PIXEL BY PIXEL SKELETONIZATION AND PRUNING USING GROUPWISE MEDIAL AXIS TRANSFORM

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ABSTRACT

Medial Axis Transform (MAT) is one of the promising tools used for the shape recognition and it poses the advantages like space and complexity reduction, ease of processing for shape recognition. MAT representation of shapes uses object centred co-ordinate system that represents bending, elongation and thickness. But MAT of the objects is very much sensitive to small perturbations of its boundary. To overcome this problem, we prune the particular portion. In our approach, we use local or global pruning for branch significance computation. For this we use group-wise approach in which we develop a group-wise skeletonization framework that gives fuzzy significance for each branch. This is called as Groupwise Medial Axis Transform (G-MAT). This approach has several applications like shape analysis and shape recognition. This approach has been tested on various geometries of the shapes and gives good recognition results.

KEYWORDS: *Medial Axis Transform, skeletonization, Groupwise Medial Axis Transform*

I. INTRODUCTION

For shape recognition we use skeleton as a shape descriptor. The method of obtaining skeleton from image is called as skeletonization. Skeleton of an object can be achieved by methods like: Medial Axis Transform (MAT), Grassfire algorithm, Shock Graph and Voronoi diagram. But MAT is less sensitive to noise, boundary deformation and also less time consuming than other three above methods.

1.1 Medial Axis Transform (MAT)

MAT represents shapes by set of centre pixels that are present inside the shape. The phenomenon of MAT is given by Blum in 1967. The important characteristics of the skeleton obtained by MAT are as follows:

1) The connectivity of derived skeleton should not vary as far as original shape is concerned.
2) The skeleton of that particular shape can be used to reconstruct its original shape.
3) The geometry of the skeleton should not change under the picture rotation.

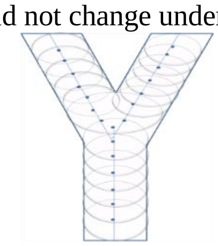


Figure 1: Skeleton of 'Y' alphabet obtained by MAT

In this paper, we propose a framework called Groupwise Medial Axis Transform (G-MAT) for pruning of skeleton. The G-MAT eliminates branches that are raised because of noise. The G-MAT is based on branch significance or confidence value provided by group of shapes. The G-MAT procedure includes MAT of each shape within the group. Then skeleton junction points are located for separating skeleton into separate branches. This is followed by calculation of a set of topological and geometrical features for each branch, which are used for calculating confidence value for each branch.

1.2 Skeleton Pruning

Pruning is nothing but technique to remove unwanted portion of the shape. As the skeleton is sensitive to noise and boundary deformations, it is difficult to obtain ideal skeletons during shape recognition. To solve this problem, skeleton pruning is used. Pruning can be classified as local, which uses information from neighbourhood surrounding of each branch or global, which uses information of whole shape of object.

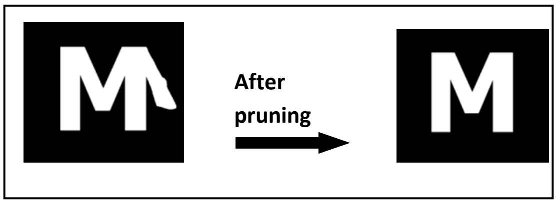


Figure 2: Pruning Result

This paper includes the methods of calculating confidence value, working algorithm for creating and evaluating database and applying MAT. It is followed by experimentation, results and discussion, applications, future work and conclusion.

II. RELATED WORK

Although there has been quite extensive work in the area of shape representation and matching, shape recognition is still an open research issue[2]. With the time, many shape-matching approaches have emerged, but high space, time complexity and moderate recognition rate are still the limiting factors for their widespread acceptance as well as popularity. Sebastian et al. [4] use the full classification of the shock graph (MA endowed with a finer classification based on dynamics of flow) [5].

