Trademark Image Recognition Using Statistical and Shape Features

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ABSTRACT

The goal of trademark examination is to reject infringement cases when trademarks are registered for patents. In order to simplify and speed up the trademark examination process, the development of a trademark image recognition system is desired. A new approach to trademark image recognition is proposed. The basic idea is to extract features from the input trademark image, and to search similar trademarks in a feature database. Appropriate shape features of the trademark images are utilized to perform preclassification. Detailed matching is performed next according to the combination of the statistical and shape features. Several experimental results show the feasibility and practicability of the proposed approach.

1. Introduction

Trademarks are usually composed of a variety of pictures, including characters, graphics, signs, or combinations of them. Business agents use trademarks to stand for their own products. Therefore, each trademark represents an important asset and should be registered for a patent to prevent from being used. Using trademarks which are similar to registered ones will infringe the patents of the existing trademarks. Trademark infringement cases are decisions about whether two trademarks are confusingly similar in the sense that they are likely to cause consumer confusion, mistake, or deception. Figure 1 shows some cases of trademark infringement. Conventionally, trademark examiners check each registration application case by themselves without the aid of an automatic processing system so that they have to look at a lot of document data. Therefore, the examiners encounter a lot of problems, like slow data input, large data volume checking, complicated matching, etc. Hence, to develop an automatic trademark recognition system for fast retrieving and matching of similar trademarks is essential. The goal of this study is to design methods to automatically analyze and recognize trademark images. But because of the complexity and difficulty of this task, semi-automatical processing will be implemented first.

An experimental multimedia database system TRADEMARK has been developed by Kato, et al.[1, 2, 3]. This system provides many image processing operations and three main functions: (a) automatic image registration and indexing by abstracted image representation; (b) similarity retrieval from actual visual examples; and (c) multimedia document formatting of retrieved data. The National Bureau of Standards under the Ministry of Economic Affairs of the Republic of China [4] has made a draft of trademark classification. This draft is based on some sociological factors and customs of people and forms a standard classification scheme for artificial examination. Brossman and Cross [5] built a legal expert system that contains a database of trademarks and can reason about their similarities to assess possible infringement. The system includes a character recognition component which determines the location and identity of each alphabetic character in the trademarks. A thinning algorithm is used to locate the skeleton of an image. A structural model is then formed. The proposed recognition system works quite well in the context of locating characters in artworks. Kuo and Cross [6] presented a system for retrieving similar wordmarks which are trademarks or part of them consisting solely of words.

In real cases, many registered trademark images are quite complicated. Some examples are pictures of human beings, animals, plants, and Chinese characters. For instance, the trademark shown in Figure 1(a) is a cartoon men. It is very difficult to identify these kinds of trademarks because the meanings and semantics of trademark images need be taken into consideration. Character recognition is also a difficult task. Many research works are focused on this topic in recent years. In order to simplify the objectives of this system, we make some assumptions as follows.

1. Trademarks treated in this study are confined to simple and regular pictures, or geometric graphics.
2. Characters in a trademark image are not checked and so are digged out or filled up before the image is processed in this study.
3. In trademark image recognition, we concentrate our attention to analyze the shape of the trademark image and do not consider color features. That is, we ignore the colors of trademarks and convert each color trademark image into a gray-scale image.

Whenever a trademark image is read in, a user first performs image preprocessing to improve the quality of the image. After all the preprocessing works on the trademark images are completed, statistical and shape feature extraction is performed subsequently. The parameters of features are then calculated accordingly and are stored in the database. Similar trademarks are recognized and then the image data are

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presented visually. Figure 2 shows the overall system flow of trademark image recognition.

2. Trademark Image Preprocessing

Image preprocessing is an essential work in trademark image analysis because the quality of an input image is often degraded by sketching or scanning. Therefore, in order to get more precise information of a trademark image and prevent noise from influencing the correctness of extracted features, noise removal and some image modification operations are needed. In addition, image normalization is needed for scaling the original image to the same size, and the edges of trademark images are useful for further statistical feature extraction and shape detection.

