PEER REVIEW 2

Interactive Explainers for Geometry Processing Algorithms

Jerry Yin, Jeffrey Goh

Introduction

- We are creating a set of interactive course notes ("*interactive explainers*") for the undergraduate geometric modelling course.
- We are planning on creating articles on two topics: *half-edge data structures* (this week's demo), and *mesh subdivision*.

Meshes

- Meshes are graphs with vertices and edges, plus a set of faces.
- Each face is a cycle of vertices.
- Representing faces as a set of cycles is compact (good for storage) but bad for mesh algorithms.
  - Asking questions like "are v_3 and v_5 connected?" requires searching through all the faces!

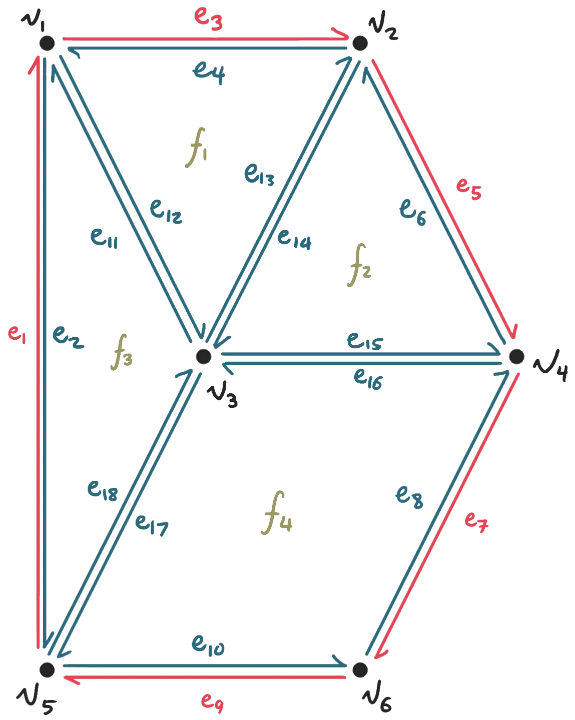
$$v_1 = (1,4) \quad v_2 = (3,4) \quad v_3 = (2,2)$$
$$v_4 = (4,2) \quad v_5 = (1,0) \quad v_6 = (3,0)$$

$$V = \{v_1, v_2, v_3, v_4, v_5, v_6\}$$

$$F = \{(v_1, v_3, v_2), (v_2, v_3, v_4), (v_1, v_5, v_3), (v_3, v_5, v_6, v_4)\}$$

Half-edge data structures

- Represent each edge as a pair of *half-edges*, each going in opposite directions.
- Each face is represented by a counter-clockwise cycle of half-edges.
- Boundary is represented by a clockwise cycle of half-edges.
- Each half-edge stores next and previous half-edges, its twin, its origin vertex, and its corresponding face.
  - Can answer most common queries in ~constant time.



$v_1 = (1,4) \quad v_2 = (3,4) \quad v_3 = (2,2)$

$v_4 = (4,2) \quad v_5 = (1,0) \quad v_6 = (3,0)$

$$V = \{v_1, v_2, v_3, v_4, v_5, v_6\}$$

$$F = \{(v_1, v_3, v_2), (v_2, v_3, v_4), (v_1, v_5, v_3), (v_3, v_5, v_6, v_4)\}$$

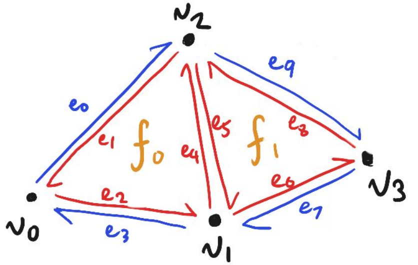
Half-edge vis

- OBJ Editor view allows user to edit a mesh defined in the popular OBJ format.
  - Specify positions and connectivity
- Visual view shows a half-edge diagram.
  - Colour encodes boundary / interior half-edge

OBJ EDITOR

```
v 0.000000 1.000000 0.000000
v 0.942809 -0.333333 0.000000
v -0.471405 -0.333333 0.400000
v -0.471405 -2.333333 0.300000
f 1 2 3
f 2 4 3
```

VISUAL



MEMORY LAYOUT

VERTEX	COORDINATE	INCIDENT EDGE
v_0	(0, 1, 0)	e_1
v_1	(0.9, -0.3, 0)	e_2
v_2	(-0.5, -0.3, 0.4)	e_4
v_3	(-0.5, -2.3, 0.3)	e_6

