CPSC 424
Meshes & Data Structures

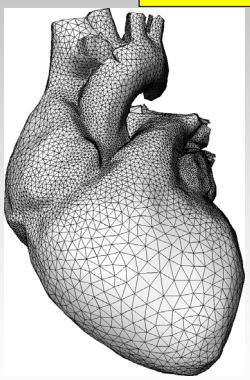
Syllabus

Curves in 2D and 3D
Properties of Curves and Surfaces
Surfaces
Polygonal meshes

- **Definitions & Data Structures**
- Subdivision (Loop, Buterfly, …)
- Simplification
- Acquisition
- Analysis & Smoothing
- ...

Meshes

Triangular mesh – mesh all of whose faces have three vertices



We will discuss connected (3-connected) manifold triangular meshes (closed or open)

Storing mesh data

Uses of mesh data:

- Rendering
- Geometry queries
  - *What are the vertices of face #3?*
  - *Are vertices i and j adjacent?*
  - *Which faces are adjacent to face #7?*
- Geometry operations
  - *Remove/add a vertex/face*

Storing mesh data (cont.)

How "good" is a data structure?

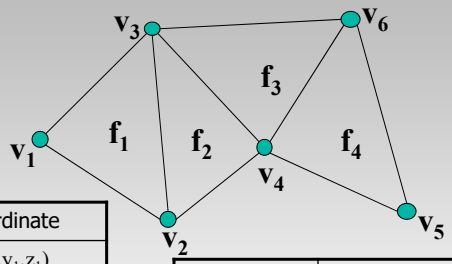
- Time to construct - preprocessing
- Time to answer a query
- Time to perform an operation (update the data structure)
- Space complexity
- Redundancy

List of faces

List of vertices (coordinates)

List of faces - triplets of pointers to face vertices (c_1,c_2,c_3)

List of faces - example



vertex	coordinate
v_1	(x_1,y_1,z_1)
v_2	(x_2,y_2,z_2)
v_3	(x_3,y_3,z_3)
v_4	(x_4,y_4,z_4)
v_5	(x_5,y_5,z_5)
v_6	(x_6,y_6,z_6)

face	vertices (ccw)
f_1	(v_1, v_2, v_3)
f_2	(v_2, v_4, v_3)
f_3	(v_3, v_4, v_6)
f_4	(v_4, v_5, v_6)

List of faces

Queries:

- What are the vertices of face #3?
  - *Answered in O(1) - checking third triplet*
- Are vertices i and j adjacent?
  - *A pass over all faces is necessary – NOT GOOD*

List of faces – pros and cons

Pros:

- Convenient and efficient (memory wise)
- Can represent non-manifold meshes

Cons:

- Too simple - not enough information on relations between vertices & faces

Storing mesh data

Uses of mesh data:

- Rendering
- Geometry queries
- Geometry operations

Storage of generic meshes **– hard to implement efficiently**

Assume: **orientable , manifold & triangular**

Half-Edge Data Structure

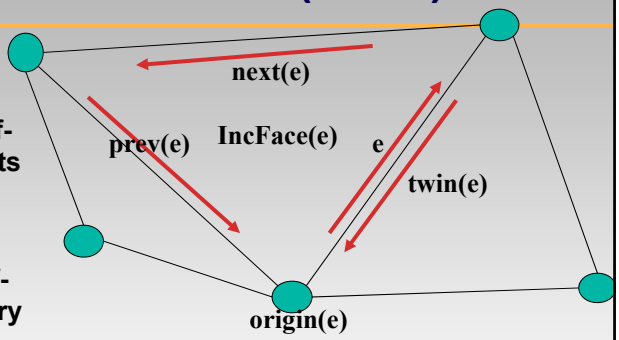
Record for each face, edge and vertex:

- Geometric information
- Topological information
- Attribute information

also called DCEL (Doubly-Connected Edge List) or Winged-Edge Structure

Half-Edge Data Structure (cont.)

- **Vertex record:**
  - **Coordinates**
  - **Pointer to one half-edge that has v as its origin**
- **Face record:**
  - **Pointer to one half-edge on its boundary**



Half-edge record:

- Pointer to its origin, origin(e)
- Pointer to its twin half-edge, twin(e)
- Pointer to the face it bounds, IncidentFace(e) (face lies to left of e when traversed from origin to destination)
- Next and previous edge on boundary of IncidentFace(e)

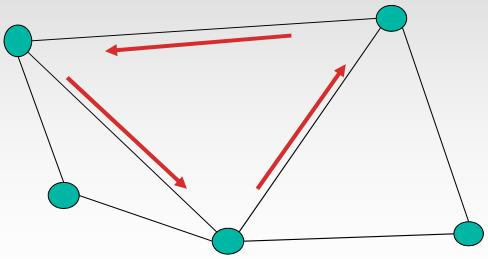
Half-Edge Data Structure (cont.)

