An Implementation of Halfedge Data Structure in Catmull-Clark Subdivision for 2-Manifold Single-sided Surface

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1 Introduction

Catmull-Clark Subdivision is a

2 Halfedge Data Structure

An object in 3D Euclid space can be represented by multiple meshes of polygons. A mesh comprises three types of geometry element: vertex, edge, and face. The adjacency structure stores the topological information (adjacency and connectivity) of the mesh. The author chose halfedge data structure as the adjacency structure in this project to realize Catmull-Clark subdivision.

2.1 Vertex, Halfedge, and Face

The definitions and assumptions of vertex, halfedge and face are shown in Table **??**. A quadrilateral face made with four halfedges is shown in Figure **??**.

	Definition	Assumption
Vertex	A 3-dimensional point.	There are no overlapping vertices (vertices that share the same position) in a mesh. But overlapping vertices can exist in different meshes.
Halfedge	An edge that starts from one vertex and end at another vertex.	A halfedge connects exactly two non-overlapping vertices and it has a direction. Less than two halfedges start from the same vertex and end at the same vertex in a single mesh.
Face	A polygon that contains a loop of vertices and halfedges.	A face has at least three non-overlapping vertices so it makes a polygon. The face has to be constructed with a complete loop of halfedges with on openings.

Table 1: Definitions and assumptions of vertex, halfedge, and face

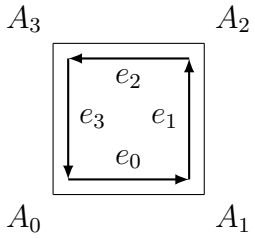

Figure 1: A quadrilateral face made with four halfedges

The vertex, halfedge, and face store their own information and pointers to the adjacent elements. The information that these elements store can be classifed into self-information and adjacency information, which is shown in Table **??**

Element	Self-Information	Adjacency Information
Vertex	vertex position vertex normal vertex ID	one outgoing halfedge
Halfedge		start vertex and end vertex predecessor and successor halfedge in the face sibling links to adjacent face boundary links to adjacent face
Face	face normal	vertices of the face. one side halfedge

Table 2: Definitions and assumptions of vertex, halfedge, and face

2.2 Face Connections

There are two types of face connections, the normal connection and the mobius connection, as shown in Figure **??**

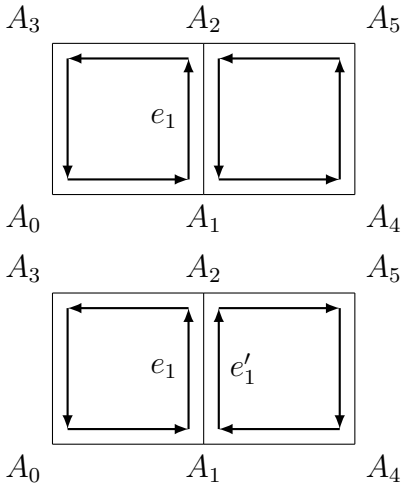

Figure 2: Normal junction (left) and mobius junction (right) between two faces

2.3 Build a Mesh

2.3.1 Build from Elements

2.3.2 Instantiation and Rotation

2.3.3 Build by Merging Meshes

3 Catumll-Clark Subdivision

3.1 General Approach of Catmull-Clark Subdivision

3.1.1 Compute Vertex Positions of New Mesh

3.1.2 Make Connections of New Mesh

3.2 Sharp Crease and Boundary Feature

3.3 Mobius Connection

4 Offset Surface

4.1 Compute Vertex Normals

4.2 Positive and Negative Offsets

4.3 Mobius Connection Issue

5 Test Cases and Discussions

6 Contribution to Knowledge