Geon Based Shape Approximation from the Edge Detected Image

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Abstract— In human mind the object models are composed of parts and that the first stage of spatial reasoning is primarily concerned with extraction of such parts from an image. Shape is an important visual feature of an image. The identification of shapes from the edge detected images is one of the promising stages in the object perception. Extraction of shapes from the edge detected images mainly using its pixel coordinates in an unsupervised manner is the challenging one. Geons are a finite set of distinct volumetric shapes, which are used to describe the shapes of, objects parts. Shape Approximation emulates the process involved in human brain, which is the approximation of geons in an unsupervised manner by performing edge gradient and positional analysis, to synthesize input information into primitive shapes along with its positional details.

Keywords— Geons (geometrical ions), Gradient, JIM (John and Irv's) model, pixel coordinates, RBC (recognition by component), SOM (Self Organizing Maps), Striated cortex

INTRODUCTION

Human visual system is a powerful, complex and highly efficient processing system which gives the humans the ability to see physical environment. The human visual system can be regarded as two important sections. Retina mediates only the initial steps in processing visual information. Most of the visual processing occurs in the cortex of the human brain. Among many functions of human vision, object recognition is arguably one of the most crucial. Human object recognition is invariant with viewpoint. Human recognition performance reflects the activation of a viewpoint invariant structural description specifying both the visual attributes of an object and the relations among them. In the striated cortex, the objects are mainly processed as components and the visual representation of these basic components are matched with the structural description in the memory. Humans can use many ways to recognize an object. Shape is an important visual feature and it is one of the basic features used to describe the image content. The idea behind shape approximation is to extract the various shapes forming an object from the edge detected image preserving the salient characteristics of the input image. The basic shapes can be estimated mainly in two ways such as supervised manner and unsupervised manner. In supervised shape approximation, the shapes are approximated by comparing shapes with some registered shape templates. In unsupervised shape approximation, shapes are approximated based on the shape similarity. Objects are mainly identified by their edges. These edges of an image could be straight lines, curved lines or other basic geometric shapes. The main problem in the shape approximation is the fitting of basic shapes in the edge detected binary image. The idea behind shape approximation is to extract the various shapes forming an object from the edge detected image preserving the salient characteristics of the input image. By Biederman's recognition-by-component (RBC) theory shapes can be represented using geons. The fundamental assumption of the theory is that a set of generalized-cone components, called geons, can be obtained from contrasts of five readily detectable properties of edges in a two-dimensional image: curvature, co-linearity, symmetry, parallelism and co-termination. The detection of this property is generally invariant over viewing position and image quality and consequently allows robust object perception. If an arrangement of two or three geons can be detected from an input, object can be quickly recognized even when they are occluded, novel, rotated in depth, or degraded. These geons are viewpoint invariant in nature. Biederman's introduction of geons to the vision community has spawned considerable interest in building geon based vision systems which will approximate the shapes of object parts, by a set of primitive volumetric models[1]. The project aims at identification of primitive parametric geons and their relative positional details from the feature extracted information for the identification of the object in an unsupervised manner. Based on the objective some of the relevant papers went through for shape approximations are explained below:

LITERATURE SURVEY

Hummel J et al (1992) presented a neural network implementation of the Biedermann's RBC theory that reflects the activation of a viewpoint-invariant structural description specifying the object's parts and the relations among them [2]. A neural net architecture that is JIM model is shown below which a 7 layer network. The JIM model layers one by one are discussed in detail. The 1st to 5th layer of the model will do the feature extraction, both structural and relational. The 6th layer of JIM model will give the details of various shapes involved in the object formation and their relational description. This can be further used for recognition process. The 7th layer will combine these cells and recognize the object.

