \theta_p) \quad (Y = y - Ry) \end{aligned} \tag{1}$$

2.3.3 Recognition of segment corresponding subjects



(a) Actual condition (b) An input image

Fig.3 Procedure for recognizing subjects

Fig.3 (a) shows an actual lighting condition, and Fig.3 (b) shows a binalized input image. Pixels whose brightness exceed a threshold value are colored in black (brightness is 0). Line laser is projected on subjects from upper left, so the segment at the far left in an image corresponds to the highest subject. Then, put the coordinate of pixels on the binalized segment as (i, J_i). Segment on object is recognized by eq. (2). Where a constant value (j_o) is given by a preexamination. If eq. (2) is satisfied, the pixel J_i and J_{i+1} are regarded as lying on the same segment.

$$|J_i - J_{i+1}| \leqq J_0 \tag{2}$$

The segment is represented by the start point (SI_{nm}, SJ_{nm}) and the end point (EI_{nm}, EJ_{nm}). Where a symbols n and m means the n-th segment in the m-th input image. Above-mentioned procedure is repeated every time when a new consecutive image is taken in. After that, two dimensional position of segment in each input image is transformed to three dimensional position by eq. (1), and start point $(SX_{nm}, SY_{nm}, SZ_{nm})$ and end one are calculated. This scanning procedure is repeated from right side of the container to left side at the regular interval.

2.4 Recognition of Subjects' Posture

2.4.1 Grouping of segments

Scanning procedure detects many segments as shown in Fig.3. From the discrepancy of segments, we could intuitively recognize a shadowed area of a subject. In order to recognize the subject by the image processing, every segments are grouped according to following criteria.

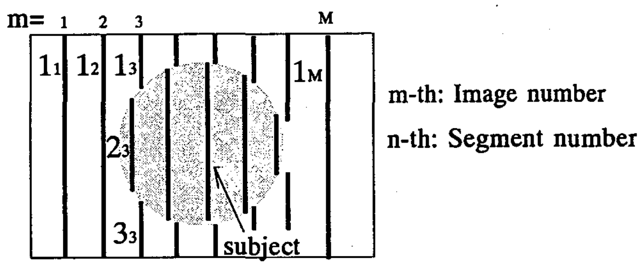


Fig.4 Image of all segments

(1) Gradient of segment

It is possible to judge gradient of subject by the shape of reflected light as mentioned in section 2.3. The gradient of segment varies depending on tilt angle and direction of subject. Therefore, segment lying side-by-side is grouped if it is oriented to the similar direction, and recognized as segment corresponding to the same subject.

(2) Three dimensional position and length of segment

The position of contour line and the length of segment varies depending on the posture and size of subject. So adjacent segment is compared consecutively one by one. If the difference of three-dimensional position and length of a segment are within a certain range values, this segment is grouped in same.

If segments satisfy both above mentioned criteria, they are grouped and regarded as segments on the same plane of the same subject.

2.4.2 Posture of subject

The posture of subject is usually represented by the normal line vector of the upper plane as shown in Fig.5 (a). The segment representing a plane have been recognized previously. Unit normal vector (a, b, c) is calculated based on the three dimensional position of start and end points of all segments. The normal vector is represented by eq. (3). Where, coefficients a, b, c are given by the least squares method as shown in eq. (3).

$$a(x-x_0)+b(y-y_0)+c(z-z_0)=0 \quad (a^2+b^2+c^2=1)$$

$$(X=x-x_0,\ Y=y-y_0,\ Z=z-z_0)$$

$$\begin{pmatrix}\sum X^2 & \sum XY \\ \sum XY & \sum Y^2\end{pmatrix}\begin{pmatrix}s \\ t\end{pmatrix}=\begin{pmatrix}-\sum XZ \\ -\sum YZ\end{pmatrix} \qquad a=s\times c,\ b=t\times c,\ c=\frac{1}{\sqrt{s^2+t^2+1}} \qquad (3)$$