2.1 Thresholding

One step of trademark image recognition is to analyze the shape of the input image, so we have to threshold the trademark image to a binary image for further processing. In bilevel thresholding [7], the gray-level distribution of a given image containing a specific object shape is usually assumed to have a valley between two peaks with the peaks representing the gray-level concentrations of the object and the background. The objective is to locate the bottom of the valley so that the object can be segmented from the background. In the proposed system, the bilevel moment-preserving thresholding technique proposed by Tsai [8] can be employed to determine automatically the threshold value. By the way, users also can specify the threshold value interactively to binarize the trademark image. Figure 3 shows the result of bilevel thresholding applied to a trademark image.

2.2 Noise Removal and Image Modification

Noise of trademark images will influence the correctness of feature extraction. Therefore, noise removal and some image modification operations are needed for improving the quality of the input image. The way we use to look for isolated noise points is to run a mask through the image. In this study, users can specify the size of noise. Therefore, we can run the different sizes of masks which depend on the size of noise the user wishes to delete through the image.

After removing the noise of a trademark image, better image quality can be obtained. But the trademark image may still include some portions which cannot be removed by the noise removal step such as characters which are not treated in this study. Therefore, further image modification is needed. Some operations of image modification used in this study are descibed as follows:

(1) draw a line;
(2) draw a point;
(3) draw/fill a circle;
(4) draw/fill a rectangle;
(5) draw/fill a polygon;
(6) set white/black;
(7) set the size of a line or a point.

2.3 Image Normalization

Sometimes the difference between the sizes of trademarks may be great so that visual confusion occurs during trademark examination. Therefore, image normalization is needed before image representation. In this study, trademark images shown in the monitor are normalized to the same size of 128 by 128. The larger of the height and the width of an image is scaled to 128, and the height and the width of the image are scaled in the same ratio to preserve the ratio of the height and the width of the original image. Figure 4 shows some examples of image normalization.

2.4 Edge Detection

The edges of trademark images are useful for statistical feature extraction and shape detection. Therefore, we also perform edge detection as one step of preprocessing. We use the Sobel operator to find the edge points of the image.

3. Feature Extraction

After completing all the preprocessing works, the system has to extract the features of the trademark image. Two main types of features utilized in trademark image analysis are statistical feature and shape feature. Statistical features represent statistical characteristics of trademark images, like area, elongatedness, density, complexity, etc. On the other hand, shape features come from the shape boundary and include circle, triangular, rectangle, symmetry, and so on.

3.1 Statistical Features

The statistical features proposed for this study are defined as follows.

(1) Area :

The area A of a trademark image is defined as the number of black pixels of the trademark image after it is thresholded.

(2) Elongatedness:

The elongatedness of the trademark image is defined as the ratio of the length of the trademark over its width [9], which can be computed by

$$elongatedness = \frac{length}{width}.$$

(3) Density:

The density of a trademark region is defined as the ratio of the area of the trademark image over the product of the length and the width of the trademark region, which is computed by

$$density = \frac{area}{length * width}.$$

(4) Component:

This feature is defined as the number of the connected components in the trademark region.

(5) Complexity:

The complexity of a trademark region is defined as the reciprocal of the sum of the average vertical run-length of the trademark region and the average horizontal run-length of the trademark region, which is computed by

$$complexity = \frac{1}{H+V} * \text{constant}$$

where

H = horizontal average run-length,

V = vertical average run-length.

The greater the complexity of a trademark image is, the more complicated the trademark is.

(6) Mesh:

The mesh of a trademark image is computed from a sequence of n by n subregions of the trademark region. We can record the number of the black pixels of each subregions S_{ij} and called it a mesh element. But to reduce the volume of these mesh elements, we simplify each mesh element into one bit in the following way. Assign to each mesh element M_{ij} the value 1 if the number of black pixels of subregion S_{ij} is more than a half of the area of S_{ij}; otherwise, assign to mesh element M_{ij} the value 0. The mesh M of a trademark region is defined as the sequence of the mesh elements of the trademark image. Figure 5 shows an example of the mesh feature. Figure 5(b) shows the mesh element of each subregion S_{ij}.

