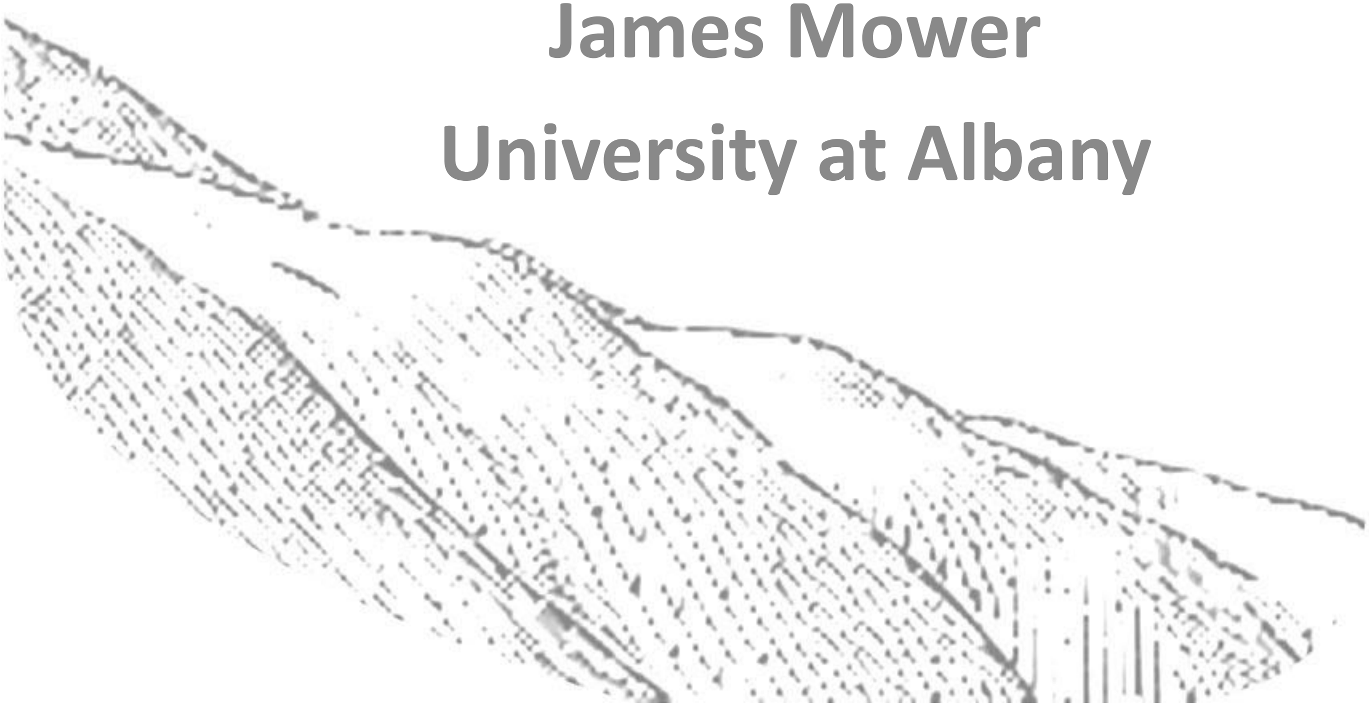
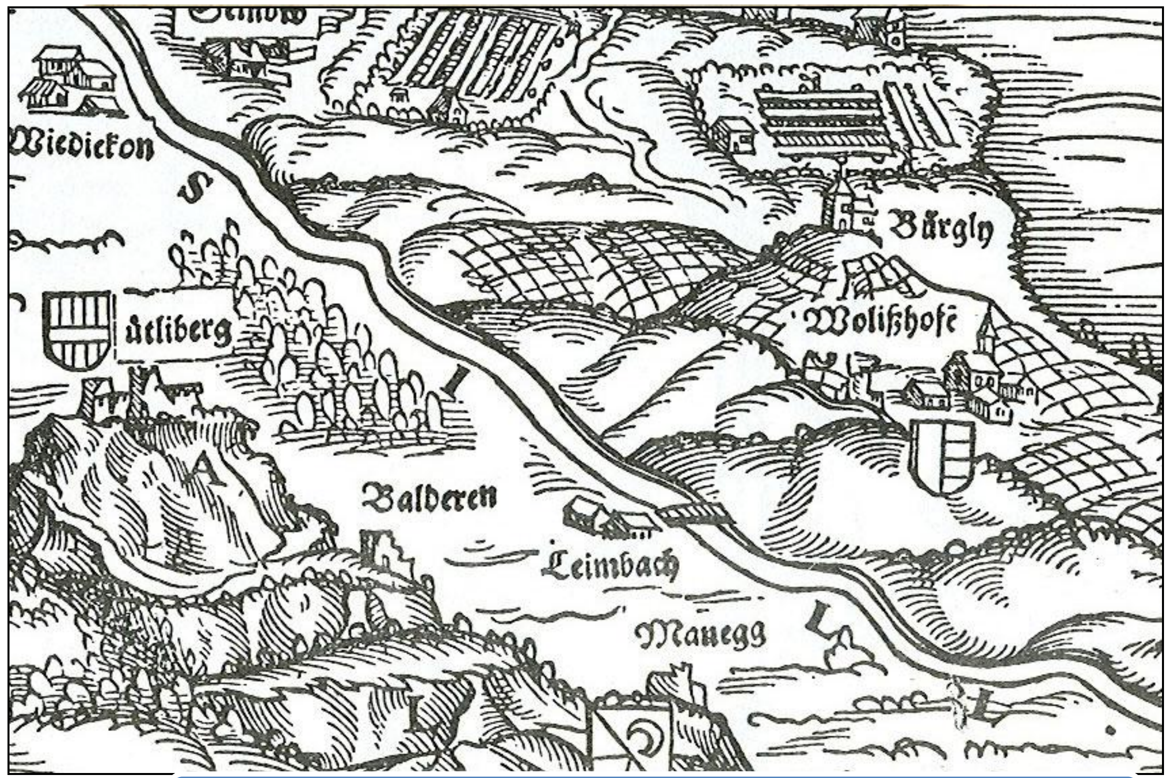
Supporting Automated Pen and Ink Style Surface Illustration with B-Spline Models

