The Development of real-time system for taking the dimensions of objects with arbitray shape

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Abstract: In this paper, we propose a method for measuring the dimensions of an arbitrary object using geometric relationship between a perspective projection image and a rectangular parallelepiped model. For recognizing the vertexes of the rectangular parallelepiped surrounding an arbitrary object, the method adopts a strategy that derives the equations for vertex recognition from the geometrical relationships for image formation between 2D image and the rectangular parallelepiped model, extracts from 2D image with vertical view features (or junctions) of minimum quadrangle circumscribing an arbitrary shape object, and then recognizes vertexes from the features with the equations. Finally, the dimensions of the object are calculated from these results of vertex recognition. By the experimental results, it is demonstrated that this method is very effective to recognize the vertexes of the arbitrary objects.

1. Introduction

Millions of packages per year are handled and shipped by Post Services and delivery services. As economy develops, these packages are increasing day after day. Sorting of these packages is typically done by the method of using the package size or destination. Especially in the case of shipping industry, shipping fees are directly related to the package size, weight and shipping destination. In addition, the measurements of the packages shipped are also critical so that the carrier can accurately determine the number of trucks, trailers, or other vehicles which will be required to transport goods to their destinations and so both customers and carriers can accurately estimate their warehousing and other storage needs. Therefore, determining the correct package size with an efficient manner is very significant for both throughput and fee calculation. [1]

By now, there are several systems that are already known for taking the dimensions of the objects [1-4]. One system[1-2], which adopted laser technology projects a parallel laser signals onto the object to be measured and then calculates the dimensions of the object from height profiles of the object. However, this laser-based system has shortcoming that it cannot take the dimensions of objects with arbitrary shapes. The other system [3-4] uses a scanned, triangulated CCD (charge coupled device) camera/laser diode combination to capture the height profile of an object when it passes through this system and to then calculate the length, width, height, volume and position of the package. However, the second using line scan camera also has shortcomings that the cost of the system is so expensive and hardware implementation is very complex.[1-3].

In order to develop a low cost system for measuring the dimensons of arbitrary shape objects, we propose a new dimensioning method using height sensor and area scan type CCD sensor. To get this purpose, the proposed method adopts a strategy that derives the equations for vertex recognition from the geometrical relationships for image formation between 2D image and a rectangular parallelpiped model, and next, extracts features(or junctions) of minimum quadrangle circumscribing an arbitrary shape object, and then recognizes vertexes from the features by the equations, and finally calculates the dimensions of the object from the recognized vertexes.

2. The proposed method for taking the dimensions of the objects with arbitrary shape

In this section, we propose a method for taking the dimensions of the 3D objects with arbitrary shape. First of all, the equations for vertex recognition are derived from the image geometry between a rectangular parallelepiped model and a 2D image to take the dimensions of the objects.

2.1 The derivation of equations for vertex recognition of a parallelepiped model

To derive these equations, we refer to Figure 1. As shown Figure 1, the basic model for the projection of points in the scene with a virtual rectangular parallelepiped circumscribing the objects with arbitrary shape, onto the image plane, is presented.

Given the real world coordinates of 2D plane, where 3D object is put, and the height (H) of camera and the origin of the world coordinate system, we can determine distance (d) between two points r′ and a′ on S-plane, by the following method. From Figure 1, we can know that a triangle, made by three points O, r and a, and another triangle, made by another three points O, r′ and a″, are similar. From this trigonometric relationship, d, the distance between two points r′ and a′ on S-plane, can be determined by

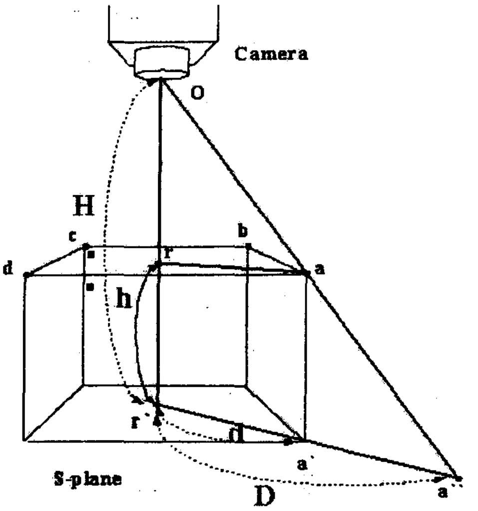


Figure 1. Geometrical model for taking the dimensions of a rectangular parallelepiped model.

