A Novel CSG Approach for 3D Reconstruction of Helix Using Spiral Sweeps

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Abstract: - Reconstruction of 3D solid models from 2D images has a wide range of important applications like Engineering production and design, character animation and multimedia, and bio medical imaging. Boundary representation (B-Rep) and constructive solid geometry (CSG) are two most widely accepted techniques for 3D modeling. In this paper we have proposed a novel CSG technique by introducing a new type of sweep, "Spiral Sweep". Our technique requires only single view and embeds topological information in basic CSG primitives to reconstruct 3D model of a helix. We have reviewed some very significant approaches emerged typically for engineering industry and compared these approaches with our approach. Our approach addresses the 3D reconstruction of helix in engineering drawings from single view which is not catered yet.

Key-Words: - CSG, 3D reconstruction, B-rep, Spiral sweeps, Helix

1. Introduction

Reconstruction of 3D solid models from 2D images has a wide range of important applications like engineering production and design, character animation and multimedia, and bio medical imaging. Boundary representation (B-Rep) and constructive solid geometry (CSG) are two most widely accepted techniques for 3D modeling. In the following section we will discuss B-Rep approach followed by a discussion on CSG approach in section 3. Section 4 reviews and compares different existing approaches; section 5 being dedicated to our approach, the discussion is concluded at a summary in section 6.

2. Boundary Representation (B-Rep)

A solid model is represented by its bounding surfaces in case of B-Rep [1]. This is just like a volume contained in a set of faces having associated topological information defining the relationship between these faces. B-Rep models can represent a wide range of solid models at the cost of complex data structure and large memory. A face in a B-Rep is a bounding region of a planar, quadratic, toroidal, or spherical surface [2]. This bounding region is represented by a close curve on the surface. Several curves may lie on a face to represent cavities in a solid. Different faces in a B-Rep model should interact with each other only at common vertices such that inscribing the whole solid.

A classification of B-reps as presented in [3] is facetted, elementary, and advanced B-Reps.

Facetted B-Reps: A solid is bounded by planar surfaces. Bounding Curves are points, Planes and Planar polygons.

Elementary B-Reps: A solid is bounded by planar, quadric, and toroidal surfaces. Bounding Curves are lines, conics, and fourth order curves.

Advanced B-Reps: A solid is bounded by planar, quadric, toroidal, and spline surfaces. Bounding curves are spline curves.

B-Rep models contain geometric as well as topological information. The geometric information comprises of face and edge equations and vertex coordinates while topological information contains the relationship of these components.

3. Constructive Solid Geometry (CSG)

CSG [4] is basically a 3D geometric representation of solids. Some basic primitives or shapes and Boolean operations (Union, Intersection, Difference) are used to construct a CSG solid. These CSG solids are represented in the form of binary trees with basic primitives at leaves and Boolean operations at parent nodes.

Basic primitive shapes may be rectangle, triangle, cuboid, cylinder, cone, sphere, and toroid. CSG representations always produced either a solid or an empty set. Different algorithms for CSG representation execute on the basis of recursive bottom up parsing [5] of CSG tree. Missing topological information is a main problem in CSG approaches. Merging a B-Rep model with CSG model may solve the issue.

4. Existing Approaches

Different 3D reconstruction techniques have evolved in the past, almost all based on B-Rep and / or CSG. The approach adopted by Markowsky and Wesley [6] handles only rectilinear objects and is one of very basic and early techniques. Planar faces are collected by determining cycles of vertices. Afterwards virtual faces are generated followed by virtual block formation of the solid model. The approach is using B-Reps. Some basic terminologies and definitions are also formulated by the authors. In an extension [7] the authors have enhanced their approach to handle 2D projections of polyhedral objects with hidden lines.

B-Rep based approach of Gong et al. [8] reconstructs solids by recognizing quadric faces in drawing views. Their approach can handle higher order curves above conic sections, too. This is an efficient approach as all the quadric surfaces along the bounding edges are retrieved in a single pass. Their algorithm is limited to perfect line drawings.

Zhang and Bowyer [9] devised a CSG based technique to represent curved as well as straight objects. The approach can also recognize fillets and is capable of handling conic and blended surfaces. The approach requires user interaction to control boundary and extension of a blend surface. The versatility of the algorithm is the generation of CNC instructions as output.

Kargas et al. [10] have employed a technique to develop 3D solid models from 2D orthographic engineering views using the concept of a hypothetical cuboid. This CSG technique can handle both curved and planar objects, however it requires user interaction.

Translational and rotational sweeps can be used for 3D Reconstruction of solids. Translational sweeps require one 3D point and an extrusion vector. Such sweeps are good for uniform objects. Pyramids, cones, and truncated cones can not be modeled using translational sweeps. On the other hand such types of objects can best be modeled with the help of rotational sweeps. One 3D line and an angle of rotation are sufficient to execute a rotational sweep.

