

Similarity Measure Determination From NURBS-Warping Method

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Abstract

With the advances in digital imagery, large accessible data storage, internet repositories, and image applications, information conveyed through images is gaining in importance. There is a need to find a desired image from a collection of images, which is shared by many groups including journalists, engineers, historians, designers, teachers, artists and advertising agencies. Humans have the capability to determine only a few selected signs, which enable them to determine the impression of a complete representation of the objects and comparing them. However, it is impossible to trace through the large image database in order to retrieve the desired image manually. Retrieval by shape is considered one of the most difficult and challenging aspects of image-based search. Thus, an effective shape retrieval system approach, which resembles the human capability in retrieving images from a database that are relevant to a query, is needed. In this paper, we propose a new similarity measure determination based on the NURBS-Warping method. In this method, the query image represented by the Non-Uniform Rational B-Spline (NURBS) descriptor is warped to best fit the shape of the database image. The similarity between two images is determined by measuring the effort been spent in the warping process. Four similarity parameters are derived to reflect the effort spent throughout the warping process. These parameters are the Total Cumulative Change in the Position of the Control Points (TCCPCP), Total Cumulative Change in the Curvature of the Control Points (TCCCCP), Total Cumulative Voting Distance Score (TCVDS) and degree of matching, which are used to compute the similarity measure for each database image. The retrieved database images are ranked according to the computed similarity measure. A set of experiments is carried out to investigate the characteristic of each similarity parameters that influence the similarity measure computation independently. We also validate the effectiveness of the computed similarity measure for retrieving a set of database images based on the human similarity judgement. The retrieval results of the proposed method are compared with the Curvature Scale Space (CSS) method proposed by Mokhtarian. The overall experiments results show that the similarity measure derived from the NURBS-Warping method show good retrieval results in a highly similar database.

1 Introduction

Many techniques in this research direction have been developed and many shape retrieval systems, both research and commercial, have been built. A number of approaches have been proposed to compare two shapes by using the distance function in the multidimensional feature space. The most well known distance functions are Minkowski distance, Hausdorff distance and Frechet distance [1]. In this feature-based matching, various features utilised are: global features technique [2], moment invariants [3], 2-D fourier transform [4], wavelet transform [5], B-Spline [6], turning function [7] and curvature scale space [8]. The details of various shape representation are found in [9]. However, feature-based matching tends to be sensitive to occlusion and small variations in shape that will affect the retrieval results. For most features, there is no guarantee that the human notion of “similarity” corresponds to the topological similarity in the feature space.

In order to derive a similarity measure in a manner that closely resembles human perception, elastic matching method is introduced [10]. Elastic matching is often used to bridging the gap between the feature-based matching and the semantic matching. This matching approach is a powerful technique because of its capability to deal with shape deformations and variations. In elastic matching approach, the similarity measure is related to a physical energy that is obtained by measuring the amount of deformation needed to explain the difference in two contours. Similarity parameter is computed from the warping process in order to evaluate the sum of local deformations needed to change one shape into another respective shape. A number of different similarity parameters that have been proposed for elastic matching are described in [11].

Elastic matching approach has been widely used in the shape-based image retrieval system [12,13]. In the Photobook system, Sclaroff and Petland have used modal vibrations to identify the amount of deformation for both rigid and non-rigid needed to align the query image to the database image. The mode amplitude of the modal vibrations indicates the amount of energy required to align two images and thus provide a similarity measure [12]. Bimbo has proposed elastic template matching using the user sketch [13]. In this,

stretching and bending energy, as well as degree of matching achieved are used to evaluate the similarity ranking of the database images. The shape similarity measure is computed through a back-propagation neural network. Although these two approaches provide a similarity ranking very close to manual ranking, but they involve a very high computation time.

