An Automatic Weight Measurement of Rope Using Computer Vision

Ki-See Joo

Abstract

Recently, the computer vision such as part measurement, and product inspection is very popular to achieve the factory automation since the labor cost is dramatically increasing.

In this paper, the diameter and the length of rope are measured by CCD camera which is orthogonally mounted on the ceiling. Two parameters which are the diameter and the length of rope are used to measure the weight of rope. If the weight of rope is reached to predetermined weight, the information is transmitted to PLC(programmable logic control) to cut the rope on the wheel. The cutting machine cuts the rope according to the information obtained from the CCD camera. To measure the diameter and length of rope on real time, the searching space for image segmentation is restricted the predetermined area according to the camera calibration position. Finally, to estimate the weight of rope, the knowledge base system which depends on the diameter, the length of rope, and weight relation between these information are constructed according to diameters of rope.

This method contributes to achieve the factory automation, and reduce the production cost since the operators are unnecessary to measure the weight of rope by try-and-error method.

I. Introduction.

Recognition and measurement of three dimensional objects are necessary for an intelligent manufacturing in small-medium factory. Generally, a stereo vision[1,2] and a laser system[3,4] are used to measure, and recognize a three dimensional object. If two dimensional information is required, single camera is used[5,6,7,8,].

Generally, to obtain two dimensional information, a camera is set orthogonally on the ceiling since two dimensional information except of object height is exactly projected on the $x_w y_w$ plane. Otherwise, the obtained image from a camera is distorted because of object height according to camera calibration position.

In this paper, a camera is used to measure the diameter and the length of rope. So far, most small-

* 목포해양대학교 해상운송시스템공학부 전임강사
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medium enterprises which manufacture rope depend on manual operation. But, production cost is dramatically increased such as increased salary, deficient man power, and decreased production rate.

The main processes in rope manufacturing enterprises are the bangsa, yeonsa, jungyeon, jegang process. The thin thread from original material is extracted in the bangsa process. These extracted thin threads are joined to make more thick threads in the yeonsa process. Lastly, these joined middle products are rejoined to produce final products in the jegang process.

So far, to produce the final manufactured rope, the middle produced products are linked in each process using manual operation. Therefore, the opportunity loss cost occurs due to increased production cost, unnecessary operators, and increased operation time. To solve this problem, the full automation is required in the entire processes. However, the full material flow automation occurs to the bottle neck problem since the established space deficiency and the production capacity difference between processes take place. That is, the line balancing problem occurs. To solve the above problem, the middle warehouse in each process can be established.

However, the established warehouse space is restricted under the current factory environment. Therefore, under the current system, to obtain the effect of factory automation, the automation of final production process is necessary since many manual operators are required in this process.

The try-and-error method based on manual operation is used to measure the weight of rope wound on the wheel. This method requires the much operation time, and many man powers. Therefore, the automatic weight measurement system is necessary to reduce many man powers, much production time, production cost, and industry damage.

Ⅱ. Coordinate system and calculation

1. Coordinate system

In the real world, the coordinate transformation from projected image on the screen is necessary to measure the diameter of rope on the real world. These coordinate systems are defined as a world, a screen, a camera, and a robot coordinate system as shown in the Fig. 1.

The camera coordinate system(x_e, y_e, z_e) is defined the camera optical axis as z_e axis, and the x_e, y_e axis are represented by the left hand's law according to z_e axis. The second coordinate system that is screen coordinate system(U, V) is described to manage the image on the screen obtained from object in the real world. Also, the screen center point is defined as the screen origin point, and the horizontal axis is defined as U axis, and the vertical axis about U axis is defined as V axis. The world coordinate system(x_w, y_w, z_w) is described using the right hand's law based on the origin point(o_w) in the real world. Lastly, the robot coordinate system(x_r, y_r, z_r) is defined as same with the world coordinate system. The x_r axis is moved as a constant distance($\triangle x$) from the origin point in the real world coordinate system along to x_w axis.