The technique of Soni and Gurumoorthy [11] is unique in a sense that they have employed rotational sweeps for the construction of solid models. They also have introduced new sweep elements such as cones, torroids, and spheres. Cicek and Gulesin [12] have extended the approach of Soni and Gurumoorthy [11] by inclusion of rotational as well as translational sweeps in their approach. They have devised a two stage process for 3D reconstruction of solid models. First stage is responsible for modeling of geometric entities to sweep on individual views. While the other stage associates these individual views into a 3D feature. The approach of Lee and Han [13] is based on hint based search followed by sweep operations on the searched entities.

Table 1. Comparison of Existing 3D Reconstruction Techniques with our Technique

Parameter / Approach		Our Approach	[6]	[7]	[8]	[9]	[10]	[11	[12]	[13]	[14]	[15]
B-Rep			√	√	√							
CSG		√				√	√	√	√	√	√	
Sweep	Translational								√		√	
	Rotational							√	√	√		
	Spiral	√										
Hybrid												√

Dimri and Gurumoorthy [14] have addressed new problem of handling cross-sectional views in an engineering drawing. Although all type of sections are not handled but still the approach is a remarkable contribution. Their approach is limited to DXF inputs only.

A very crucial research area in 3D reconstruction is to bridge the gap between B-Rep and CSG approaches. The problem is: while converting a B-Rep into a CSG, the uniqueness of the result is not guaranteed. Brenner [15] has addressed this issue and has introduced weak CSG primitives. Brenner's weak CSG primitives are different from conventional CSG primitives as the constraints are not implicit to CSG primitives; instead associated equations dictate these constraints. Brenner has combined the advantages of both B-Rep and CSG in his weak CSG primitive technique.

5. Our Approach

In this approach we have introduced a new sweep "Spiral Sweep" which is a hybrid of translational and rotational sweeps. Spiral sweep is best suited for 3D reconstruction of helix along a cylinder. Threaded bolts and screws can be modeled through this approach. Another contribution is that we have embedded topological information in our CSG entities. Figure 1 depicts the phases involved in our approach. Novelty of our approach is that it requires only single view. All the topological information for spiral sweep is gathered from single view. In our sweep model rotational sweep is dictated by Y and translational sweep is dictated by X. The diameter of sphere used as a basic primitive in our approach is R. While reconstructing 3D model of helix, syntax directed tree parsing is used. Existing approaches use simple bottom up binary tree parsing for Boolean operations while we have used syntax directed parsing for Boolean operations as topological information is implicit to basic CSG primitives.

6. Summary

In this paper we have proposed a new technique based upon spiral sweeps to generate 3D model of a helix. Another distinction of our approach is that it embeds topological information in basic CSG primitives and requires only single view. We have compared our approach amongst different existing cutting edge methods of 3D reconstruction of solid models on the basis of technique used (B-Rep, CSG, Hybrid) and type of sweeps incorporated. The comparison is shown in Table 1. 3D modeling techniques, Boundary Representation and Constructive Solid Geometry are also elaborated in brief.

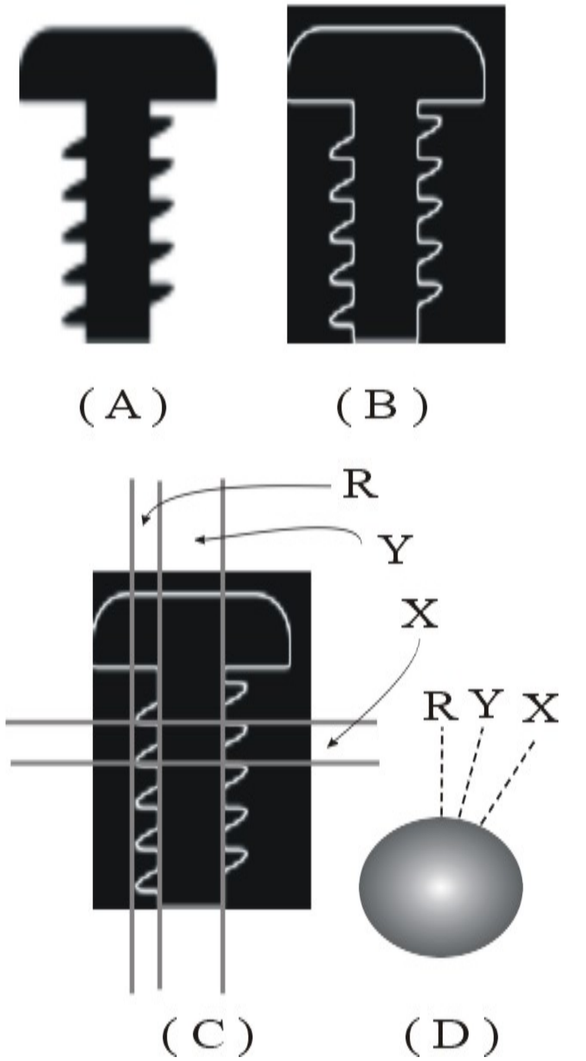

Fig. 1. Sample Execution of our Approach (A) An Object with Helix, (B) Boundary Trace of the Helix, (C) Determination of Helix in Terms of R, X and Y Parameters, (D) Basic CSG Primitive with Topological Information

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