

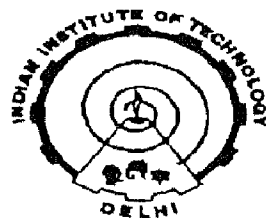
# **RECOGNITION AND SURFACE RECONSTRUCTION OF 3D OBJECTS**

By

**C. RANGAIAH**

A thesis submitted in partial  
fulfillment of the requirements  
for the degree of

**DOCTOR OF PHILOSOPHY**



**Department of Electrical Engineering  
INDIAN INSTITUTE OF TECHNOLOGY, DELHI**

August 1993

*DEDICATED TO*

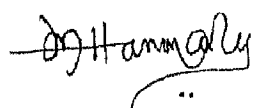
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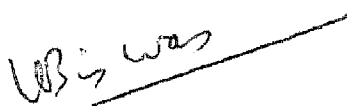
This is to certify that the thesis entitled **RECOGNITION AND SURFACE RECONSTRUCTION OF 3D OBJECTS** submitted by Mr.C.Rangaiah to the Department of Electrical Engineering, Indian Institute of Technology, Delhi for the award of Degree of Doctor of Philosophy is a record of the original bonafide research work carried out by him under our guidance and supervision.

The thesis and any part thereof has not been submitted to any other university /institution for award of any degree or diploma.



**Dr.M.Hanmandlu**

Dept. of Electrical  
Engineering  
I.I.T. Delhi  
New Delhi-110016



**Prof.K.K.Biswas**

Dept. of Computer Science and  
Engineering  
I.I.T. Delhi  
New Delhi-110016

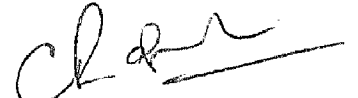
## ACKNOWLEDGEMENT

I express my profound gratitude and sincere thanks to Dr. M. Hanmandlu and Prof. K.K. Biswas for the constant encouragement and guidance during my research work, but for which this thesis would not have attained its current form

I wish to thank administration of Osmania University, particularly Head of the ECE department, for sponsoring me to do Ph.D. under QIP and also thank for providing me partial financial assistance for presenting a paper at International Conference in USA during this research work.

My thanks are due to Mr. K.R. Kaushik who helped me during my research work in AI Lab.

Lastly, I should not fail to thank my wife Mrs. C. Kalavati who looked after the children during my research. I thank all the friends during my stay at IIT, Delhi.



(C. RANGIAH)

## ABSTRACT

The importance of object recognition has been increasing in various fields in view of its vast potential for automating time critical, hazardous, sensitive operations. Depending upon the kind of data available about the object such as intensity data or range data, methods have been developed. For 2D object recognition intensity data is all that is required to process but for 3D object recognition we need to have either range data or a sequence of intensity data derived from multiple views. The problem of evolving a 3D shape from its 2D images is known as "reconstruction" which forms an important ingredient in robotics applications as well as other applications, eg. medical imaging. In this thesis an attempt is made to study some recognition and reconstruction problems using model based methodology. However, the problem of reconstruction of curved surfaces has been formulated differently using a sequence of images.

Coming to the problems tackled, we may mention that in the recognition case we have started with polyhedral 3D object recognition and ended up with 3D curved object recognition utilizing the framework of Faugeras and Hebert [FAUG 1986] which lead to modified formulation for polyhedral object recognition and a new matching technique for the 3D curved object recognition. These two problems aim at identifying the observed surfaces of an object in the form of features in the corresponding known CAD model. An extension of this problem to a general situation wherein an observed object is identified in

stored models of various objects is studied by restricting ourselves to 3D edge data only as against surface data in the above two problems. In this method, outer edges are used for shortlisting the models and the inner edges are used for selecting the final model that is identified with the object by way of minimum least squares error. In this connection a new matching technique has been devised for contour matching of 3D edge points.

In the event of non-availability of range data, the problem of reconstruction of a surface from multiple views gains prominence. Along the lines of model based methods, a model based stereo vision method of [COOP 1988] has been implemented to reconstruct a planar surface. A new method is proposed for reconstruction of a curved surface from extremal contours in multiple views using differential geometry. Though this method is not model-based, it offers several other possibilities such as obtaining structure and motion parameters required in scores of applications such as, military, medical field etc.

