Vector Graphics Complexes

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Abstract

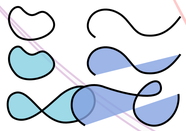
Basic topological modeling, such as the ability to have several faces share a common edge, has been largely absent from vector graphics.

We introduce the vector graphics complex (VGC) as a simple data structure to support fundamental topological modeling operations for vector graphics illustrations.

Problem

Most vector graphics tools use a data structure essentially following the *Scalable Vector Graphics* (***SVG***) specification:

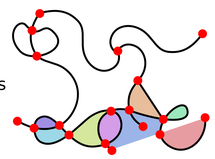
- Closed or open paths
- Filled or not
- Can overlap



Issues:
- Cannot represent multiway joins
- Cannot represent shared edges

A few other vector graphics tools use ***planar maps***:

- 2-complex embedded in $\mathbb{R}^2$
- Can represent multiway joins
- Can represent shared edges

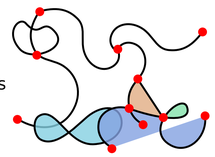


Issues:
- Cannot represent overlapping objects
- Editing geometry can invalidate topology

Our Solution

We introduce the ***vector graphics complex***:

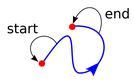
- 2-complex **immersed** in $\mathbb{R}^2$
- Can represent multiway joins
- Can represent shared edges
- Can represent overlapping object
- Editing geometry never invalidates topology



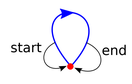
Idea:
- **Superset of SVG and planar maps**
- Overlap *when you want to*
- Intersect *when you want to*

Data Structure

```
class Cell { set<Cell*> star; };

class Vertex: public Cell { Point p; };

class Edge:   public Cell { Vertex * start;
                            Vertex * end;
                            Curve curve;    };

struct Halfedge { Edge * edge; bool b; };

struct Cycle { Vertex * steiner;
               vector<Halfedge> halfedges; };

class Face: public Cell { vector<Cycle> cycles; };
```

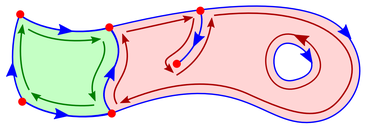


open edge



open edge (special case)

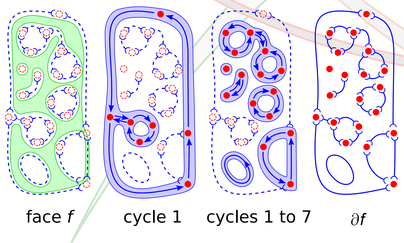
closed edge



Faces and Cycles

A *face* is defined by one or several *cycles*, where each cycle is one of:

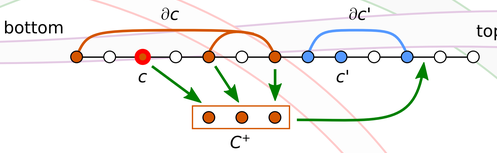
- **Non-simple cycle**
  Looping sequence of consecutive oriented open edges
- **Simple cycle**
  Oriented closed edge
- **Steiner cycle**
  Single vertex



Depth Ordering

All cells are globally ordered via a doubly-linked list, and are rendered back to front.

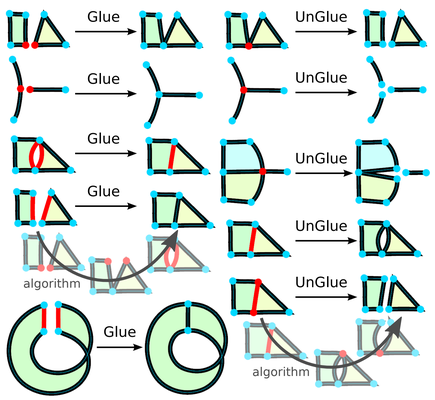
Users can use **raise** or **lower** to alter this ordering.

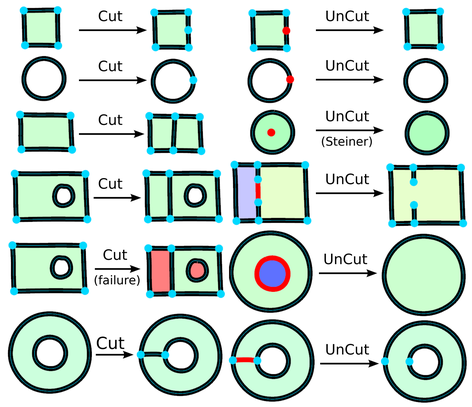


Raise(selected cell c):

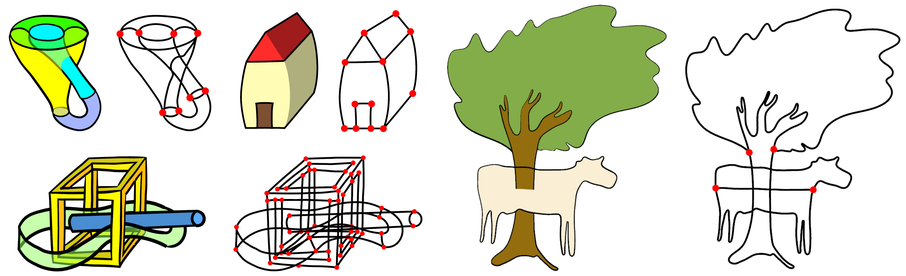
- Search from bottom to find c.
- Compute C^+ = subset of ($c \cup \partial c$) that is above c.
- Search up from c for the first cell c' satisfying:
  (c' not in ∂c) AND (c' overlaps with c)
- Move C^+ above the highest element of ($c' \cup \partial c'$).

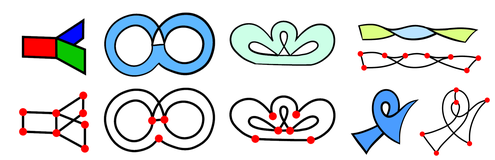
Topological Operators

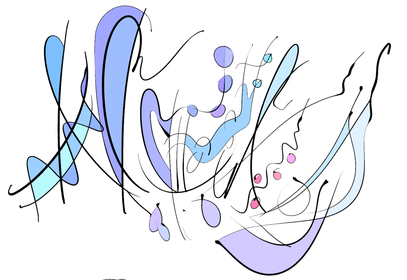


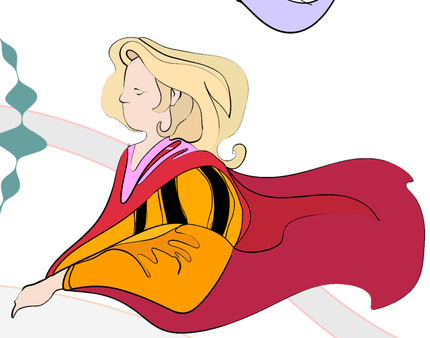


Results









Limitations

- Creating a face is tedious: the user must select all boundary edges.
- Multiway joins are not correctly rendered.

Future Work

- Extension to animation, including when changes in topology occur
- "Click-to-fill" tool

Related Work

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