2.5 Approaching Direction of Robot Hand for Grasping Subject

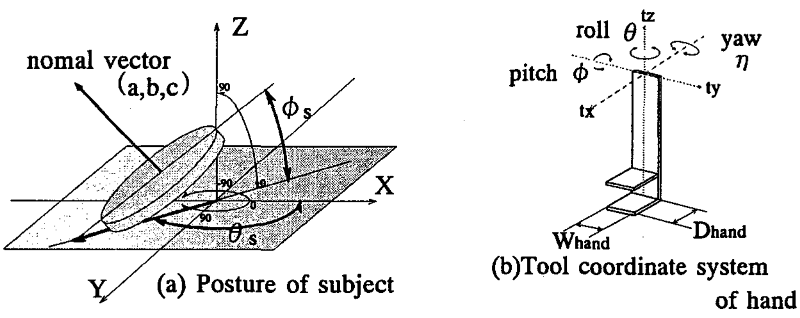


Fig.5 The posture of an object and a robot hand

There are three parameters that should be determined to pick up a subject by a robot, that is yaw, roll and pitch. The robot could approach to subject and grasp it successively following those parameters. Here, put the roll angle of robot hand by a symbol θ , pitch is ϕ and yaw is η as shown in Fig.5 (b). The angle θ , ϕ , and η are deduced from the unit normal vector (a, b, c) of the plane in eq. (3). In this paper, we assume that the shape of subject is look like thin plate. So, θ is set so that the robot hand could approach to subject from the perpendicular direction of the contour line. Before the calculation of three parameters of the robot, the posture of subject is represented by following parameters, θ_s, ϕ_s, η_s. (Fig.5 (a)) They are calculated by eq. (4).

$$\theta_s = \arctan(b/a) \quad , \phi_s = \arctan\left(c/\sqrt{a^2 + b^2}\right) \quad , \quad \eta_s = 0 \tag{4}$$

The rotation angle ϕ and η of robot hand are deduced from eq. (4). They are expressed by eq. (5).

$$\phi = \arcsin\{\cos(\theta - \theta_s)\sin\phi_s\} \tag{5}$$
$$\eta = \arcsin\{\sin(\theta - \theta_s)\sin\phi_s\}$$

2.6 Recognition of Surrounding Situation of Subjects

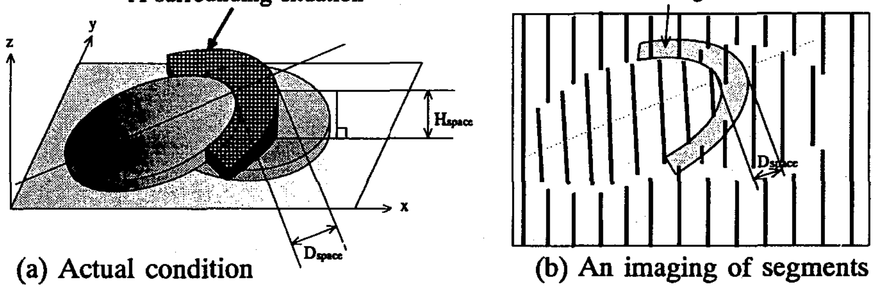


Fig.6 A surrounding situation

Plural subjects lay or lie in surrounding of the subjec6 picked-up next, since subjects are piled in the container without setting in array. They could interfere the robot hand to approach closely to a targeted object. Therefore, it should be examined whether the robot hand could approach to the targeted subject without collision with its neighboring ones. Height of all subjects should be measured before this evaluation in order to examine whether the robot hand could be inserted into clearance between the targeted subject and neighbouring ones. The height H (i, j) of a segment are given by eq. (6). Where, H (i, j) means the relative height of segment from the lowest place in the image.

$$i = \frac{x - x_{min}}{Lpp}, j = \frac{y - y_{min}}{Lpp}, H(i,j) = z - z_{min} \quad \text{(Lpp: length per pixel)} \tag{6}$$

Results given by eq. (6) are used to get three dimensional space, whereinto the robot hand move fleely to approach the targeted subject. This three dimensional space is represented by width (D_{space}) and height (H_{space}), and they are given by eq. (7). However, its volume and shape vary depending on posture of the subject and size of the robot hand. Where, the depth D_{hand} of robot hand is shown in Fig.5 (b). Δ D and Δ H are given by considering the measurement error of three dimensional position.

$$D_{space} = D_{hand} \cos\theta + \Delta D,\ H_{space} = D_{hand} \sin\theta + \Delta H \tag{7}$$

The shaded area shown in Fig.6 (b) means the space given by eq. (7).

