Drawing Similarity Measurement Using Object Alignment

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Abstract. Shape similarity plays important role in human perception. Humans always look for similarities between the shape of what they see and the shape of what they saw via comparison. Shape similarity has many applications in different fields such as cognitive science, medicine and computer science. This is a study in which a system is designed and implemented to measure similarities of two circular drawing shapes. The system follows different steps and techniques related to digital image processing such as; binarization, morphological operations and image segmentation. The novelty of the system comes from image alignment in which some transformation is performed to eliminate size dependency in similarity measurement. The transformation works on changing the origin point followed by stretching. In this study 30 pairs of circular shapes are considered. The results shows the system has 91.38% accuracy in average while maximum accuracy among 30 pairs of samples is 99.98% and minimum accuracy is 69.15%.

1. Introduction

One of the most important abstract notions in the human perception of the world is similarity [1]. There are many types of similarities such as: color similarity, sound similarity, size similarity, shape similarity, etc. Among these similarities, shape similarity has higher rank as paying attention to. We care about shape similarity every day throughout our interaction with other people whose faces we recognize [2].

Similarity performs critical roles in many fields in science from medicine [3] [4] and cognitive science [5] [6] [7] [8] to computer science [1] [9] [10] [11]. Shape similarity is a broad area that has many subareas such as drawing similarity in which the shapes are simple geometric shapes same as; circle, square, triangle, etc. Because of importance of shape similarity, we design and implement an algorithm (system) that measures shape similarity. Specifically, we pay attention to drawing similarity in which the shapes are circular.

2. Related studies

There are numerous studies and researches regarding shape similarity, and several studies particularly about drawing similarity. We consider some of these studies.

There is a study in shape similarity in which researchers propose two algorithms focusing on engineering parts and rotation of the objects in the scene. Researchers conclude that mixing both algorithms has higher accuracy [12].

In manufacturing, there is a research in which researchers used graph theory to develop a system that is capable to detect topological similarity of a component to the available components in the database [13].
Some researchers proposed a system that measures the similarity of 3D shapes. They use the idea that says two similar 3D shapes look similar from different viewing angles. They use Fourier descriptor as well as Zernike moments as features for retrieval, and encoded 100 orthogonal projections of a shape to implement their idea [14].

There is a partial image retrieval system in industrial engineering drawings that accepts a drawing as query. The system searches database and returns the drawings in which query image was found. The system uses graph representation to find similar parts [15].

3. Statement of the problem
There are several studies and researches regarding measurement of similarity in drawings and we considered some of them. Although all of these researches are powerful and functional in their field of studies, none of them pays attention to the size of the objects that are considered for similarity measurements. There are cases in which two shapes (objects) might be similar but in different size. For example two circles having different radius are 100% similar, but all of the previous studies about similarity did not pay attention to this matter.

4. Objective of the study
Based on the problem stated earlier, the general objective of the study is to design and implement a system to compute the similarity of drawing shapes. The system needs to pay attention to the size of shapes. The system uses digital image analysis and works on two circular (round) shapes.

Specifically, the system;
1) Detects the two shapes, and
2) Computes the similarity of the two shapes based on percentage.

5. Methodology
We consider the proposed system to measure similarity of two shapes called sh1 and sh2 while sh1 exists in an image called im1 and sh2 exists in another image called im2.

5.1. Binarization
The first step is to convert im1 and im2 to binary images using thresholding in which the threshold is 200 (see Figure 1).

![Figure 1. Original image (left) and binary image (right)](image)

5.2. Noise removal
After binarization, because of having some noise, we need to use some morphological techniques to remove the noise. We do erosion to remove extra islands (see Figure 2, Left and Figure 2, Center) when the size of structuring element is 23×23, followed by dilation to fill holes existed in the shape (see Figure 2, Center and Figure 2, Right) when the size of structuring element is 17×17.
5.3. Normalization
The im1 and im2 might generally have different dimensions (width and height). Besides, sh1 and sh2 drawn by a person might also have different size in width and height. In this regard, to find the similarity of sh1 and sh2, we need to normalize them to have similar dimensions. We use the technique image registration for alignment and normalization in which we perform the following steps:

a) Contour detection; to find the boundary of sh1 and sh2 (see Figure 3).
b) Adding bounding rectangle; to find the dimensions (the width and the height) of sh1 and sh2 (see Figure 3).
c) Finding normal-frame; to locate both of sh1 and sh2 inside the normal-frame. In this case, im1 or im2 might be stretched out vertically, horizontally or both. After the stretching, im1 and im2 will have the same dimensions.

The width and the height of the normal-frame are computed based on equation (1) and equation (2), while $w_1$, $w_2$, $W_{nf}$, $h_1$, $h_2$ and $H_{nf}$ mean width of sh1, width of sh2, width of normal-frame, height of sh1, height of sh2 and height of normal-frame respectively.

$$W_{nf} = \max\{w_1, w_2\} \tag{1}$$
$$H_{nf} = \max\{h_1, h_2\} \tag{2}$$

Figure 3. Before (left) and after (right) contour detection and bounding rectangle

d) Finding the origin; to locate the shape inside the normal-frame. The origin is the pixel that shows the start of the bounding box in the normal-frame. In fact, the origin shows the margin around the bounding rectangle in the normal-frame. If x is the coordinate of origin in x-axis and y is the coordinate of origin in y-axis, we compute x and y based on equation (3) and equation (4) respectively.

$$x = \frac{W_{nf} - w}{2} \tag{3}$$
$$y = \frac{H_{nf} - h}{2} \tag{4}$$

In equation (3) and equation (4); $w$ and $h$ are width and height of the shape respectively. In other words, $w$ can be $w_1$ or $w_2$ while $h$ can be $h_1$ or $h_2$.