In our work, we propose a different shape similarity retrieval method based on elastic template, which is related to the work by Bimbo [13]. We referred to this approach as NURBS-Warping method. NURBS-Warping method is an extension effort of the elastic matching method in order to improve the efficiency and the computation time of the warping process [14]. In this paper, our main contribution is to derive a different set of similarity parameters from the NURBS-Warping method, with an intention that these similarity parameters represent the characteristics of the human similarity perception. These similarity parameters are used to derive a meaningful similarity measure for use in displaying a set of relevant images from a highly similar database.

This paper is organised as follows. In Section 2, an overview of our proposed method is presented. Section 3 introduces the method to determine the similarity parameters from the NURBS-Warping method. Section 4 explains the computation of similarity measure. Section 5 presents the experiments to investigate the characteristic of each similarity parameters in determining the shape similarity measure of two shapes. We also evaluate the effectiveness of this shape similarity measure in a manner to display an accurate retrieval results requested by a query image. Section 6 concludes the approach presented in this paper and discusses the future directions of our research.

2 Proposed Method

The proposed method is inspired by the manner in which humans perceive objects and compare them. In the NURBS-Warping method, the query image is represented by NURBS, with the position of the control points and their weights as variable parameters. This NURBS-based representation of the query image is deformed iteratively by an external force in order to improve its match with the database image, by adjusting the NURBS control points. The weights of the corresponding control points are fixed throughout the warping process in order to make this process simple and fast. Gradient vector flow (GVF) is chosen as an external force in order to provides an efficient convergence of the query image to the boundary of the database image [15]. The GVF is computed from the edge map of the database image itself. This will improved the efficiency of our warping method. The iteration is considered complete when all the deformed control points have converged and locked themselves on

the boundary of the database image. The smoothness of the deformed template is maintained throughout the warping process. The similarity between two images is determined by measuring the effort spent in the warping process.

For the purpose of retrieval by shape similarity, representation is preferred such that the salient perceptual aspects of a shape are captured and are able to imitate the human perception in perceiving shapes. The representation method is important, because the effectiveness of the representation will determine the accuracy of the retrieval results. In this method, we represent the query image by NURBS in a manner that this shape descriptor is able to model all various form of shape [16]. In addition, in contrast to the work by Bimbo, the NURBS-Warping method updates the position of the NURBS control points explicitly without any recalculation of the NURBS boundary points in each iteration of the deformation and eliminate the difficulty in determining the weights associated with the smoothness and continuity constraint. Therefore, the speed of the warping process is improved [14]. The optimum position of the control points is achieved through the gradient descent technique. Although the gradient descent technique has the risk of resulting in a local minimum, it is less computational intensive compared to the global minimum optimisation technique such as graduated non-convexity algorithms and genetic algorithms. In this work, gradient descent technique is chosen owing to its fast computation time in the warping process, which is an important factor in the shape-based image retrieval system.

Before the warping process is carried out, the query image is normalized with a transformation matrix, (T) based on the orientation of the database image. The normalization step is important to ensure the similarity measure is solely determined from the warping process without being affected by the orientation differences between the query and database images. Owing to the NURBS property that the representation has the characteristic of shape invariance under affine transformation [17], it plays a significant role in the normalization step, in a manner that the NURBS descriptors need not be computed again for new normalized query image. Thus, the NURBS descriptors are normalized by subjecting them to the same transformation matrix, (T) . After the query image is superimposed on the database image, the query image is then warped to match the shape of the database image. With this warping method, we take the full advantages of the underlying NURBS representation to measure the similarity measure for use in the retrieval process.

3 Similarity Parameters Computation

At every iteration of the warping process, the adjusted set of control points is in correspondence with the set of control points at the previous iteration and both sets are

of same size. With this correspondence property, the similarity parameters are obtained from the warping process.