FACE	EDGE
f_0	e_2
f_1	e_5

HALF-EDGE	ORIGIN	TWIN	INCIDENT FACE	NEXT	PREV
e_0	v_0	e_1	$\varnothing$	e_9	e_3
e_1	v_2	e_0	f_0	e_2	e_4
e_2	v_0	e_3	f_0	e_4	e_1
⋮					

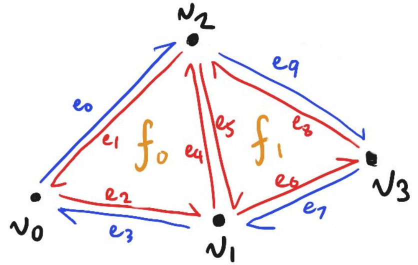
Half-edge vis

- Memory layout view shows all the records stored in the data structure.
  - Colours are the same as in the half-edge diagram.

OBJ EDITOR

```
v 0.000000 1.000000 0.000000
v 0.942809 -0.333333 0.000000
v -0.471405 -0.333333 0.400000
v -0.471405 -2.333333 0.300000
f 1 2 3
f 2 4 3
```

VISUAL



MEMORY LAYOUT

VERTEX	COORDINATE	INCIDENT EDGE
v_0	(0, 1, 0)	e_1
v_1	(0.9, -0.3, 0)	e_2
v_2	(-0.5, -0.3, 0.4)	e_4
v_3	(-0.5, -2.3, 0.3)	e_6

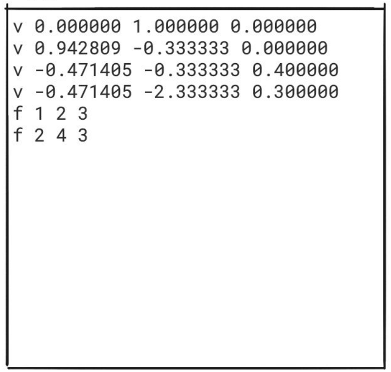
FACE	EDGE
f_0	e_2
f_1	e_5

HALF-EDGE	ORIGIN	TWIN	INCIDENT FACE	NEXT	PREV
e_0	v_0	e_1	$\emptyset$	e_9	e_3
e_1	v_2	e_0	f_0	e_2	e_4
e_2	v_0	e_3	f_0	e_4	e_1
⋮					

Half-edge vis

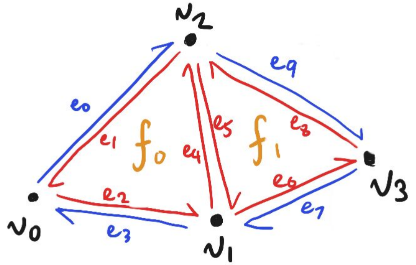
- Interactivity:
  - Can edit OBJ contents
  - Can drag vertices to change position
  - Linked highlighting
  - Idea (might not be feasible): can edit memory layout (and corrupt / uncorrupt data structure)

OBJ EDITOR



```
v 0.000000 1.000000 0.000000
v 0.942809 -0.333333 0.000000
v -0.471405 -0.333333 0.400000
v -0.471405 -2.333333 0.300000
f 1 2 3
f 2 4 3
```

VISUAL



MEMORY LAYOUT

VERTEX	COORDINATE	INCIDENT EDGE
v0	(0, 1, 0)	e1
v1	(0.9, -0.3, 0)	e2
v2	(-0.5, -0.3, 0.4)	e4
v3	(-0.5, -2.3, 0.3)	e6