$$d = \frac{hD}{H} \tag{1}$$

At this time, as coordinate of a" is known by calibration information and a' is on line between r' and a", equation (2) and (3) are derived from the fact that the distance between r' and a' is d.

$$a_x^{'} = \pm \frac{d}{\sqrt{1 + \left(a_y^{''} / a_x^{''}\right)^2}} \tag{2}$$

$$a_y^{'} = \frac{a_y^{''}}{a_x^{''}} a_x^{'} \tag{3}$$

If four junctions such as a, b, c, and d on image, made from vertical view, are extracted by feature extraction, coordinates of vertexes of the object can be easily recognized with equations (1), (2), and (3).

2.2 The proposed method

Figure 2 shows the proposed method that is consisted of three main steps such as object extraction, feature extraction and dimension measurement. Further details of the method are explained using figure 2 to figure 5.

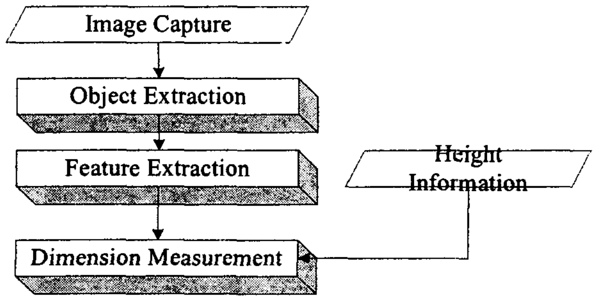


Figure. 2. A flow chart for taking the dimensions of the object

Figure 3 shows object extraction and feature extraction, the first and second step, of three steps in Figure 3. At first step, object extraction is divided into two phases that binarizes difference image between object image and background image and then eliminates small isolated regions after region labeling. At the first phase, images for object extraction are captured form CCD camera with downward vertical view. If the small isolated regions are eliminated, there is only object region on 2D image.

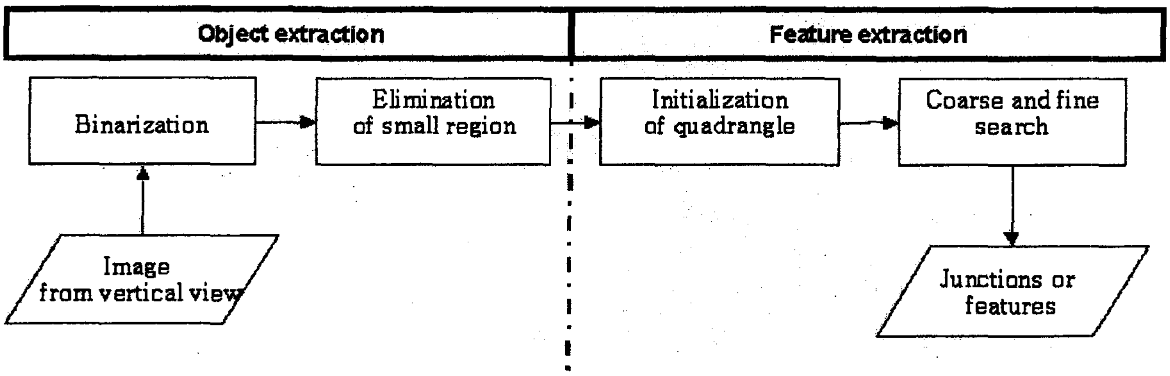


Figure 3. A flow chart for object extraction and feature extraction

The next step of the proposed method is feature extraction. As shown in figure 3, the feature extraction consists of initialization of quadrangle phase that initializes quadrangle circumscribing object from object image, and coarse to fine search phase that searches a circumscribed quadrangle with minimum area of object and then determines four junction points of quadrangle as feature points. In initialization phase, such a sequential process as centroid determination, generations of horizontal and vertical line crossing centroid, and horizontal and vertical search, initialize a circumscribed quadrangle. Figure 4-(a) shows results of centroid determination and generations of horizontal and vertical line. Next process of initialization is horizontal/vertical search. In this process, a pair of horizontal lines move to upper side or down side until each line do not meet object region as shown in figure 4-(b). And a pair of vertical lines move to left side or right side until each line do not meet object region as shown in figure 4-(b). The result of this initialization is shown in figure 4-(c).