Figure 4 shows the result of normalization for a sample of im1 and im2.
5.4. Image segmentation
At this point we already have two normalized images that are ready for similarity measurement. To do this, we partition each image into 9 (3×3) parts having equal size in width and height as Figure 5 shows.

5.5. Similarity computation
At this point, im1 and im2 have 9 partitions called p1, p2, …, p9. We compare the number of black pixels in im1 and im2 regarding each partition based on equation (5), where $R_n$ is the ratio regarding $p_n$ while $1 \leq n \leq 9$, $P_{\text{min}}$ is the smaller number of black pixels in $p_n$ of im1 and im2, and $P_{\text{max}}$ is the greater number of black pixels in $p_n$ of im1 and im2;

$$R_n = \frac{P_{\text{min}}}{P_{\text{max}}} \times 100$$

In fact, $R_n$ shows the percentage of similarity in $p_n$. In this regard, there is some exception when both $P_{\text{min}}$ and $P_{\text{max}}$ are equal to zero. In this case $R_n = 100$ since there is no black pixel in the relevant partition of im1 and im2. In other words, $R_n$ of im1 and $R_n$ of im2 are 100% similar when there is no black pixel.

Since we have 9 partitions, we will have 9 ratios; $R_1$, $R_2$, …, $R_9$ that show similarities at partitions 1, 2, ..., 9 respectively. Now, we compute total similarity among all ratios as equation (6) shows;

$$\text{Total Similarity} = \frac{\sum_{i=1}^{9} R_i}{9}$$

6. Result and discussion
We applied the designed algorithm on 30 pairs of circles drawn by test subjects who were randomly selected. Each pair of samples consists of 2 circles drawn consecutively on a piece of white blank sheet of paper with printed guideline-box. The guideline-box contains two printed 2x2-inch squares. The test subjects were asked to draw the two largest possible circles inside two squares without obstructing the said guideline-box. Then two squares in the guideline-box were separated and digitalized by a scanner at 1200dpi.
After applying the algorithm and having similarities of 30 pairs of images, we contacted an expert who is an official psychologist to rate the similarity of 30 pairs of images. According to the expert, in psychology they rank the similarity from 1 to 10 while 1 is the lowest and 10 is the highest. In this regard, for homogeneity we multiplied the ranks made by the expert by 10. Then, for error calculation, we followed usual equation (7).

$$\text{Error} = \frac{\text{Total Similarity Rank} - (\text{Rank} \times 10)}{\text{Rank} \times 10} \times 100\%$$

(7)

Table 1 shows the complete result regarding 30 pairs of circular shapes.

| Pair | Similarity measured by System | Similarity ranked by Expert | Error (%) | Accuracy (%) |
|------|-------------------------------|----------------------------|-----------|--------------|
| 1    | 79.42                         | 80                         | 0.72      | 99.28        |
| 2    | 81.79                         | 80                         | 2.24      | 97.76        |
| 3    | 84.35                         | 80                         | 5.44      | 94.56        |
| 4    | 84.40                         | 80                         | 5.50      | 94.50        |
| 5    | 81.00                         | 70                         | 15.71     | 84.29        |
| 6    | 79.66                         | 70                         | 13.80     | 86.20        |
| 7    | 78.51                         | 60                         | 30.85     | 69.15        |
| 8    | 75.86                         | 60                         | 26.43     | 73.57        |
| 9    | 81.56                         | 80                         | 1.95      | 98.05        |
| 10   | 80.50                         | 80                         | 0.63      | 99.38        |
| 11   | 80.87                         | 70                         | 15.33     | 84.47        |
| 12   | 83.22                         | 80                         | 4.03      | 95.98        |
| 13   | 81.09                         | 80                         | 1.36      | 98.64        |
| 14   | 80.02                         | 80                         | 0.02      | 99.98        |
| 15   | 83.73                         | 80                         | 4.66      | 95.34        |
| 16   | 77.42                         | 70                         | 10.60     | 89.40        |
| 17   | 43.97                         | 50                         | 12.06     | 87.94        |
| 18   | 82.45                         | 70                         | 17.79     | 82.21        |
| 19   | 79.83                         | 80                         | 0.21      | 99.79        |
| 20   | 78.28                         | 70                         | 11.83     | 88.17        |
| 21   | 80.04                         | 80                         | 0.05      | 99.95        |
| 22   | 76.79                         | 80                         | 4.01      | 95.99        |
| 23   | 79.03                         | 80                         | 1.21      | 98.79        |
| 24   | 69.52                         | 60                         | 15.87     | 84.13        |
| 25   | 78.39                         | 70                         | 11.99     | 88.01        |
| 26   | 84.41                         | 80                         | 5.51      | 94.49        |
| 27   | 75.33                         | 60                         | 25.55     | 74.45        |
| 28   | 78.19                         | 80                         | 2.26      | 97.74        |
| 29   | 75.49                         | 70                         | 7.84      | 92.16        |
| 30   | 82.34                         | 80                         | 2.93      | 97.08        |

Based on the results in Table 1, the average error is 8.62% and the average accuracy is 91.38%. The maximum accuracy among 30 pairs of samples is 99.98 while the minimum accuracy is 69.15%.

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