The mesh feature is useful for template matching. As to the mesh size n, if n is too small, the information of the trademark image will be blurred and less significant. On the contrary, if n is too large, the mesh data will occupy a large space of database and will take much processing time. Empirically we found that n=10 is appropriate for this study.

Some other statistical features like the horizontal and the vertical projection profiles of a trademark image and the distribution of the run-lengths are also important for trademark image analysis, but the essences are already included by the features defined above in this study. According to our experimental experience, the proposed features represent the statistical trademark characteristics quite sufficiently and reduce the complexity of processing and the storage of the parameters.

3.2 Shape Features

The statistical features defined in the last section are still not enough to represent all characteristics of trademark images. A lot of similar trademarks cannot be identified just using statistical features. According to the human visual point of view, judging whether two trademarks are similar or not is often based on some special shapes or objects of the trademarks. That is, it is sometimes necessary to use shape features to recognize similar trademark images. The shape features of trademark images used in this study are defined as follows.

(1) Circle:

This feature is defined as the number of circles existing in a trademark image. The circular shapes can be detected using the Hough transform(HT). The use of the HT to detect circles was outlined by Duda and Hart [11]. If a circle is parameterized by its center coordinates (a, b) and its radius r, then they are related to the positions of the edge points (x, y), which form the circle via the constraint:

$$(x-a)^2+(y-b)^2=r^2.$$

(2) Triangle :

This feature is defined as the number of triangles existing in a trademark image. Three steps are required for triangle detection.

First, extract the lines of the trademark image using the HT. Second, judge the relationship of every three lines. Check the angles determined by these lines which must be in the range $[30^\circ,120^\circ]$. Finally, if the ratio of the black pixels in the regionsurrounded by these three lines over the area of this region is greater than a threshold value, then a triangle is decided to exist in the trademark image.

(3) Rectangle :

This feature is defined as the number of rectangles existing in a trademark image. Similar to the method of extracting the triangle feature, the rectangle feature can be extracted. Some examples of triangle or rectangle feature extraction are shown in Figure 6. In Figure 6(a) one triangle and one rectangle were detected, and in Figure 6(b) three rectangles were found.

(4) Symmetry :

This feature means the order of rotational symmetry of a trademark. To compute this feature, we check whether a trademark image is rotationally symmetric by Leou and Tsai [12].

The above shape features can be extracted automatically. If the result of automatic shape extraction by the system is incorrect, the users can adjust the result interactively. Also used in this study are some other shape features which are difficult to detect automatically and need be input by users interactively. These shape features are described as follows.

(5) Polygon (each with the number of edges larger than 4) :

This feature means the number of polygons existing in a trademark image.

(6) Line :

This feature means the number of straight lines, streamlines and fold-lines existing in a trademark image. Figure 7 shows some examples of lines. The trademark shown in Figure 7(a) contains three lines, and that in Figure 7(b) contains two lines.

(7) Alphabetical character :

This feature indicates the alphabetical characters contained in a trademark image. Figure 8 shows some examples of alphabetical characters. An alphabetical character of 'P' exists in the trademark of Figure 8(a), and an 'S' in Figure 8(b).

(8) Irregular shape :

This feature means the number of irregular shapes in a trademark image.

4. Similar Trademarks Retrieval by Trademark Image Recognition

To handle a large number of registered trademark images, multi-class trademark recognition is necessary. For high-speed retrievals, the scheme of pre-classification by the shape features of trademark images followed by detailed matching is proposed. The similarity between two patterns or objects can be measured on the basis of the maximum-likelihood or minimum-distance criterion. In this study, the similarity measure between trademark images is based on the minimum-distance criterion. We assume that each trademark image is a point in multi-dimension space. The closer a candidate is to an input trademark image, the more similar the candidate to the input is.