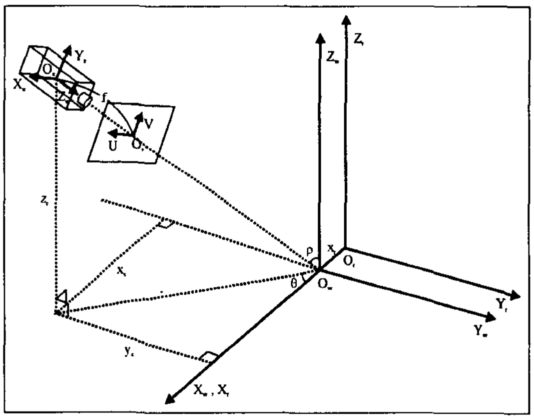

Fig. 1. Coordinate system

2. Coordinate calculation

The image obtained from CCD camera is segmented into the background and the rope to measure the diameter of rope. The feature points of an object are extracted from the segmented image since the calculation time about all points on the obtained image takes very much. The world coordinates about the extracted feature points are calculated using coordinate transformation among three coordinate systems by equation (1), (2). In the equation(1), the pan angle θ of a camera represents the angle between the x_w axis and the projection line of the optical axis upon the $z_w=0$ plane. The tilt Φ represents the angle between the z_w and z_e axis.

$$p(h) = (x_e, y_e, z_e) = (x_w, y_w, z_w)V$$

$$V = \begin{pmatrix} -\sin\theta & -\cos\theta\cos\Phi & -\cos\theta\sin\Phi & 0 \\ \cos\theta & -\sin\theta\cos\Phi & -\sin\theta\sin\Phi & 0 \\ 0 & \sin\Phi & -\cos\Phi & 0 \\ 0 & 0 & d & 1 \end{pmatrix}$$

where θ : pan angle Φ: tilt angle,

d : the length between the origin point in world coordinate and camera position

.... (1)

$$(x_w, y_w, z_w) = (x_e, y_e, z_e)\ V^{-1} \quad \text{.............................(2)}$$

Ⅲ. The weight measurement of rope

Generally, to measure the object dimension from obtained image, image segmentation, feature extraction of an object, object recognition, and coordinate calculation are required as following Fig. 2.

1. Image segmentation

Since a computer can't recognize the object from the obtained image, the image segmentation algorithm is required to recognize background and object on the image[9,10,11]. The real time processing is difficult if an entire image area is processed for image segmentation.

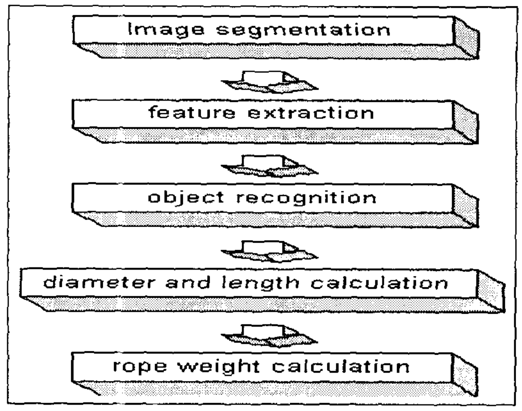

Fig. 2. Rope weight measurement process

Since the passing rope between machines exists always a finite area in the screen under a fixed calibration position, the image segmentation area is restricted in a finite area for real time processing. Also, the system success depends on adaptation between day and night since the entire gray value of image is varied according to lightness. Therefore, the average gray level of 5x5 area in image segmentation step is used. According to the average gray level, day and night are distinguished as following equation (3).

$$k = \frac{\sum_{i=1}^{5}\sum_{j}^{5} p_{ij}}{25} \quad \text{.......................................(3)}$$

if $k \geq \triangle x \rightarrow$ *day, else* $k < \triangle x \rightarrow$ *night*

where p_{ij} : the gray value in pixel i, j, $\triangle x$: *the threshold value*

The edge which is the boundary point between two areas represents the discontinuous points of gray value in the entire image. The edge types commonly found from image are such as a concave roof edge, a convex roof edge, a concave ramp edge, a convex ramp edge, and a step edge as shown in the Fig. 3.

However, since an edge is points obtained from the gray level difference of two areas, the derivative of lightness is calculated as shown in the equation

(4), the edge points are detected by comparison with the threshold value. Also, edginess which is the strength of edge is calculated using the equation (5).