The shape recognition technique has to be robust to visual transformations like articulation and deformation of parts, viewpoint variation and occlusion. Thus, the shape representation has to effectively capture the variations in shape due to these transformations. In previous recognition applications, shapes have been represented as curves [6,7], point sets or feature sets, and by medial axis [8,9,10,11,12], among others. 2D shape matching is achieved using hierarchical tree structure extracted from shock graph that in turn extracted from the skeleton of the shape of interest. It attempts to decompose a shape into a set of parts. [15] matches skeleton graphs by comparing the geodesic paths between skeleton endpoints. In contrast to typical tree or graph matching methods, it does not consider the topological graph structure. The proposed comparison of geodesic paths between endpoints of skeleton graphs yields correct matching results. This method is able to produce correct results in the presence of articulations, stretching, and contour deformations. But the performance of this method is limited in the presence of large protrusions, since they require skipping a large number of skeleton endpoints.

In [17], an algorithm is presented for identifying and representing the ligature structure, and restoring the non-ligature structures that remain. This leads to a bone graph, a new medial shape abstraction that captures a more intuitive notion of objects allies parts than a skeleton or a shock graph. It offers improved stability and within-class deformation invariance. In [22], some critical points on skeleton of silhouette are used for recognition and classification of human body movement and uses MLP with back-propagation for recognition of movement. But it does not focus the stability issues under articulation and deformation.

[21] proposes the G-MAT(Group-wise Medial Axis Transform), which is a groupwise skeletonization framework that yields a fuzzy significance measure for each branch, derived from information provided by the group of shapes for the determination of the pruning order of skeleton branches, using geometric and topological branch feature information provided by the group as a whole. Although the geometric and topological branch features used in this paper provided superior performance, there remain substantial opportunities for improvement using more sophisticated, pose-invariant features. Also, the algorithm is confined to few shapes. [13] discusses skeletonization method for the skeleton feature points extracted from human body based on silhouette images which uses gradient of distance transform to detect critical points inside the foreground. Then, it converge

and simplify critical points in order to generate the most important and elegant skeleton feature points and finally, presents an algorithm which connects the skeleton feature points and estimates the position of skeleton joints. But the results are unsatisfied and even encounter some mistakes when the joints are hidden or kept out. That is because this approach uses the uniform scales of the human body parts to determine the position of the inner joints such as elbow and knee joints, there might cause some errors between the scales of the different bodies.

In [14], Skeleton of silhouette is being used for recognition and classification of human body movement and MLP with back-propagation is being used for recognition of movement. It resulted average recognition rate of 92 %. But, it does not focus the stability issues under articulation and deformation.

III. METHODS

The given method is iterative and with each iteration, a single branch is pruned from the entire group. The selection of branch is done according to optimum value of objective function. This requires calculation of groupwise confidence value for every branch, which is calculated using G-MAT.

We calculate these confidence values using G-MAT. Greater confidence value of specific branch shows that branch indicate signal rather than noise. This confidence value depends on four parameters:

1. Confidence value based on Description Length (DL)
2. Confidence value based on Model Variance (MV)
3. Confidence value based on Corresponding Branch Similarity (CBS)
4. Confidence value based on Overall Branch Similarity (OBS)

3.1 Confidence value based on Description Length (DL)

The DL of medial shape is used to measure the compactness of shape. The branches that decreases DL by more proportion defers from the entire group and thus decreases the confidence value.

$$\gamma DL(b_{ij}) = \frac{-(DL - DL_{ij}) - \gamma_{min}}{\gamma_{max} - \gamma_{min}}$$

Where, DL is the description length of the shape including b_{ij}, DL_{ij} is the description length of the shape with b_{ij} removed, and γ_{min} , γ_{max} are the smallest and largest unnormalized confidence values found in the group of skeletons.

3.2 Confidence value based on Model Variance (MV)

Here we calculate the contribution of each branch in each skeleton by which the total variance of medial shape calculated from the group of skeletons. Higher confidence values are assigned to branches that make small contribution to model variance as these branches are similar to the other branches in the model.

$$\gamma MV(b_{ij}) \cong -\frac{\sigma_{ij^{\pi}}}{\sigma_{j^{\pi}}} \beth_{j^{\pi}}$$

Where, $\sigma_{ij^{\pi}}$ is the feature difference of b_{ij} from the mean of the features of b_{ij} and from its corresponding branches, $\sigma_{j^{\pi}}$ is the feature variance of b_{ij} and from its corresponding branches, and $\beth_{j^{\pi}}$ is the contribution of b_{ij} and from its corresponding branches to the total variance in the medial shape.