4.1 Pre-classification for Trademarks

The amount of time for trademark retrieval increases naturally in proportion to the number of trademarks. Because of the large set of the registered trademark images, it is reasonable to use the pre-classification technique to yield a smaller number of candidate trademarks for each input trademark image when we are developing a trademark image recognition system.

In this study, the eight shape features defined in Section 3.2 are used for pre-classification. That is, trademark images are classified into eight classes C_1, C_2, ..., C_8 according to their shape features. Trademarks with the same shapes are grouped together. Class C_1 gathers the trademarks which contain the circle feature. And classes C_2, C_3, ..., C_8 gather the trademarks with the features of triangles, rectangles, symmetry, polygons, lines, alphabetical characters and irregular shapes, respectively.

We cannot discriminate trademark images without overlapping by pre-classification because a trademark image may possibly contain more than one shape feature. Therefore, each trademark image may be preclassified into more than one class.

4.2 Proposed Similarity Measure and Weight Assignment

The similarity measure used in the proposed approach is the Euclidean distance. This is the most commonly used measure. The goal is to compute the distance between the feature vector of the input trademark and that of each trademark image in the database. The trademarks with smaller distances from the input trademark are taken to be the better matches.

The Euclidean distance (normalized by the standard deviation) between two vectors P and R, denoted as D(P,R), is defined by

$$D(P,R) = \sqrt{\sum \left[\frac{d(p_i, r_i)}{\sigma_i} \right]^2}$$

where P denotes the feature vector of the input trademark image, and R denotes the feature vector of a trademark in the database, and p_i and r_i are the *i*th feature components of P and R, respectively, σ_i is the normalization factor for the *i*th component, and the distance function $d(p_i, r_i)$ is given by

$d(p_1, r_1)$ = the difference of area features between P and R,
$d(p_2, r_2)$ = the difference of elongatedness features between P and R,
$d(p_3, r_3)$ = the difference of density features between P and R,
$d(p_4, r_4)$ = the difference of component features between P and R,
$d(p_5, r_5)$ = the difference of complexity features between P and R,
$d(p_6, r_6)$ = the number of the different mesh elements between P and R,
$d(p_7, r_7)$ = the sum of differences between the values of all the shape features of P and R.

In notations, $d(p_6, r_6)$ may be written as $d(p_6, r_6) = \sum_i \sum_j |M_{ij} - N_{ij}|$ where M_{ij} and N_{ij} are the mesh element of P and R, respectively. Also the value of σ_i used in the present case is the standard deviation of each of the 400 sample vectors, and is defined by

$$\sigma_i = \sqrt{\frac{1}{400} \sum_{k=1}^{400} (r_k - \mu_i)^2}$$

where

$$\mu_i = \frac{1}{400} \sum_{k=1}^{400} r_k .$$

When matching the mesh feature, some infringement cases involving rotationally similar or mirror similar must be treated. In order to avoid these rotationally similar or mirror-similar infringement cases, it is necessary to match the meshes of the trademarks in the database with the mesh of the input trademark after rotating or mirroring. In real cases, two rotationally similar trademarks may be made identical after rotating an arbitrary angle, but 90°, 180°, and 270° rotationally similar ones are the most common cases. To decrease the time for processing the rotational mesh, we match the mesh after rotating the mesh for each of the angels of 90°, 180°, and 270°, and mirroring the mesh horizontally and vertically. And modify the equation $d(p_6, r_6)$ by

$$d(p_6,r_6) = \min\{ d(m, m_{0^\circ}), d(m, m_{90^\circ}), d(m, m_{180^\circ}), d(m, m_{270^\circ}), d(m, m_h), d(m, m_v) \}$$

where

- m : the mesh elements of the input trademark,
- m_{0° : the mesh elements of a trademark candidate,
- m_{90° : the mesh elements of m_{0° after rotating 90°,
- m_{180° : the mesh elements of m_{0° after rotating 180°,
- m_{270° : the mesh elements of m_{0° after rotating 270°,
- m_h : the mesh elements of m_{0° after horizontal mirroring,
- m_v : the mesh elements of m_{0° after vertical mirroring.