Lastly, the edge direction is calculated by equation (6). If the edginess is greater than the threshold value, then this point is considered with edge point.

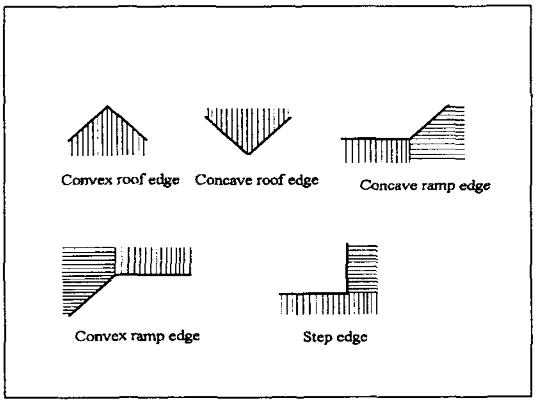

Fig. 3. The edge types

$$\Delta f(u,v) = \frac{\partial f(u,v)}{\partial u} + \frac{\partial f(u,v)}{\partial v} \quad \cdots\cdots (4)$$

$$\Delta f = |G_u| + |G_v| \quad \cdots\cdots (5)$$

$$\Delta(u,v) = \tan^{-1}(G_u, G_v) \quad \cdots\cdots (6)$$

where $\triangle f(u,v)$: the lightness derivative, $\triangle f$: The total edginess

G_u: The edginess of u axis, G_v: The edginess of v axis

$\triangle(u,v)$: The edge direction

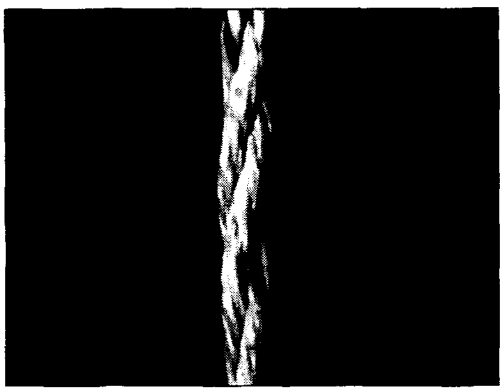

Fig. 4. The captured original image

The original image captured using orthogonally mounted camera is shown in the Fig. 4. As a result, the recognized upper and low line of rope using the image segmentation algorithm are shown in the bellow Fig. 5. The diameter of rope is measured by the horizontal length calculation between the upper and low line. The diameter is measured easily since the rope is vertical to the screen. The diameter is calculated difference of the U coordinate value of low and upper line as following equation (7).

$$R_d = U_u - L_u \quad \cdots\cdots (7)$$

where R_d: The rope diameter, U_u: The u coordinate of upper line

L_u: The u coordinate of low line

2. The length recognition of rope

To measure rope length, the first and the second detection line on the screen are set as shown Fig. 6. The first detection line drawn on the screen is painted with black per a finite second, the part of painted rope is recognized at the second detection line. Since the length between the first and the second detection line is known, the length of rope

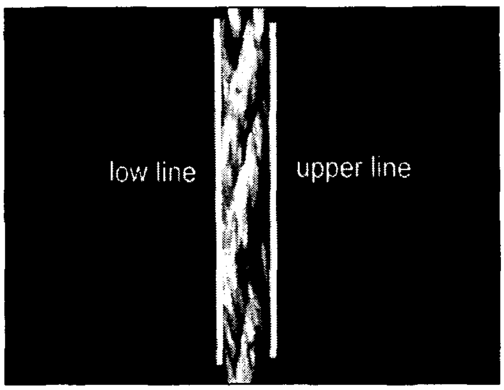

Fig. 5. The recognized upper and low line

is calculated easily by counting the length between the first and the second detection line on the image.

