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VECTORIZATION OF IRREGULAR SHAPED ENGINEERING DRAWINGS TO CAD FORM

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Abstract: An approach to vectorizing binary image of engineering drawing, specially irregular shape is presented in this paper. The preliminary steps include detection and elimination of noise components and skewness. Lines, circles and arcs are detected using existing Hough, transform and chain method is used for both bounded and unbounded irregular shapes.

Keywords: Chain code; Hough transform; B-Spline representation; vectorization

Introduction

Engineering drawing is very much essential and useful in almost all types of industrial design. For preserving and handling, paper based engineering drawings are not convenient and cost effective. The problem becomes much simpler when high-speed computers are used to store these drawings in a suitable electronic form. Scanning device is used to digitize paper based drawing into an electronic form which consists of large number of black and white pixels and this raster image needs lots of disk space. The quality of the original hard copy and the resolution of the scanning device affect the accuracy of the conversion. Although almost all engineering drawings consist of some primitive geometric structures like straight lines, circles, circular arcs, there may be some irregular shapes. A computer aided design (CAD) system also operates with such primitive structures and irregular shapes. To preserve and revise engineering drawings a vectorization scheme is required which can convert the raster image into a collection of primitives as a CAD system is not suitable to handle raster image. The process of vectorization extract all primitive geometric structure including irregular shapes from the raster image of an engineering drawing accurately and saves them in a parametric form. From this vectorized data information, original drawing form which can be recovered, needs less disk space and suitable for use in CAD systems. The problem we are dealing with is to extract the required parameters for irregular shapes from the given drawings.

The scheme, which is a precursor to our approach, was proposed by Mukhopadhyay and Chanda (1998). This deals with only the regular geometric shapes of a paper based engineering drawing, converting it into binary raster image using a scanning device and performing some preprocessing operation on the image to remove noise. Then primitive geometrical structures of various types are detected from the image, but one at a time and saved in parameterized form. Several researchers have also attempted the work of vectorization. Filipski (1992) has suggested a method of vectorization through symbolic processing. Dori (1995) has developed methods of vectorizing arcs

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and dimension sets in engineering drawings. Das and Langrana (1997) have suggested a variation of geometric approach to recognize dimension sets in engineering drawings. Nagasamy and Langrana (1990) have devised a method for vectorization which involves image segmentation, line thinning and critical point (corner) detection.

Materials and Methods

The process of vectorization of engineering drawings associates with accurate identification of parameters of both regular and irregular shapes. As there are lots of methods for vectorizing primitive structures like straight lines, circles and circular arcas which are not included here. An irregular shape whether it is bounded or not can be represented by a starting point on the boundary, step size factor to move forward and the tangent angles at each step point of the boundary with any fixed axis. After identifying the lines, circles, circular arcs and irregular shapes separately, we have saved the minimal information about their geometries and positions with respect to the image background in vectorized form.

Input Specification: The scanning of paper based hard copy of the engineering drawing produces a binary raster image consisting of only black and white pixels corresponding to the foreground and background respectively. For simplicity we have chosen engineering drawing which contains no text document, also there is no dimension set present in the image. The images are scanned using flat bed scanner at a given resolution. For designing the algorithm and for processing the image data, we have adopted the following assumptions which are satisfied by large set of engineering drawings.

- The straight lines in engineering drawings are oriented at integral multiples of 15 degrees. Secondly, most of the lines among them are oriented either horizontally or vertically.
- The minimum length of a line is one tenth of an inch.
- The minimum length of an irregular shape is 10 pixels.
- The minimum spacing between any two lines is one twentieth of an inch.
- The image is contaminated with a salt and pepper like signal independent additive noise.

The input binary image is contaminated with salt and pepper noise, which is manifested as small black granular spots over a white background and white holes of small size over foreground of the image. Before we proceed with any operation on the image, we must remove the noise. The input scanned image may be tilted. This tilt or angular skew may be due to improper placing of the hard copy image on the scanning device or it may be inherently present in the original hard copy of the image. In the preprocessing steps the image is made free from such angular skew.

Proposed Algorithm: The proposed algorithm for vectorization of engineering drawing is composed of the following steps.