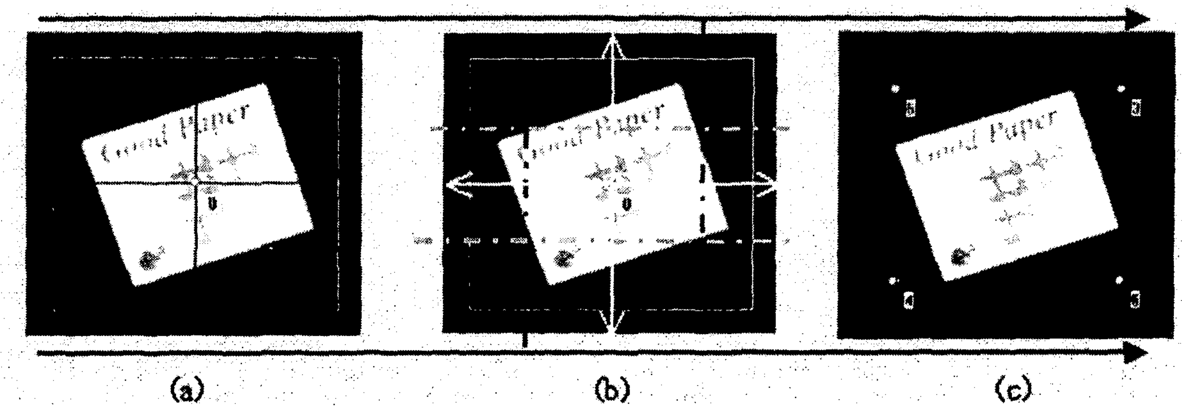


Figure 4. The process of initializing the circumscribed quadrangle of an object

At the next phase, the circumscribed quadrangle with minimum area of object is searched using coarse to fine search method. As shown in figure 5, two pairs of lines and the centroid of object are input for coarse to fine search, where initial value of counter, I, is 0 and initial value of rotation angle, Theta, is 0. If two pairs of lines and the centroid of object are input, area of circumscribed quadrangle is calculated at the present counter and angle. After area calculation, if I is smaller than 9, I is increased as I+1 and Theta is increased as Theta + X and then each circumscribed lines are rotated around the centroid in X degree. Else if I equal to 9, the present phase determines the angle with minimum area among nine areas as result of search. At this time, value of X is 10degree in the process of coarse search and is 1degree in the process of fine search. After coarse search, fine search is carried out and inputs for fine search are only the angle and four junctions or four lines made by coarse search. If coarse and fine search is ended, four junctions, four features, are acquired from four lines of the angle with minimum area.