3.3 Confidence value based on Corresponding Branch Similarity (CBS)

To obtain these confidence values we firstly calculate an error value for every branch that shows mismatch between that particular branch features with features of all other branches. Then confidence value for all skeleton loci is obtained as,

$$\gamma CBS(\,b_{ij}) = 1 - \frac{\epsilon_{ij}\,(\pi, F)}{(n_s - 1)n_f}$$

The denominator $(n_s - 1) \times n_f$ represents the normalize confidence values with maximum possible error that can be observed on a given branch.

3.4 Confidence value based on Overall Branch Similarity (OBS)

This is similar to CBS but here we compute Overall Branch Dissimilarity of the group of skeletons.

Now we pruned the branch and obtained new set of branch features to compute the confidence value for a branch as,

$$\gamma OBS(b_{ij}) = \frac{-(E - E_{ij}) - \gamma_{min}}{\gamma_{max} - \gamma_{min}}$$

IV. WORKING PROCEDURE

4.1 Create Database

In this project, to evaluate we required database from which we can evaluate the results. For that firstly we create our database which is divided in two parts: Black & White Image with its medial axis transforms i.e. MAT.

Steps to Create Database:

- Load the Database
- In case of database is not available create new one
- Read original image & convert it into Black & White image
- Resize the image in order to get uniform image
- Call user defined function **apply MAT**
- Check if the database is empty or not
- If database is not empty increase database count by 1
- Then original image with its MAT image is shown
- Save this database with % record
- After that it will ask what we have to do next
  (i) Add more images in database
  (ii) Clear the whole database
  (iii) Exit

Figure 3: Create Database

4.2 Evaluate Database

In this, we evaluate the result from database which is created by us. After the evaluation it shows the result with maximum matching image.

Steps to Evaluate Database:

- For the evaluation, try to load the database

- Find the size of database
- Pick the image file which we want to evaluate
- Read the image and convert it into Black & White image
- Resize the image
- Apply the **MAT**
- For count 1, find the current skeleton
- Find the difference between skeletons which will created at the time of evaluation with stored database images
- Now find the foreground difference
- So matched image mark as current minimum
- Compare if the other skeleton image is less
- The name it as maximum match found with image number. This will appear in command window of MATLAB
- Then that image title as " Image with maximum match"

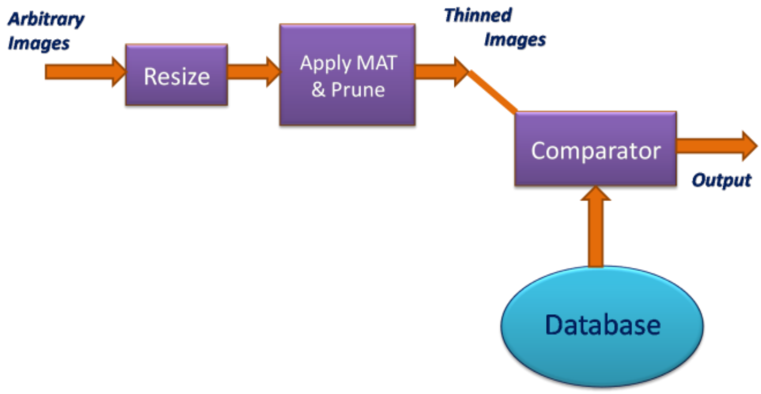


Figure 4: Evaluate Database

4.3 Apply MAT

In apply MAT, we using the one special developed algorithm which convert the given image into its Medial Axis Transform means skeleton. This algorithm is used in both Create Database and Evaluate Database.