Operations supported:

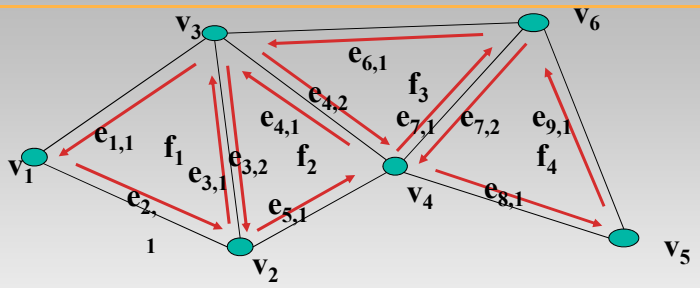
- Walk around boundary of given face
- Visit all edges incident to vertex v

Queries:

- Most queries are O(1)



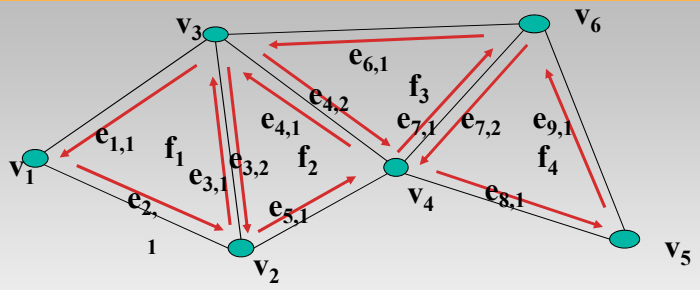
Half-Edge Data Structure - example



Vertex	coordinate	IncidentEdge
V_1	(x_1,y_1,z_1)	$e_{2,1}$
v_2	(x_2,y_2,z_2)	$e_{5,1}$
v_3	(x_3,y_3,z_3)	$e_{1,1}$
v_4	(x_4,y_4,z_4)	$e_{7,1}$
v_5	(x_5,y_5,z_5)	$e_{9,1}$
v_6	(x_6,y_6,z_6)	$e_{7,2}$

face	edge
f_1	$e_{1,1}$
f_2	$e_{5,1}$
f_3	$e_{4,2}$
f_4	$e_{8,1}$

Half-Edge – example (cont.)



Half-edge	origin	twin	IncidentFace	next	prev
$e_{3,1}$	v_2	$e_{3,2}$	f_1	$e_{1,1}$	$e_{2,1}$
$e_{3,2}$	v_3	$e_{3,1}$	f_2	$e_{5,1}$	$e_{4,1}$
$e_{4,1}$	v_4	$e_{4,2}$	f_2	$e_{3,2}$	$e_{5,1}$
$e_{4,2}$	v_3	$e_{4,1}$	f_3	$e_{7,1}$	$e_{6,1}$

Half-Edge – pros and cons

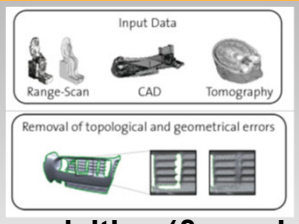
Pros:

- All queries in O(1) time
- All operations are O(1) (usually)

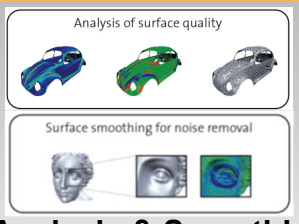
Cons:

- Represents only manifold meshes

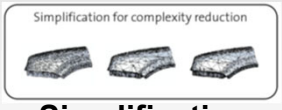
Processing Pipeline



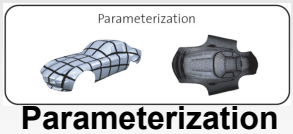
Acquisition (& repair)



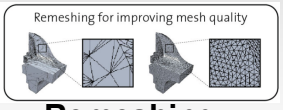
Analysis & Smoothing



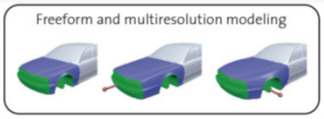
Simplification



Parameterization



Remeshing



Modeling

[Botch, 2006]