The influences of the features on the trademark image recognition result are not equivalent. Therefore, different weights for different features are needed. We should give a larger weight to a feature that have more important influence. After setting the weights of these features, we can modify the distance to be a weighted distance as follows:

$$D(P,R) = \sqrt{\sum \left[\frac{w_i \times d(p_i, r_i)}{\sigma_i} \right]^2}.$$

About the determination of the weights of the features, we found empirically that the statistical features and the shape features contribute equally to trademark image analysis. Therefore, we set $\sum_{i=1}^{6} w_i = 0.5$ and $w_7 = 0.5$. As to the statistical features, the influences of the statistical features are almost equivalent except the mesh feature. The mesh feature composed of n by n mesh elements has more contribution than the other statistical features. Therefore, the weight of the mesh feature is larger than the weights of the other statistical features. As to the shape features, we found empirically that the symmetry feature and the alphabetical character feature usually have stronger influences in the visual point of view. Therefore, the weights of these two features are larger than the weights of the other shape features. The weights of all the features preset for use in this study are shown in Figure 9.

4.3 Trademark Recognition

In trademark image recognition, the goal is to retrieve a set of similar trademark images, not only the best matched one. All trademarks sufficiently similar to the input trademark are picked out as the candidates for further inspection. Therefore, the number of similar trademarks may be more than one. The detail of the recognition procedure is descrribed in the following:

Algorithm : Recognition procedure.
Input : A new trademark image for registration.
Output : Some similar trademark images.
Method :

Step 1 : Input the new trademark image.
Step 2 : Perform the preprocessing works.
Step 3 : Extract the statistical and shape features.
Step 4 : Classify the input image into appropriate classes (called retrieved classes) using the shape features.
Step 5 : Calculate the weighted distances between the input trademark and all the trademarks in the retrieved classes obtained in Step 4.
Step 6 : Accept the trademarks whose weighted distances are smaller than a threshold.
Step 7 : Sort these trademarks in the increasing order according to their weighted distances. The smaller the weighted distance is, the more similar to the input the retrieved trademark image is.
Step 8 : Show candidates nine by nine in accordance with the orders of their weighted distances.
Step 9 : Permit the user to retrieve other desired trademarks by specifying a combination of certain shape features and go to Step 5.

5. Experimental Results

5.1 Experimental Results

The proposed trademark image recognition method was implemented on a Sun Sparc Workstation based on the C language. The speed of trademark recognition is satisfactory. Similarity retrieval in the feature database takes about two or three seconds per trademark image.

Four hundred trademark images were tested in the proposed system. Because it is difficult to collect infringement cases, some of the tested trademarks are redrawn to simulate infringement cases. The average number of the trademark candidates whose distances are smaller then the reject threshold is about 36. The reject threshold is set to be 450. The user also can adjust the reject threshold interactively according the result of retrieval. And the trademark candidates are shown nine by nine per page in the increasing-distance order.

At present, nearly 80 percent of the trademark images can be retrieved from those which the tester feels similar by inspection. The recognition results of some of the test samples are shown in Figures 10 and Figure 11. (a) of each of the figures shows the normalized trademark image of the tested sample, (b) shows the extracted features, and (c) shows the best eighteen similar trademarks in accordance with their distances in the increasing order. The first element of each grid in (c) denotes the rank of the candidate. The second is the number of each tested trademark. The distance of the candidate is denoted by the third element. The original image is shown in the lower part of the grid.

Good experimental results of testing 400 sample images proves the feasibility of the proposed approaches.

5.2 Discussions

For most of the tested samples, visually similar trademarks were retrieved as the candidates satisfactorily. The trademark candidates are sorted according to their distances in the increasing order. It is found that the first candidate is not necessarily the most similar one. But generally, the earlier a trademark candidate appears in the order, the more similar it is to the tested sample.