Preprocessing Steps: This step involves noise cleaning and skew correction.

Noise Cleaning: The noise has been removed from the image using morphological filtering of the scanned input binary image with structuring elements of suitable size and shape. As we know morphological closing fills holes smaller than structuring elements and opening removes objects smaller than structuring elements, the input binary image is made to undergo a morphological closing followed by a morphological opening operation respectively. The resulting image is free from noise as in Fig. 1(b).

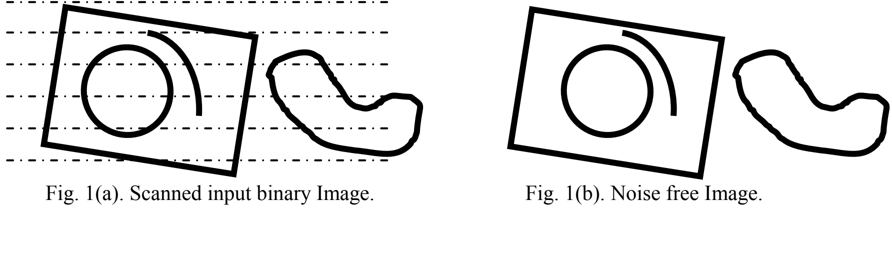

Fig. 1(a). Scanned input binary Image.   Fig. 1(b). Noise free Image.

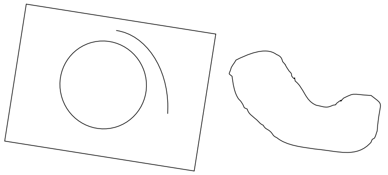

Fig. 1(c). Thinned image.

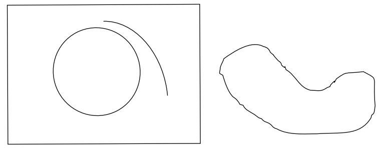

Fig. 1(d). De-skewed image.

De-skewing the Image: For skew estimation we have made use of Hough transform for estimating the skew in the image. Skew may be estimated by a morphology based method (Das and Chanda, 1997). If p is the perpendicular distance of the straight line from some reference origin in the x –y planes and θ is the angle between the perpendicular p and x-axis. Both p and θ are made to take only discrete values. For all black pixels in the input binary image we have implemented the accumulator ACM [p][θ]. To pick-up skew angles accurately we compute the global maximum θ_{max} of the two-dimensional accumulator array ACM.

$$\theta_{max} = \text{Max}(\text{ACM}[p][\theta])$$

The angle θ_{max} is the most frequent angles i.e. the angle at which maximum number of lines are oriented. If this θ_{max} is exactly equal to 0 degree or 90 degree or 180 degree, there is no skew in the image; otherwise skew angle is measured as:

$$Skew = \begin{cases} 0-\theta_{\max} & if \quad \theta_{\max} \approx 0 \\ 90-\theta_{\max} & if \quad \theta_{\max} \approx 90 \\ 180-\theta_{\max} & if \quad \theta_{\max} \approx 180 \end{cases}$$

After estimating the skew in the image the next step is to rotate the image through the skew angle using the following geometric transformation:

$$x_r = x\cos\theta_{skew} + y\sin\theta_{skew}$$
$$y_r = -x\sin\theta_{skew} + y\cos\theta_{skew}$$

Now the skew of an image is identical with the skew of a thinned version of the same image. To speed up the process of estimating the skew angle Hough transform is executed on a thin version of same binary image. A single scan boundary removal thinning algorithm (Shaha *et al*., 1993) has been used to serve the purpose.

Detection of Primitive Geometric Structure: Lines, circles and circular arcs - all these primitive geometric structures can be detected using Hough Transform (Mukhopadhyay and Chanda, 1998). After detecting all the lines, an image consisting of line elements so detected by taking set theoretic union of reconstructed line images due to all angles is constructed. The reconstructed image containing the line structures only is subtracted from the input image to form another image, which consists of only circles, circular arcs and also some irregular shapes. After detecting all the circles and circular arcs, an image is constructed containing all circles and circular arcs by taking set theoretic union of reconstructed circle and circular arc images due to all radii.