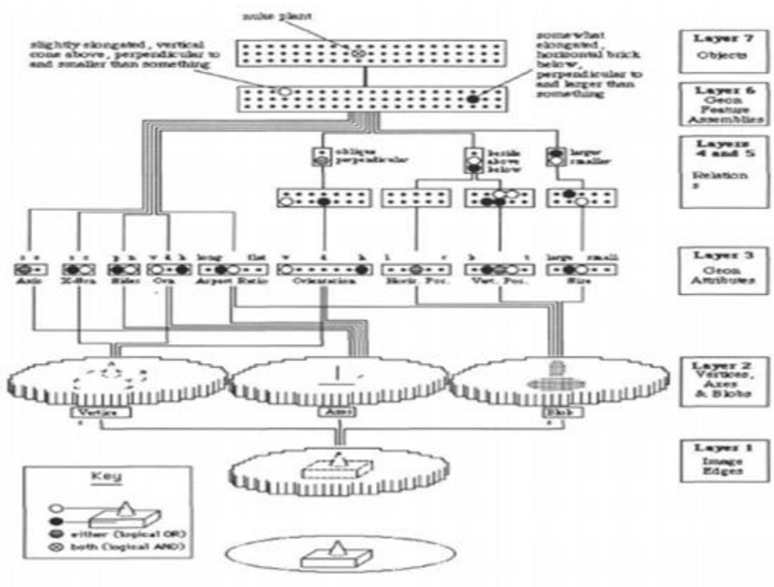

Figure1- Neural net model for object recognition. [From Hummel & Biederman (1992)]

A shape based object recognition using artificial neural network was developed by Vries J (2005), which talks about the human object recognition, recognition by components and the neural network methods [6]. The system mainly consists of two parts: - combination creation and object classification network. The neural network used is the SOM. The paper also shows various tests done on this system and their results.

Bilodeau G et al (2007) proposed a qualitative, volumetric part-based model to improve the categorical invariance and viewpoint invariance in content-based image retrieval, and also a novel two-step part-categorization method is presented to build it [8]. The method consists first in transforming parts extracted from a segmented contour primitive map and then categorizing the transformed parts using interpretation rules.

Zhang D et al (2004) introduced Review of shape representation and description techniques and generally classified these techniques into two classes of methods: contour-based methods and region-based methods [5]. They also beautifully explained the advantages and disadvantages of both methods

Bilodeau G et al (2001) proposed a method to hypothesize the volumetric primitives from object parts [4]. A combination of the concepts from the two existing approaches, a model fitting and a rule based approach is presented. Certain rules have been created for 18 volumetric primitives differentiated by axis type, sweeping rule type and section type. The steps are explained below:

- Part contours are simplified to one of a finite number of spatial constant curvature primitives
- Fuzzy classifer studies the contour of simplified parts and generates multiple hypotheses of volumetric primitives for each part.

Based on this primitive shapes can be identified.

Yu X et al (2011) extended their work on a novel approach for extracting 2D geons from 2D images and also define a finite 2D geon set based on the parametric representation of 3D geons [10]. The process is composed of three major parts:

- image pre-processing which includes image background removal and segmentation
- arc-geon detection
- Polygon-geon detection.

And also proposed a general procedure for matching the extracted 2D geons to given models for object recognition.

Xing W et al (2012) presented part based structural description of 3D objects, which combines the geometric features of individual parts with topological connections among them [12]. They described and extracted the geometric features of individual parts and topological connections among them. They classified geons according to four qualitative geometrical attributes: axis shape, cross-section edge shape, cross-section size sweeping function, and cross-section symmetry. These attributes provide distinct shape characteristics useful for symbolic object recognition.

Daghameen K et al (2007) presented an efficient algorithm for line recognition using integer arithmetic [7]. An algorithm to find the properties of a line using the properties of those actual straight line segments that form a line is presented. The main advantage of the algorithm is its simplicity and robustness. The algorithm can detect any line that is continuous in the plane.

Chen W et al (2010) presented a fast geometry figure recognition algorithm based on edge pixel point Eigen values [9]. A proposed new algorithm, which can recognize the closed geometry figures such as polygon, circle and ellipse has been explained. The problem they pointed out with this algorithm is that the figure other than polygon, circle or ellipse will not suit the algorithm best.

Rotaru F et al (2011) proposed a 2D polygon recognition method [11]. First, adaptive convex polygonal vertex detection is applied and then a polygonal fitting algorithm using as input the two vertices and the object contour provides a precise object identification and description. The algorithm is suitable for robot vision, quality control or photogrammetric applications when the image objects to be processed have polygonal shapes. A software environment was designed to test and use the proposed method, to evaluate its speed and accuracy. This technique is a synthesis of a general method to recognize any kind of polygonal shape on any kind of images.