The contributions of the thesis thus lie in presenting some new methods and extending to general 3D object recognition and devising entirely new methods for surface reconstruction which can be seen to offer many other solutions for the related problems such as structure from motion and estimation of motion parameters.

## Chapter 1

### INTRODUCTION

The importance of 3D vision is widely recognized in the robotics field because it provides a visual feedback to a robot and inferences obtained from the feedback offer a rich source of information for path planning and manipulation. Incorporation of vision in a robotic set up would also lead to much more flexibility of operation, lower operational cost, increased reliability and performance, and ability to tackle hazardous situations. As a result one can witness a growing interest in the area of visually controlled robot manipulation such as electronic assembling, automated welding, painting etc. 3D vision has entered in a big way into scene analysis, military applications and medical imaging. These applications invariably need part/object identification and sometimes pose (position and orientation) determination both of which have been of great interest to research worker.

As the objects to be identified may lie in any position and in any orientation, identification and pose determination become difficult with 2D (intensity) images of 3D objects. This is borne out of the fact that the depth information is not available from 2D images and the perspective effects are lost when 3D objects are projected on to a image plane. We are thus forced to consider range images obtained either through direct methods, viz., structured lighting or a range finder or through indirect methods, such as stereo and

motion sequences. In the absence of these we may go back to intensity images to reconstruct surfaces of a 3D object.

Recognition is the process of generating awareness of something already known. Computer vision researchers have always strived to achieve human like capabilities for a vision system so that it can sense and analyse the environment around and respond accordingly. One of the fundamental characteristics of a human vision system is to recognize a 3D object from its 2D images and one would like to have this capability for the machine. However, depending on the complexity of a 3D object, one may require multiple images of the same object in different views to be able to recognize it. At this juncture, the need for model-based methods arises as they lessen the requirement of multiple views through knowledge stored in a model. The power of this methodology is a compelling force behind our intention to solve for both the problems of recognition and reconstruction of 3D objects in this thesis. We now briefly describe the salient features of this methodology as means for the solution of problems under consideration.

## **1.1 MODEL BASED APPROACH**

A model based system consists of:

- (i) Model formation
- (ii) Description of objects
- (iii) Matching module

### **1.1.1 Model formation**

The process of generating detailed object information and storing that information is called model formation. Usually, objects are modelled using either view centred (view dependent) representation or object centred (view independent) representation.

A view centred representation of a 3D object comprises a finite set of models where each model describes the object's 2D projection as seen from a particular view point on the view sphere. This representation is taxing at the matching stage and does not yield position information of the object to be recognized in view of intensity images used.

An object centred representation needs surface or volumetric models in 3D case. We are interested to use surface information for two reasons: Firstly, they provide three dimensional cues for surface groupings leading to a volumetric description of objects in the scene. Secondly, using surfaces as the model and data primitives facilitates matching between model and data and also during analysis of situations involving occlusion.

### **1.1.2 Modelling**

A function of modelling in the context of matching is to enumerate the geometric and topological features of an object and organise them in an efficient manner. Models based on geometric properties of visible surfaces or

silhouettes of an object are commonly used to describe the shape of the object. We now see the relative merits of 2D and 3D models. 2D models have the advantage that they can be automatically constructed from a set of prototype objects, one from each possible view point, but they do not provide full 3D description of an object explicitly and their completeness depends on the complexity of the object and the number of positions of view points used. On the other hand, 3D models allow the most general and complete descriptions of objects from an unconstrained view point. These can also be derived directly from a CAD modeller.

### **1.1.3 Description of Objects**

The problems of selecting the geometrical features used to describe an object is integrally related to the problem of model description. The features can be roughly categorized under three heads:

- (i) Global features like perimeter, centroid, curvature and moment of inertia, etc.
- (ii) Local features like line segment, arc segment and corners.
- (iii) Relational features like relative distance and orientation between substructures. We note here that a surface information yields local features whereas a volumetric information yields global features. We are more concerned with the former for the reasons cited above.

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