Detection of Irregular Shapes: The reconstructed image containing the circles and circular arcs only is subtracted from the image containing all types of shapes except lines to form another image, which consists of only irregular shapes. The following methods of detecting irregular shapes are based on Generalized Chain Coding (Jain, 1997).

Detection of Bounded Shapes: Detection of bounded irregular shapes comprises the following steps:

(a) Select any point arbitrary on the boundary of the irregular shape.
(b) Save this arbitrary point as the starting point as it is assumed a bounded shape.
(c) Move forward counter clockwise with a fixed step size *t*, which must be a discrete quantity.
(d) Store the tangent angles with x-axis at each step point.
(e) Continue until there are no more boundary points or meet with the starting point.

The smaller the value of step size, the more accuracy can be obtained. Finally, we can represent a bounded irregular shape with only a starting point, step size *t* and some angles. The detection process of the bounded irregular shapes is shown in Fig. 2.

Detection of Unbounded Shapes: Detection of unbounded irregular shapes comprises the following steps:

(a) Select any point arbitrary on the boundary of the irregular shape.
(b) Temporarily store this arbitrary point.
(c) Move forward clockwise with a fixed step size *t*, which must be a discrete quantity and temporarily store the tangent angles with x-axis at each step point until there are no more boundary points and store this end point as the 1st end point.
(d) Reverse the sequence orders of temporarily stored tangent angles obtained from step (c) and store them permanently.
(e) Go back to the temporarily stored starting point and move forward counter clockwise with the same step size until there are no more boundary points and store the tangent angles at the end of the previously stored angle list.

Thus, an unbounded irregular shape can be represented with only the 1st end point, step size *t* and some angles.

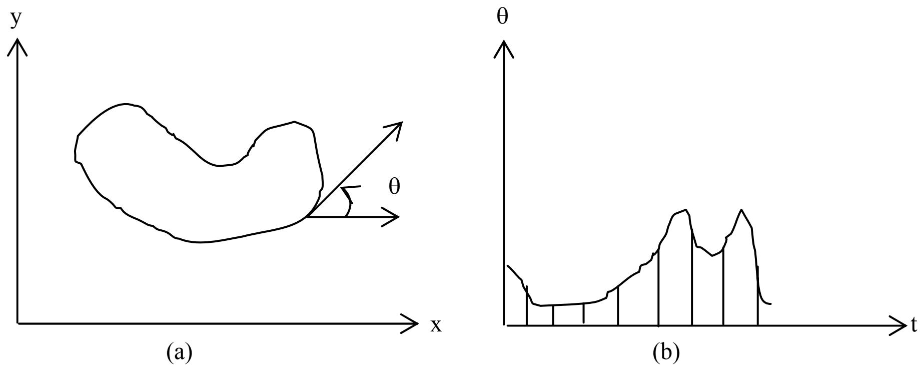

Fig. 2. Detection of bounded irregular shape, a. Contour; b. θ vs. t curve. Encode θ(t).

From these stored attributes of primitive structures i.e. lines, circles, circular arcs and irregular shapes a CAD image can be reconstructed and it can be compared with the original binary image. To increase the accuracy of the reconstruction of irregular shapes, i.e. to make the boundary curvature smoother B-Spline representation (Jain, 1997) can be used.

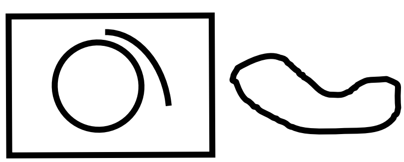

Fig. 3. Reconstructed image (adding original thickness).

Results and Conclusion

The reconstructed image resembles with the original binary image. It is free from noise and tilt. Also the geometric structures in the reconstructed image look more perfect than those of scanned image except thickness of the shapes. In pre processing steps the different shapes have been thinned for faster processing. If the thickness of original shapes is saved as a parameter, then the original thickness of the shapes can be recovered (Fig. 3). Also space required for the reconstructed image is much less than that of original image in raster form. As representing irregular shape depends on the number of step size, which requires some extra memory space, this work can be extended on this issue.

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