Steps to Apply MAT:

- Apply MAT algorithm to input Black & White image
- Check the input image is in logical form (0 & 1) else convert it
- Then construct the circles considering the center of image surface
- Declare an array for storing indices of the circles radius
- Find the cumulative sum of the indices
- Generate the Hull Surface (the circles on the surface of the image)
- Remove the vertices which are out of the object or which does not forms a boundary. That vertices are pruned by pruning algorithm
- Check if the elements belongs to the array
- Build distance table of that image i.e. distance between centers of the circles
- Trim the image by joining the circles
- Keep only the required distances i.e. remove the other surfaces from the image
- Store the vertices and the skeleton of the image
- Check for the places, where a White pixels can be inserted hence insert the white pixel there by checking conditions
- Check the output vertices

Then thinned skeleton is obtained which is further stored in database at the time of creation and evaluate at the time of evaluation.

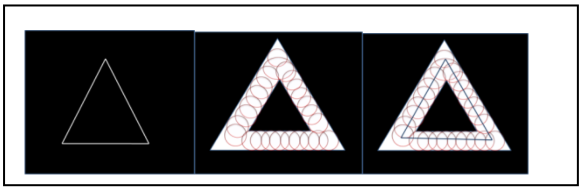
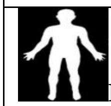
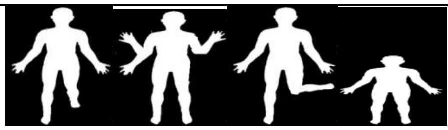
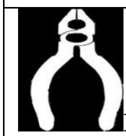
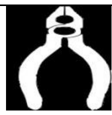
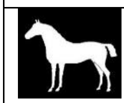
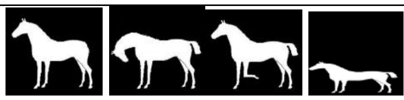
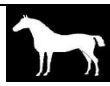
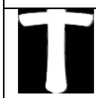
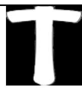
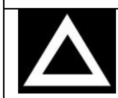
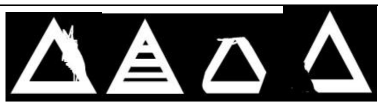
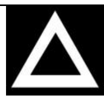


Figure 5: MAT Formation

V. EXPERIMENTATION

Firstly we take any shape, alphabet, etc. on that we apply our algorithm i.e. Create database which also include MAT Algorithm by which we obtained original image with its medial axis transform image further its stored in database as percent records.
At the time of evaluation we take any arbitrary image and apply Evaluate database algorithm which also includes MAT algorithm. After that in result we get image with maximum match. We have used MatLab (Version 7.3) for the simulation.

Table: 1 The Result Analysis table of various shapes

Image saved in Database	**Query Images**	**Object with Max. Match**
 **Human Shape**		
 **Mechanical Tool (Plier)**		
 **Alphabet "M"**		
 **Animal Shape (Horse)**		
 **Mechanical Tool (Hammer)**		
 **Triangular Shape**		

VI. RESULT AND DISCUSSION

The above result table shows that when query images containing noise, small boundary perturbations etc. are compared with image saved in database, if there exists a real matching on the basis of confidence value then we get that saved image from database with maximum match as an output. This method gives good result almost for all types of geometrical shapes including human posture, mechanical objects, alphabets and animal silhouette. It is efficiently able to find the best match for the set of deformed input shapes.

VII. APPLICATIONS AND FUTURE WORK

The G-MAT has its applications in the fields like 2D shape recognition, Pattern recognition, Biological part matching, Computer graphics, Geographic information systems, Robotics and Atomized Industrial inspection.The proposed approach is quite efficient for various geometrical shapes. But it has time and computational complexity because of multiple stages of algorithmic costs. The future direction for the extension of this work is to apply it for 3-D objects. There, it may require a different approach for splitting of 3-D skeleton in to its components. Also, the medical images and diagnostics is still an open area.

VIII. CONCLUSION

In this paper, we proposed the G-MAT method which is very much effective approach for pruning using topological and geometrical branch features provided by the group as a whole. The groupwise approach is third method for branch pruning in addition to the local and global approaches. This approach depends upon four parameters Description Length, Modal Variance, Corresponding Branch Similarity and Overall Branch Similarity. This approach is very much effective for the removal of noisy skeleton branches, classification of noise skeleton and providing skeletons that are similar for similar object. We also demonstrated results for various shapes of objects.

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