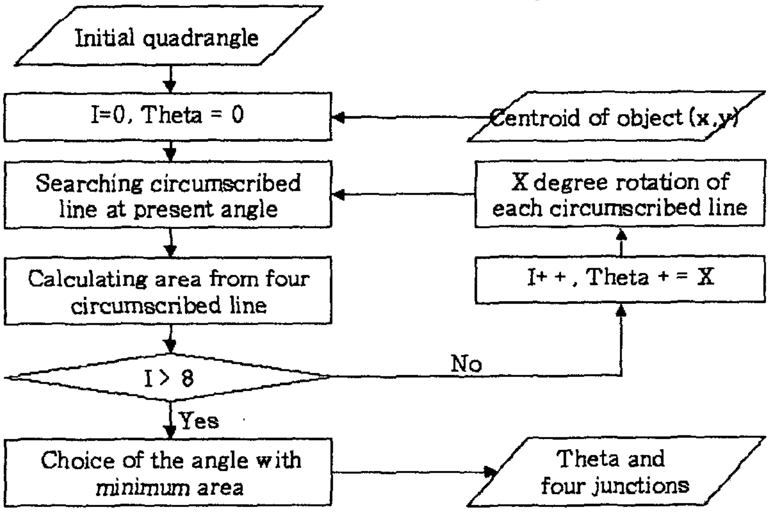


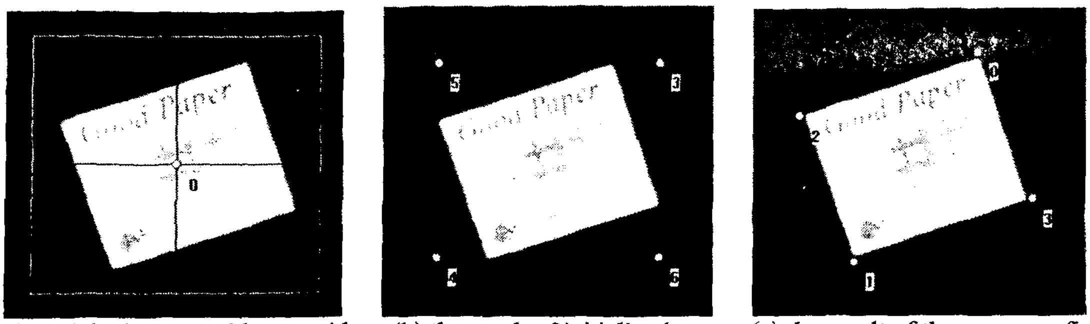
Figure 5. A flow chart for coarse and fine search

If features are extracted, the recognition of the dimensions is carried out. By using equations (1), (2), and (3), vertexes of the object are recognized and then the dimensions of the object are taken from the vertexes. If all real coordinates on S-plane for four features are determined, width and length of object is calculated with these real coordinates.

3. Experimental results and conclusions

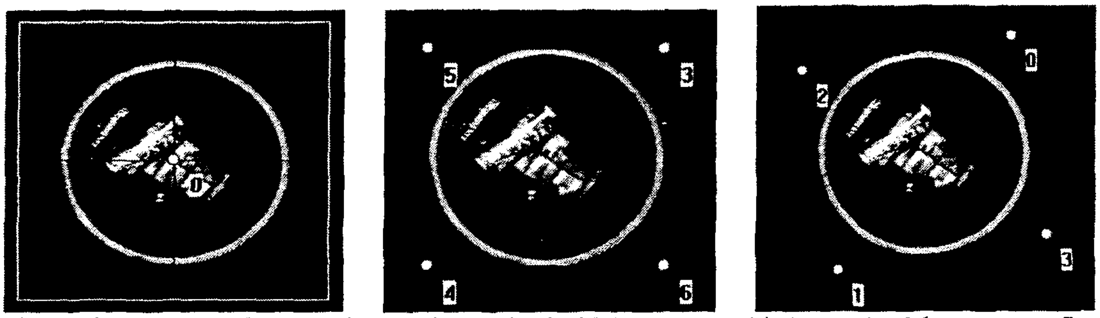
Packages with rectangular parallelepiped shape and arbitrary shape were employed for our experiment. Under the system configuration of Pentium III-800 and 128MB RAM, the experiment was carried out and images have the size of 640 x 480 and 256 gray levels a pixel. Figure 6 and 7 shows the results of coarse to fine search for objects with rectangular parallelepiped shape and arbitrary shape. From figure 6 and 7, it was presented that the proposed method is so effective to extract minimum circumscribed quadrangle of objects of rectangular parallelepiped and arbitrary shape.

Table 1 shows results of dimension measurement by equations (1), (2), and (3), and processing time consumed for taking the dimensions. Results of dimension measurement showed that the errors between the real dimensions and the measured dimensions were below 5mm. Also the results of dimension measurement showed that the errors between the real volume and the measure volume are below 5%. In addition, the processing time of each package was appeared as about 0.15sec to about 0.3sec. Through analysis of results of dimension recognition, it was demonstrated that the proposed method was so effective for taking the dimensions of the object with arbitrary shape.



(a) the original image with centroid of an object (b) the result of initialization of circumscribed quadrangle (c) the result of the coarse to fine search

Figure 6 results of extraction of minimum circumscribed quadrangle of a rectangle parallelepiped object



(a) the original image with centroid of an object (b) the result of initialization of circumscribed quadrangle (c) the result of the coarse to fine search

Figure 7 results of extraction of minimum circumscribed quadrangle of an arbitrary shape object

Table 1 Results of taking the dimensions (cm)

Type / Method	A			B			C		
	length	width	height	length	width	height	length	width	height
	33.0	19.0	15.5	29.5	16.3	19.2	39.5	57.0	29.0
Results of dimension recognition	33.1	18.8	15.5	29.4	16.5	19.2	39.6	57.5	29.0
Error	< 0.3	<0.5	<0.2	<0.3	<0.2	<0.2	<0.2	<0.6	<0.2
Processing time	0.16			0.17			0.25		

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