2.7 Selection of Subject

It is necessary to determine the order for picking up subjects because two or more objects are recognized by the above mentioned procedure. In order to choose one subject picked up next, a criterion (K) is showed in eq (8). This equation contains several coefficients expressed below. Then, a group of segments with highest value of the criterion is chosen and picked up first.

$$K = (d \times k_1 + e \times k_2 + f \times k_3) \times k_4 \quad \text{(d, e, f are the optimal value)} \tag{8}$$

(1) Coefficient k_1: Outline shape

Outline shape of each group is found by connecting all end points of segments. After this procedure, the outline shape of each group is evaluated and represented by a coefficient k_1, which is given by considering the inclination of the subject. Where the coefficient k_1 comes closer to 1 as inclination of subject approaches to horizontal.

(2) Coefficient k_2: Grasping space

When the grasping space becomes large, subject could be grasped easier. Therefore a coefficient k_2 is defined by considering the grasping space. The actual grasping space of each subject is compared to the minimum space required to grasp the subject successfully. Then its ratio is represented by the symbol k_2.

(3) Coefficient k_3: Position of group

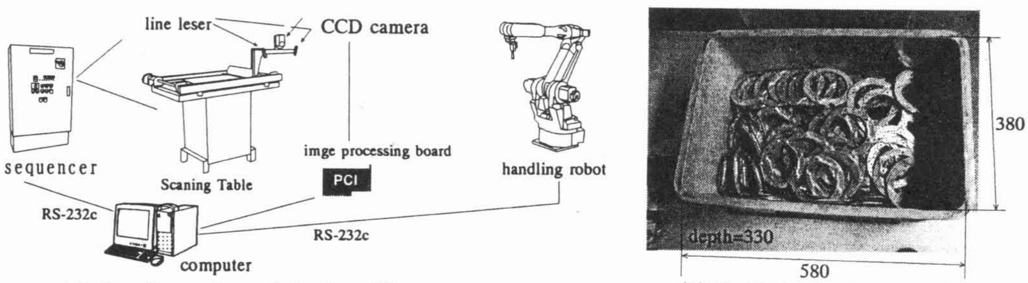
Because subjects are piled in the container, the subject at the higher place is easier to be grasped. Therefore, the ratio of overlapped area is checked and represented by a coefficient k_3.

(4) Coefficient k_4: Movement space of hand

There is a possibility that the robot or the hand collides with the container during the picking operation. The postion of hand is checked and judged whether the subject could be picked-up without any collision of the hand. Coefficient k_4 is introduced in order to represent this possibility. (possible: 1, impossible: 0)

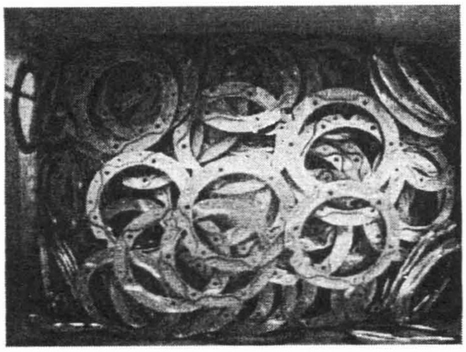
3. APPLICATION EXAMPLE

A handling robot system is shown in Fig.7 (a). Fig.7 (b) is the picture of subjects piled in the container. The effectiveness of this system was actually verified.

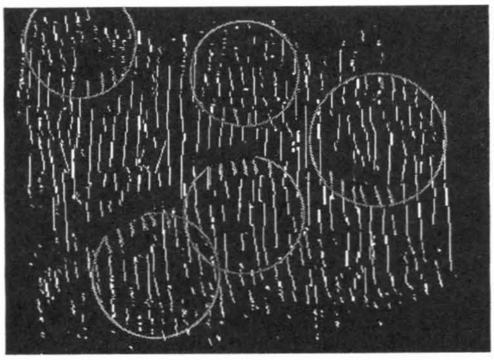


(a) Configuration of the handling system (b) Subjects in the container

Fig.7 Parts handling system



(a)Subjects in a contaner



(b)Result of Image Processing

Fig.8 Image Processing

Fig.8 shows a result of the image processing. Circle means the estimated contour line of a subject which could be grasped.

4. CONCLUSION

This research proposed an image processing method for developing a handling system of subjects piled in container. Firstly, the position and posture of a subject, and other adjacent ones are recognized by the line laser projected on them. Secondly, the order for picking up subjects are determined by a priority rules. Finally, a handling robot system was constructed by using the proposed method, and the effectiveness of this method was actually verified.

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