The majority of the extracted feature values are satisfactory, but some of them are not very accurate. The error in the feature values will influence the correctness of recognition. Particularly for the shape features, they are not only difficult to extract automatically but also prone to be neglected by users' interactive input. Therefore, it is necessary to be more careful in interactive input in order to avoid the oversight of the shape features.

Some of the tested trademark images depict a bird or an apple. Therefore, the recognition results of such trademarks are not good because the required reasoning and unstructured recognition for this kind of shape is far beyond the capabilities of current artificial intelligence and pattern recognition techniques.

6. Conclusions

A semi-automatic trademark recognition system has been successfully implemented. Several achievements in different phases are summarized as follows.

In the image preprocessing phase, a method of automatical thresholding was employed to binarize the trademark image. Noise removal and some image modification operations were employed for improving the quality of trademark image.

In the feature extraction phase, some statistical and shape features were used to recognize similar trademarks. The experimental results evidently showed their effectiveness.

In the similar trademark retrieval phase, a scheme for preclassification using the shape features of trademarks was proposed. And then sufficiently similar trademarks can be retrieved by the proposed detailed matching method based on the minimum-distance criterion. Similarly, the experimental results has revealed the feasibility of the proposed methods.

As a matter of fact, trademark examination cases mostly are based on the subjective judgment of the examiners and is a complicated task. Therefore, the system need further adjustment and test for improvement. This research is a long-range work and needs much more opinions and ideas from experts and scholars.

References

[1] T. Kato, K. Fujimura and H. Shimogaki, "TRADEMARK: Multimedia image database system with intelligent human interface," *Systems and Computers in Japan*, Vol. 21, No. 11, 1990.

[2] T. Kato and H. Shimogaki, "TRADEMARK: Multimedia database for trademark and design patterns," *Technical Report of SIG-PRU, I. E. I. C. E., Japan, PRU88-9*, 1988.

[3] T. Kato, K. Fujimura and H. Shimogaki, "Architecture and user interface of intelligent multimedia database system TRADEMARK," *Bulletin of ETL*, Vol. 52, No. 7, pp. 1019-1038, 1988.

[4] 經濟部中央標準局和交通部電信研究所, "商標圖形分類基準草案," 1993.

[5] C. Brossman and G. R. Cross, "Model-based recognition of characters in trademark artwork," *Pattern Recognition Letters*, Vol. 11, pp. 363-370, 1990.

[6] S. Kuo and G. R. Cross, "A string-matching procedure," *Pattern Recognition*, Vol. 24, No. 7, pp. 711-716, 1991.

[7] R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, Addison-Wesley, U. S. A., 1992.

[8] W. H. Tsai, "Moment-preserving thresholding: a new approach," Computer Vision, *Graphics, and Image Processing*, Vol. 39, pp. 439-451, 1987.

[9] P. A. Devijver and J. Kittler, *Pattern Recognition*, Prentice-Hall, London, U. K, 1982.

[10] A. Rosenfeld and A. C. Kak, *Digital Picture Processing*, Academic Press, New York/San Francisco/London, 1982.

[11] R. O. Duda and P. E. Hart, "Use of the Hough transformation to detect lines and curves in pictures," *Communication ACM*, Vol. 15, No. 1, pp. 11-15, 1972.

[12] J. J. Leou and W. H. Tsai, "Automatic rotational symmetry determination for shape analysis," *Pattern Recognition*, Vol. 20, No. 6, pp. 571-582, 1987.

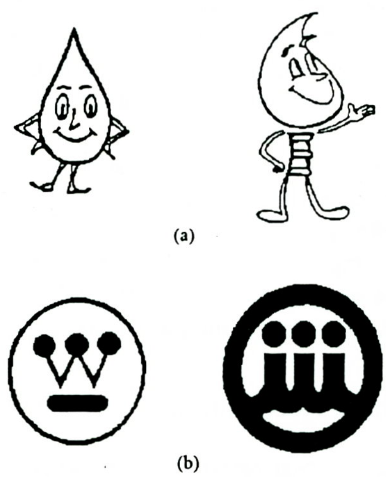


Figure 1 : Some examples of trademark infringement cases.