Literature study showed that, if there are any discontinuities in the edge detected image it will be difficult to fit the geons into the image that is RBC theory does not attempt to provide mechanism to reduce the complexities of real scenes to simple geon shapes. And also around 36 geons along with its combinations should be stored in the memory. The other method of which is Eigen value analysis was found to more or less satisfy the project objective, but the limitation of this method is that it is apt only for some primitive shapes. So by modifying this approach and after carrying out simulation edge gradient analysis is found to be more suitable for shape approximation. The concept of SOM obtained from literature survey has also helped in obtaining the primitive shape codes.

METHODOLOGY

The input taken is the contour and high curvature point information of an edge detected image, which is in the form of pixel coordinates. On this information a gradient and positional analysis is performed. Based on the rules corresponding to primitive shapes a neural network gets trained. The trained output is compared with the analyzed output and the compared output gives the approximated geons which can be represented in the form of codes. The proposed block diagram is shown below:

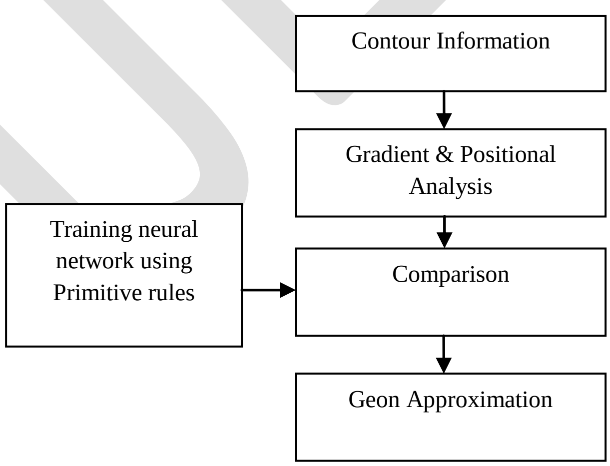

Figure 2 – Block Diagram of Shape Approximation

Contour information

The input is the contour information of an object which is in the form of pixel coordinates. The pixel coordinates of the 2D shapes are considered as the input.

Gradient & Positional Analysis

From the contour and the high curvature point information, an edge gradient analysis is performed.

The steps for an Edge Gradient analysis are as follows:

M(i,1)=A3X(i+1,1)-A3X(i,1) (1)

n1(i,1)=A3Y(i+1,1)-A3Y(i,1) (2)

Gradient (k,1)=n1(k)/M(k) (3)

Angle= $\tan^{-1}(\frac{n1(k)}{M(k)})$ (4)

From the first equation we get the gradient for x pixel coordinates, in the second equation the gradient for y pixel coordinate is calculated. A total gradient or slope is obtained from the third equation. And an angle is calculated from the pixel coordinates which provides the direction of the pixel values. This analysis provides all necessary information for synthesis of primitive shapes.

For the identification of an object, shapes as well as its relative position are critical. From the input which is the contour and high curvature point information, a positional analysis is also performed for finding the relative positions of the primitive shapes. This generates the positional parameters of the primitive analyzed, based on centre, its extend, etc.

Neural network

The neural network which finds best apt for comparing in an unsupervised manner is found to be SOM.

Self Organizing Maps (SOM) is a type of neural network [3]. The network is called "Self Organizing" because it does not require supervision or human intervention. The network learns its own through unsupervised competitive learning. During training the neural networks receives a number of different input patterns, study the significant features in these patterns and learns how to classify input data into appropriate categories. Unsupervised learning algorithms aim to learn rapidly and can be used in real-time. SOM attempt to map their weights to conform to the given input data. A SOM does not need a target output to be specified unlike many other types of network. The important characteristics of the SOM are:

- There is competitive learning among the neurons of the output layer (i.e. on the presentation of an input pattern only one neuron wins the competition – this is called a winner);
- The neurons are placed in a *lattice structure.*
- The neurons are tuned to various input patterns;
- The network is user friendly

The structure of SOM is shown below:

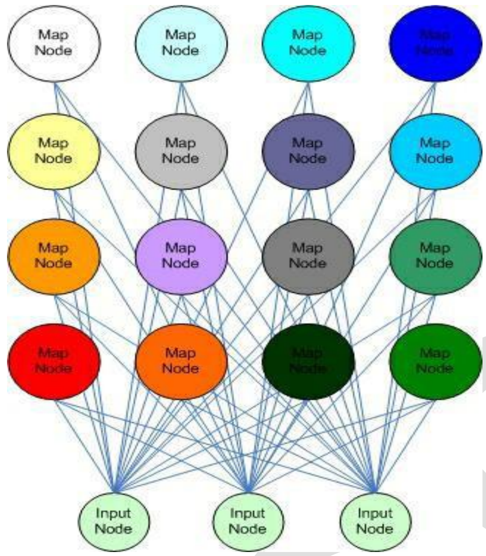

Figure 3- Structure of SOM

The figure shown above is a 4×4 SOM network. Here each map node is connected to each input node. For this node network there are possibly 48 connections. The map nodes are not connected to each other. In this configuration, each map node has a unique (i, j) coordinate. This configuration makes it easy to reference a node in the network, and to calculate the distances between nodes. A map node will only update its' weights based on what the input vector tells it.

The architecture of SOM is shown below:

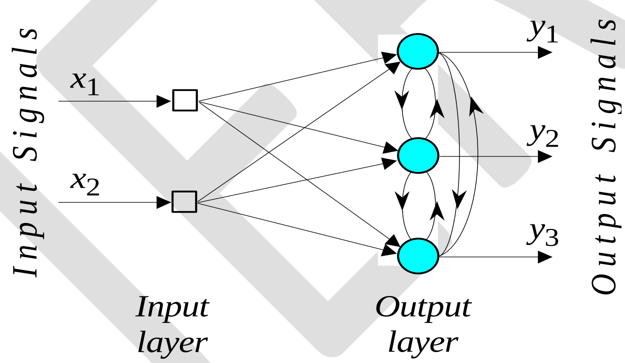

Figure 4 – Architecture of SOM

The lateral connections are used to create a competition between neurons. The neuron with the highest activation level among all neurons in the output layer becomes the winner. This winning neuron is the only one that produces an output signal and all other neurons are suppressed in the competition. Depending on the distance from the winning neuron, the lateral feedback connections can produce both excitatory or inhibitory effects, This is achieved by the use of a Mexican hat function which describes synaptic weights between neurons in the Kohonen layer.

By analysis of the characteristics of the basic shapes, certain rules have been arrived for identifying shapes. Based on these rules the SOM get trained.

Comparison

The trained output based on the primitive rules is compared with the gradient analyzed output that results to shape approximation which is mainly represented as codes for shape and its relative positional details.

SIMULATION RESULTS

Simulations were done in Matlab. For example based on the pixel coordinates of rectangle, two horizontal and two vertical lines along with its relative positional details such as top right, bottom, bottom left, up information is obtained. And certain codes have been assigned to this information. The edge detected image of rectangle is shown in Fig 5 and its corresponding pixel coordinates is shown in Fig 6.

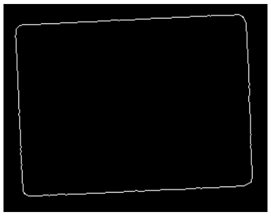

Figure 5- Edge detected image of rectangle

A204

	A	B
1	68	199
2	68	198
3	68	197
4	68	196
5	68	195
6	68	194
7	68	193
8	68	192
9	68	191
10	68	190
11	68	189
12	68	188
13	68	187
14	68	186
15	67	185
16	67	184
17	67	183
18	67	182
19	67	181
20	67	180

G7

A
64
288
392
512

Figure 6- Pixel coordinates and corner breakpoints

The output codes corresponding to rectangle is shown below:

```
Command Window

shape_out =

     1
     2
     1
     2
     0
```

```
Command Window
position =

    11
     8
    14
     7
     0
```

Figure 7- Shape & Position Codes for rectangle

Similarly based on the pixel coordinates, output for other shapes such as square, circle, ellipse etc were also obtained. Differentiation between similar looking shapes like circle and ellipse were carried out by analyzing the values of certain characteristic parameters.

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CONCLUSION

According to the prime requirement, one of the suitable approaches which provide better approximation is to perform a Gradient Analysis. Shape approximation, from the edge detected contour information is successfully obtained by performing edge gradient analysis. It has the advantages as no templates are required and easy realization

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