FACE	EDGE
f0	e2
f1	e5

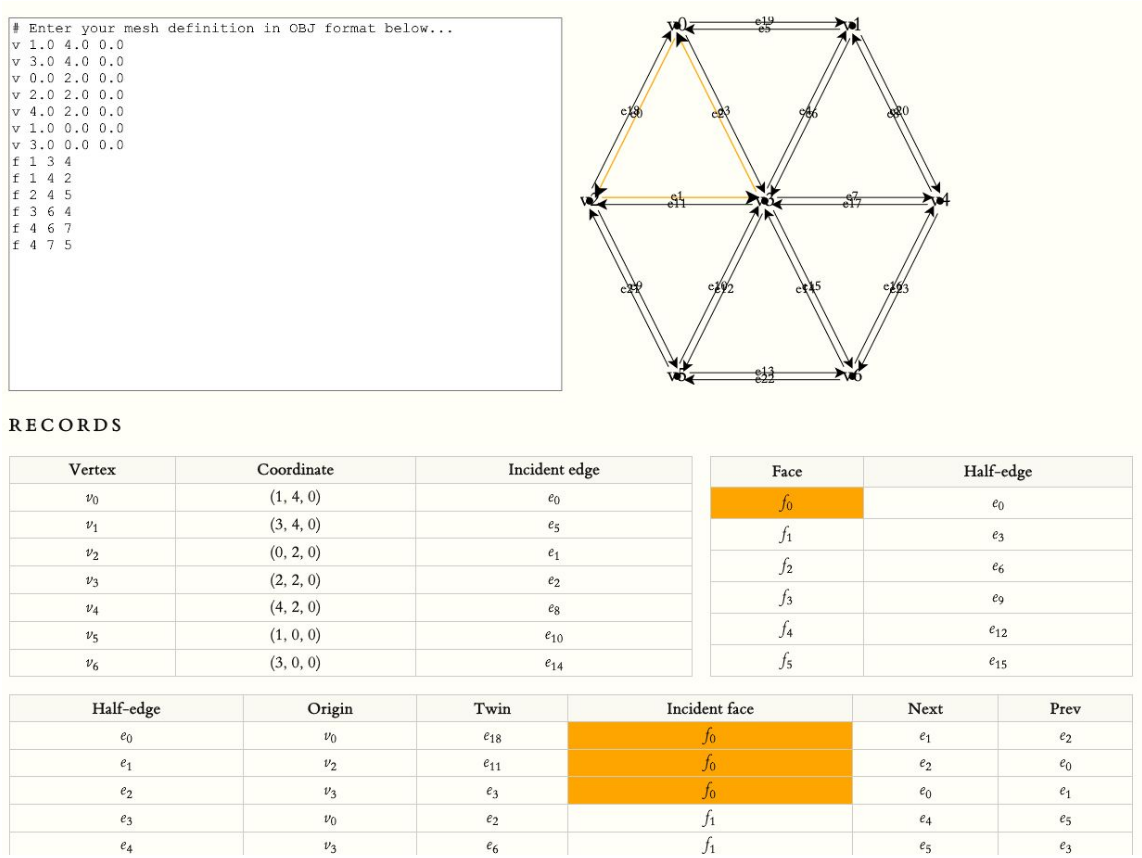
HALF-EDGE	ORIGIN	TWIN	INCIDENT FACE	NEXT	PREV
e0	v0	e1	∅	e9	e3
e1	v2	e0	f0	e2	e4
e2	v0	e3	f0	e4	e1
⋮					

Implementation

- 2D Visualization:
  - Multiple single pages generated using Idyll.
  - Create using D3 and implement it with Idyll.
- Idyll:
  - a markup language and toolkit for writing interactive articles.
  - can be integrated with React / D3 to create custom components.

Current progress (demo)

- Can edit vertices and connectivity, diagram and tables update automatically
- Implemented labels and linked highlighting (incomplete)



```
# Enter your mesh definition in OBJ format below...
v 1.0 4.0 0.0
v 3.0 4.0 0.0
v 0.0 2.0 0.0
v 2.0 2.0 0.0
v 4.0 2.0 0.0
v 1.0 0.0 0.0
v 3.0 0.0 0.0
f 1 3 4
f 1 4 2
f 2 4 5
f 3 6 4
f 4 6 7
f 4 7 5
```

RECORDS

Vertex	Coordinate	Incident edge
v_0	(1, 4, 0)	e_0
v_1	(3, 4, 0)	e_5
v_2	(0, 2, 0)	e_1
v_3	(2, 2, 0)	e_2
v_4	(4, 2, 0)	e_8
v_5	(1, 0, 0)	e_{10}
v_6	(3, 0, 0)	e_{14}

Face	Half-edge
f_0	e_0
f_1	e_3
f_2	e_6
f_3	e_9
f_4	e_{12}
f_5	e_{15}

Half-edge	Origin	Twin	Incident face	Next	Prev
e_0	v_0	e_{18}	f_0	e_1	e_2
e_1	v_2	e_{11}	f_0	e_2	e_0
e_2	v_3	e_3	f_0	e_0	e_1
e_3	v_0	e_2	f_1	e_4	e_5
e_4	v_3	e_6	f_1	e_5	e_3