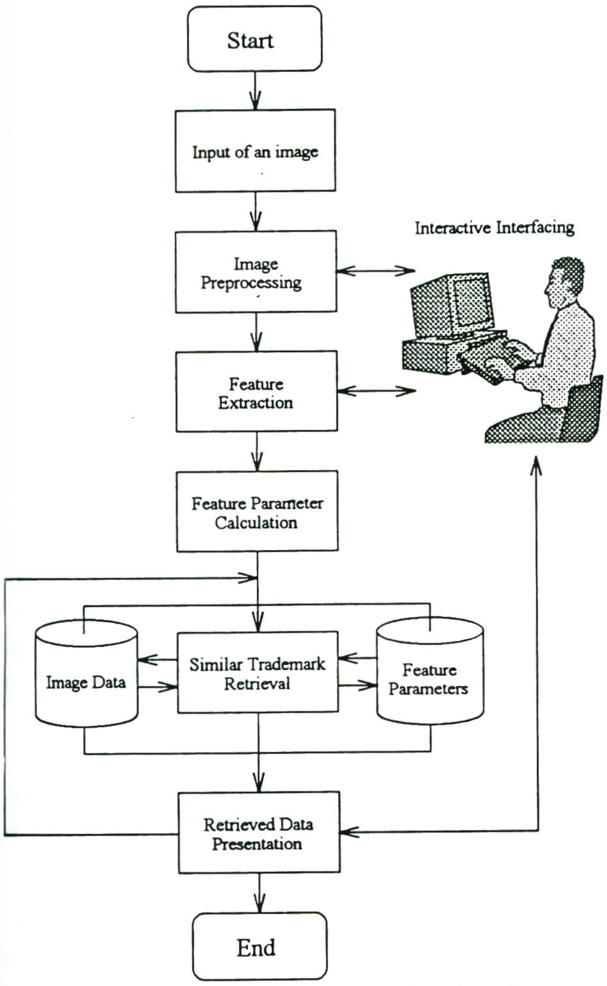
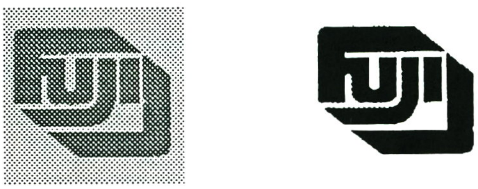


Figure 2 : The overall flow of the proposed trademark system.



(a) (b)

Figure 3 : An example of bilevel thresholding. (a) Original image; (b) the result of bilevel thresholding.

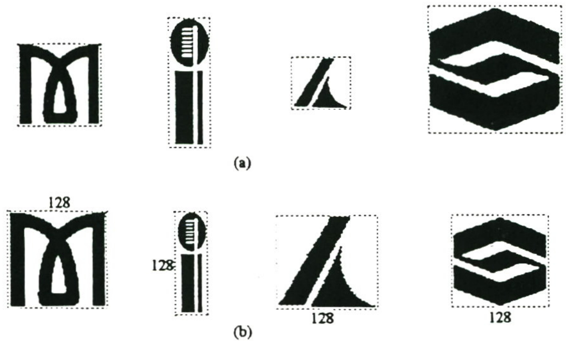
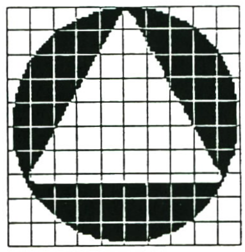


Figure 4 : Examples of image normalization. (a) Original images; (b) results of image normalization.