In order to ensure that the similarity measure reflects the effort spent throughout the warping process, three similarity parameters are determined by the Total Cumulative Change in the Position of the Control Points (TCCPCP), Total Cumulative Change in the Curvature of the Control Points (TCCCCP) and Total Cumulative Voting Distance Score (TCVDS), which are the sum of the cumulative change in the position of the control points, cumulative change in the curvature of the control points and cumulative voting distance score respectively at each iteration until completion of the warping process. The cumulative change in the position of the control points is computed by cumulating all the distances between the positions of the control points at the two different iterations by using Euclidean distance function, illustrated in Fig. 1.

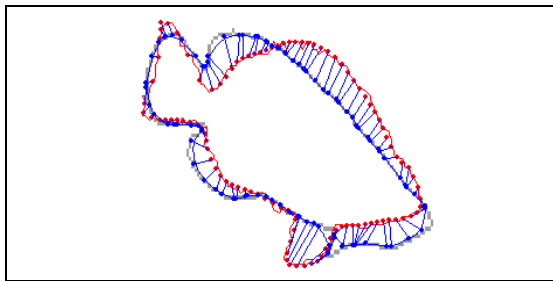


Figure 1: The cumulative change in the positions of the control points is computed by adding all the distance of the joining lines (blue).

The cumulative change in the curvature of the control points is computed by cumulating all the differences in the curvature of the control points using an approximation curvature function, introduced by Williams [18].

For the computation of the voting distance score, a voting score that is 1 or 0 is given to each control points if the distance between the positions of the control points at the two different iterations is larger or lesser than a prespecified voting threshold value respectively. The cumulative voting distance score is computed by cumulating all the voting scores given for each control points at the particular iteration of the warping process. The voting threshold value is adaptively computed for each query image based on the highest computed distance between two iterations.

The warping process is continued until the cumulative change in the position of the control points is equal to or less than a prespecified threshold value. Thus, the computed TCCPCP, TCCCCP and TCVDS are implicitly representing the effort spent throughout the warping process. Upon completion of the warping process, the final similarity parameter, the degree of matching is computed. At this stage, two types of

matching features are computed. The reconstructed NURBS boundary, generated from the final deformed control points, is superimposed on the boundary of the database image. The overlapping points between the two boundaries are detected. The first matching feature is a measure of the closeness of the deformed query image towards the database image, while the second matching feature is a measure of the closeness of the database image towards the deformed query image. The first matching feature is the percentage ratio of the number of overlapping points and the number of database image's boundary points. The second matching feature is the percentage ratio of the number overlapping points and the deformed query image's boundary points.

If only one of the above matching features is considered, the determination of the degree of matching value will be inaccurate because there is a risk that only a part of the deformed query image has completely covered the database image's boundary and vice versa. In our method, the degree of matching value is determined as the combination of these two matching features by computing the average value of the first matching feature and the second matching feature. These four similarity measure parameters introduced in this section, are used to determine the similarity measure.

4 Similarity Measure Determination

The degree of matching indicates the effectiveness of the warping process. The TCCPCP, TCCCCP and TCVDS only have a meaningful value if the warping process effectively warps the query image to the shape of the database image. With this extra similarity measure parameter, degree of matching, only selective TCCPCP, TCCCCP and TCVDS of the database images are considered in the similarity measure determination if their degree of matching value is equal or more than a desired matching threshold value. The three selective similarity measure parameters are normalized. The most similar database image with the query image with has a normalized similarity parameter value of 1.

Human judge similarity at three different levels. These are: coarse level, fine level and complex level. The similarity parameters at these three levels may be referred to as:

- Similarity of Coarseness
- Similarity of Fineness
- Similarity of Complexity

The term complexity refers to the degree to which a variety of shapes such line, curve, convex and concave segments are combined in forming a shape. The similarity parameters: TCVDS, TCCPCP and TCCCCP measure the similarity of coarseness, similarity of fineness and similarity of complexity respectively.