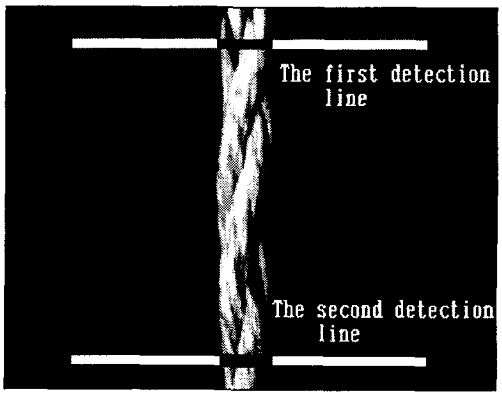

Fig. 6. The established detection lines on the screen

3. The weight measurement of rope using knowledge base information

To measure the weight of rope using computer vision, the diameter, the length, and the material texture information of rope are required. Since the material texture of rope is same always with polyester, the texture information is excluded. That is, the diameter, and the length information are used to measure the weight in this paper.

The manufactured products are commonly several types such as 10, 12, 14, 16, and 24mm according to diameters. Therefore, the knowledge base information of several operators to measure the weight according to the lengths for each diameters are constructed as following Fig. 7.

In the Fig. 7, the knowledge base that is used by weight measurement system must contain three kinds of information such as average diameters, lengths, and weight relation between average diameters and lengths. These knowledges are used to measure the weight of rope and partially synthesized procedures to more complex one.

To make knowledge base information system, the knowledges are used the experts who operates the weight measurement process with manned operation.

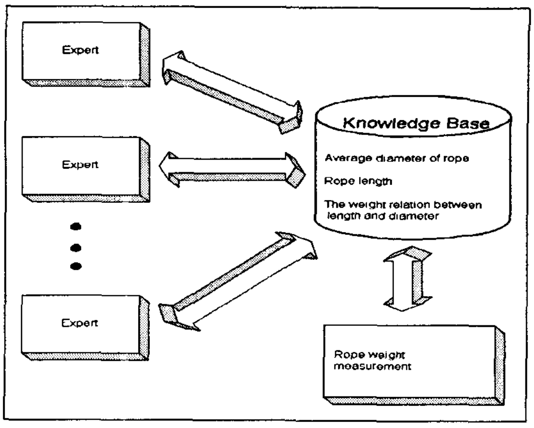

Fig. 7. The knowledge acquisition for rope weight

Ⅳ. Experimental result

The weight measurement method of rope proposed in this paper is experimented with 100 packed rope which are sold products in the market. In the experimental table 1, the first column describes the diameters of manufactured products. The second column represents the market product weight. The third column describes the measured weight from proposed method in this paper. The forth column represents the average error rate.

Table 1. The experimental results of proposed algorithm

	predetermined weight	measured average weight	average error rate
10mm	25kg	24.8~25.1 kg	-1.6%~0.4%
12mm	25kg	24.7~25.1 kg	-0.8%~0.4%
14mm	30kg	29.8~30.2 kg	-1.0%~0.7%
16mm	30kg	29.8~30.2 kg	-1.0%~0.7%
24mm	40kg	39.9~40.1 kg	-0.5%~0.25

Ⅴ. Conclusion

The automatic inspection systems using computer vision are applied to factory automation. Among the automatic inspection system, the exact dimensional measurement system are very important since the inspection operators are reduced. Also, the automatic inspection system is used in the CAM (computer aided manufacturing) system based on CAD(computer aided design).

In this paper, the automatic inspection system is widely applied in the weight measurement system of rope. The average error rate of diameter measurement is ±1mm. This error rate is acceptable in the real application. Also, the error rate of weight is - 0.98% ~ 0.8%. The developed system is set to the rope manufacturing company. In the future work, the automatic counting system for produced products is necessary to make fully automation in the field of jegang process.

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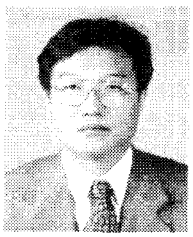

주 기 세(Ki-See Joo)

1988년 2월 한양대학교 공과대학 산업공학과(공학사)

1992년 5월 Texas A&M Univ. (공학석사)

1996년 2월 고려대학교 공과대학 산업공학과(공학박사)

1996년 3월~1997년 2월 대불대학교 기계·산업시스템 공학부 전임강사

1997년 3월~현재 목포해양대학교 해상운송시스템 공학부 전임강사

관심분야 : 로봇 비젼, 이동로봇, 데이터베이스