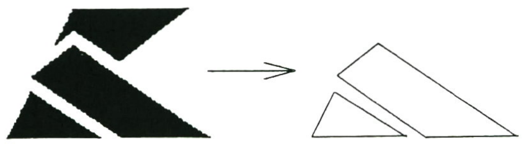


(a)

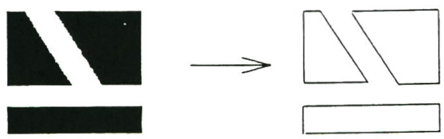
0	0	0	1	1	1	1	0	0	0
0	0	1	1	0	0	1	1	1	0
0	1	1	1	0	0	0	1	1	0
1	1	1	0	0	0	0	1	1	1
1	1	0	0	0	0	0	0	1	1
1	1	0	0	0	0	0	0	1	1
1	0	0	0	0	0	0	0	0	1
0	1	1	1	1	1	1	1	1	0
0	0	1	1	1	1	1	1	0	0
0	0	0	1	1	1	1	0	0	0

(b)

Figure 5 : An example of mesh feature. (a) Original image; (b) the mesh element of each subregions S_{ij}.



(a)



(b)

Figure 6 : The results of triangle and rectangle feature extraction. (a) one triangle and one rectangle are detected; and (b) three rectangle are detected.

(a) (b)

Figure 7 : Examples of trademarks including line features.

(a) (b)

Figure 8 : Examples of trademarks containing alphabetical character features.

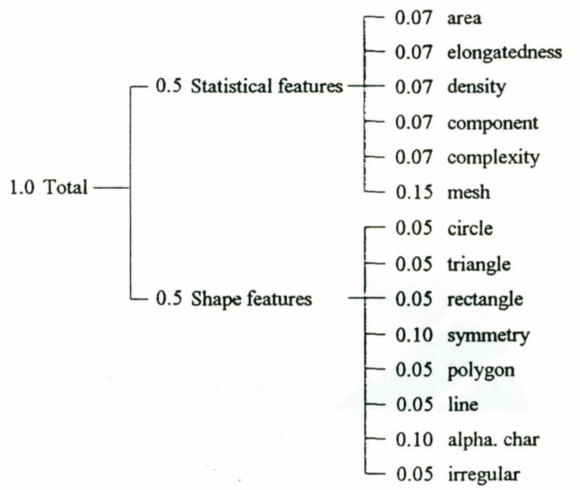
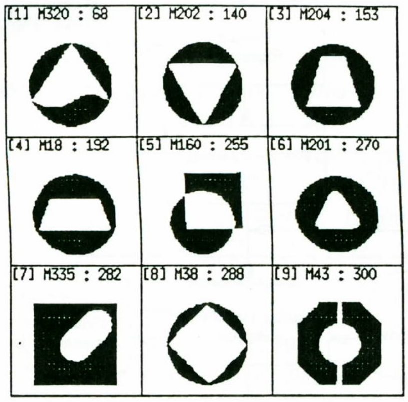


Figure 9 : The weights of all the features used in this study.

features	value	features	value
area	4526	triangle	1
elongatedness	1.0309	rectangle	
density	0.382	symmetry	3
component	2	polygon	
complxity	23	line	
circle	1	alphab. char	

(a) (b)

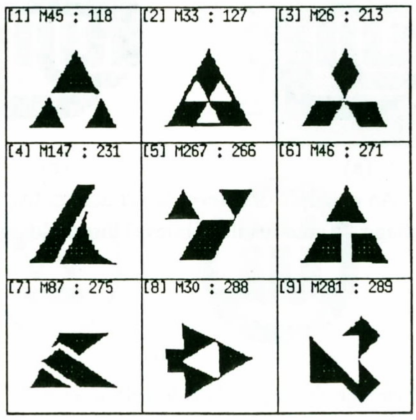


(c)

Figure 10: The recognition result of sample No. 1. (a) The normalized trademark image; (b) the feaure values of the sample; and (c) the best nine similar trademarks.

features	value	features	value
area	3479	triangle	4
elongatedness	1.2037	rectangle	
density	0.354	symmetry	3
component	3	polygon	
complxity	18	line	
circle		alphab. char	

(a) (b)



(c)

Figure 11: The recognition result of sample No. 31. (a) The normalized trademark image; (b) the feaure values of the sample; and (c) the best nine similar trademarks.