The overall similarity measure is computed by the weighted additions of the normalized similarity parameters as follows:

$$sm = w_1 * TCCPCP + w_2 * TCVDS + w_3 * TCCCCP \quad (1)$$

where w_1 is the weight for the similarity of fineness
 w_2 is the weight for the similarity of coarseness
 w_3 is the weight for the similarity of complexity
 sm is the similarity measure

The choice of the similarity weights depends on the importance of each type of similarity properties for determining the similarity measure. Thus, the choice of the suitable similarity weights depends on the purpose of the retrieval system itself. In our work, all three types of similarity parameters are chosen to play an equal role in the similarity measure determination. We choose $w_1 = w_2 = w_3 = 1$.

5 Experiments Results And Discussion

In this work, two sets of experiments to validate the effectiveness of the proposed method in the shape-based retrieval system. We also compare our retrieval results with the Curvature Scale Space (CSS) retrieval results. CSS is developed by Mokhtarian and Abbasi [8], and has been selected for MPEG-7 standardization.

The first experiment is carried out to investigate the characteristic of each similarity parameters in determining the similarity measure based on human similarity properties. In the experiment, we use six synthesis images as database images. Fig. 2 illustrates the database images D1 to D6 and the D1 is used as a query image, Q1.

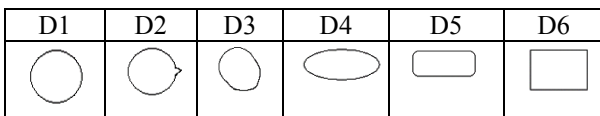


Figure 2: The database has 6 images (D1-D6) and D1 is selected as a query image, Q1.

D1 is exactly same as Q1. D2 is obtained by adding a small protrusion to D1, to simulate a fine change. D1 is altered in its shape by 50% to simulate a partial coarse change in the shape of D3. D4, D5 and D6 are arbitrarily selected geometrical shapes. Q1 is put through the NURBS-Warping process to match with the database images, D1 to D6 and 6 sets of similarity parameters: TCCPCP, TCVDS and TCCCCP are computed. Based on the values of these parameters, the retrieved database images are illustrated in Fig. 3 with the highest ranked image displayed close to the query image and the lower ranked images are displayed further from the query image.

With TCCPCP as the similarity parameter, image D2 is ranked higher than D3, illustrating that this parameter is capable of taking into consideration the fine details. Where as, TCVDS has ranked D3 higher than D2. This indicates that TCVDS focuses on the coarse detail rather than fine detail. From the results shown using TCCCCP, it may be seen that the database images are ranked accordingly as the difference in the complexity between the database images to the query image increases. The final ranked database image is the most complex among all the database images to the query image because its shape contains mixture of straight lines and curves. Thus, the TCCCCP is capable of measuring similarity between two images based on the complexity.

D1	D2	D3	D4	D5	D6
TCCPCP					
D1	D3	D2	D4	D6	D5
TCVDS					
D1	D4	D3	D2	D5	D6
TCCCCP					

Figure 3: The retrieved images based on the TCCPCP, TCVDS and TCCCCP respectively.

Therefore, it may conclude that TCCPCP represents the similarity of fineness, the TCVDS represents the similarity of coarseness and the TCCCCP represents the similarity of complexity.

The second set of experiments is aimed at proving that the similarity measure computed from these three similarity parameters is capable to retrieve a set of database images based on the human similarity judgement. In these experiments, a collection of 1100 highly similar silhouette images is used, which is the fish database. The query images are selected from the database itself. The query image is superimposed on the database image, and the normalized NURBS control points are adjusted toward the database image under the attraction of GVF force generated from the boundary of the database image itself. The warping process is continued until the cumulative change in the positions of the control points is equal to or less than a prespecified threshold value. The prespecified threshold value used here is 5 units. At the end of the warping process, the TCCPCP, TCVDS, TCCCCP and degree of matching are computed. The above experimental process is repeated for each database image. As explained previously, the similarity measure is meaningful only if the query image effectively warps towards the database image, in which the degree of matching indicates the effectiveness of this warping

process. Thus, in our experiments, only if the degree of matching is equal to or more than 70, the similarity parameters: TCCCP, TCVDS and TCCCP are used to further compute the similarity measure.

During retrieval, the similarity measure for each database image is computed based on the Eq. 1. The relevant images are retrieved from the database if their similarity measures are equal to or more than a similarity threshold value. In these experiments, the desired similarity threshold value used is 0.75. The most similar database image to the query image will have a similarity measure equal to 1, and the similarity measure is decreases as the order of ranking decreases. Finally, the effectiveness and accuracy of the retrieval system based on the computed similarity measure is validated by comparing our retrieval results with the results obtained from the CSS method.

In this paper, we only show two sets of retrieval results. The retrieval results for these two query images using the NURBS-Warping method are displayed in Figs. 4(a) and 5(a). Figs. 4(b) and 5(b) illustrate the retrieval results, using the CSS method. The image shown on top left corner of each figure is the query image, its similarity measure is 1. For the CSS method, no similarity measures are recorded because their similarity computation process is different and cannot be compared directly with our similarity measure. In each figure, the first 15 retrieved images, with decreasing order of similarity measure, are shown.


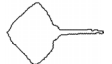








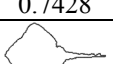
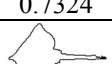

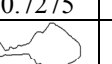
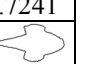
				
1	0.8179	0.8084	0.7552	0.7496
				
0.7428	0.7324	0.7318	0.7275	0.7241
				
0.7191	0.7163	0.7148	0.7146	0.7140

Figure 4(a): The search results of the first query image using NURBS-Warping method.


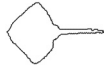






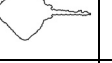






				
				
				

Figure 4(b): The search results of the first query image using CSS method.





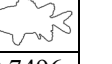




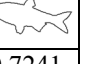




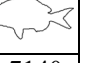
				
1	0.8179	0.8084	0.7552	0.7496
				
0.7428	0.7324	0.7318	0.7275	0.7241
				
0.7191	0.7163	0.7148	0.7146	0.7140

Figure 5(a): The search results of the second query image using NURBS-Warping method.











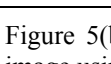
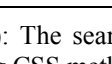
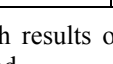
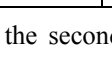
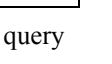
				
				
				

Figure 5(b): The search results of the second query image using CSS method.

From these results, it is seen that both the NURBS-Warping and CSS methods are equally capable of retrieving relevant images from the database at the coarse level. The retrieval results in Fig. 4(a) shows that all the first 15 retrieved database images are very similar to the query image. In this, the database images at the top 10 ranking are very similar to the query image by having shape structure similar to the shape of the query image. This can be seen from the retrieval results that having a straight long tail and a flat body. However, from the results illustrated in Fig. 4(b), do not comply with the human judgement as those in Fig. 4(a).

The NURBS-Warping method outperforms CSS method if the similarity between the database image and the query image are compared in fine detail. Comparison at fine level is an important property, if the shape of the query image is complex. This is illustrated through the results in Fig. 5. In Fig. 5(a), the top 5 retrieved database images have a very rough top fins that are similar to the query image whereas the top 5 retrieval results in Fig. 5(b) do not have such feature. NURBS-Warping method reflected similarity of shapes very accurately although the images contain in the database are very similar to each other. Therefore, it may be concluded that the NURBS-Warping is capable of performing coarse as well as fine similarity matching simultaneously.

6 Conclusion And Future Work

A comprehensive shape-based image retrieval system for highly similar database is presented. From the results presented in Section 5, it is clear that NURBS-Warping method is a powerful technique in deriving similarity measure that closely resembles the human similarity judgement. NURBS-Warping method has the

ability to warp the query image to complex database images, effectively. Similarity matching procedure introduced here may be tuned to the desired level of importance to coarse or fine detail as required by the purpose of the retrieval system. Our future work involves exploiting the ability of NURBS-Warping method, to focus on fine detail in medical image analysis.

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