James Mower
University at Albany



Perspective Landscape Rendering

- Demonstrated in Tuscan landscape paintings by da Vinci
- Extended to woodcuts in the 16th century by Murer and others



Study of a Tuscan Landscape, Da Vinci, ca. 1473

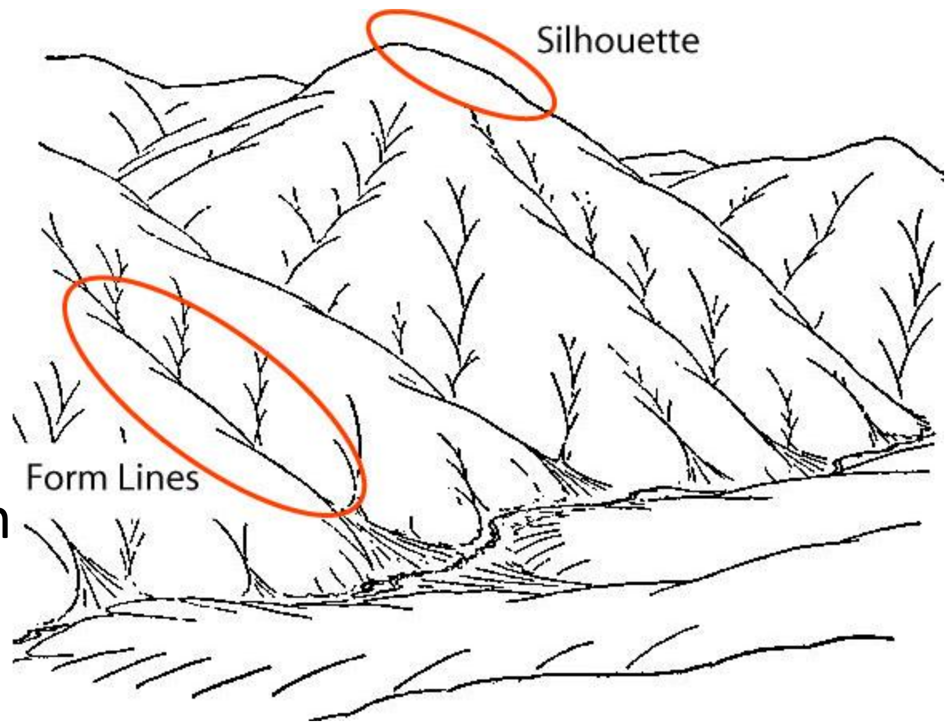
Geomorphological Illustrators

Automating Pen and Ink Illustration

- Apply a non-photorealistic rendering (NPR) approach
- Use an “economy of lines”
  - Markosian and others, 1997
- Depict the essential form of an object using a minimal number of strokes

Linework

- Landscape features are represented with 2 types of linework
  - Silhouettes
    - Boundaries between visible and invisible surfaces
  - Form Lines
    - Surface trends



W.M. Davis

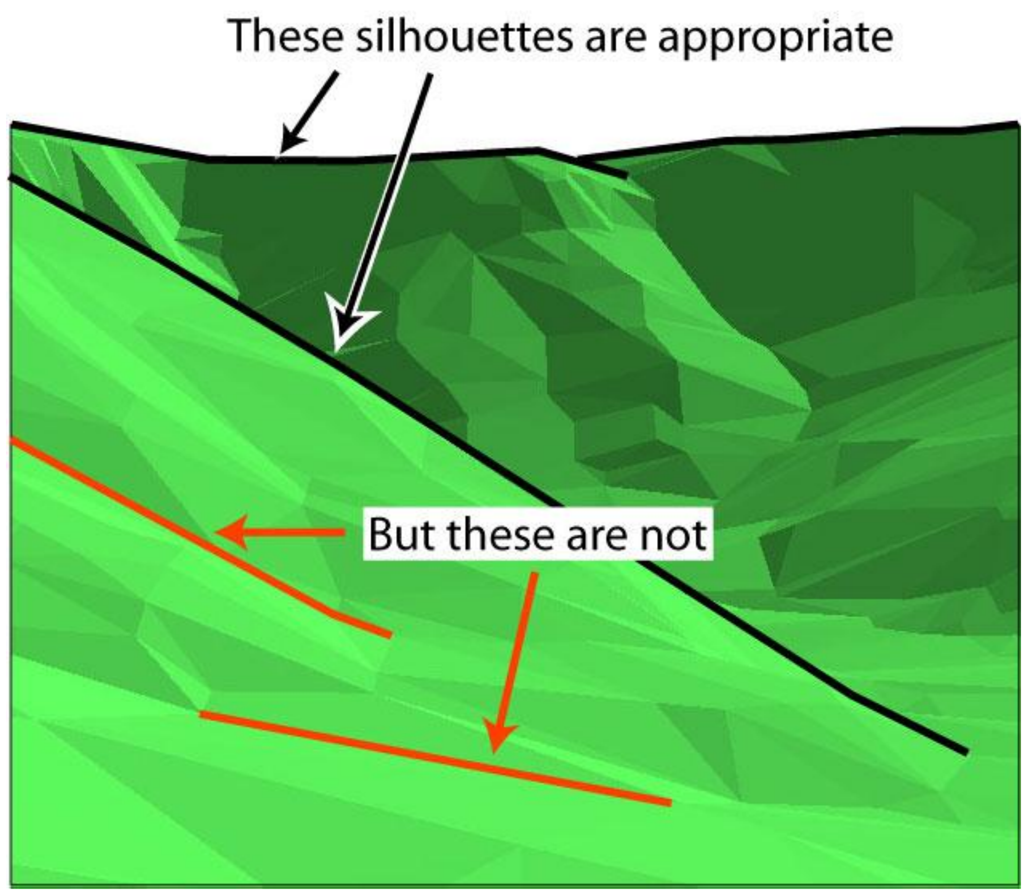
Representing Elevation

- More samples, less interpolation
  - TIN
  - Polyhedron
  - Interpolated values lie on plane
- Fewer samples, more interpolation
  - “Global” polynomial functions of order p
  - Polynomial patches of order p
  - Interpolated values evaluate to degree p-1 surface

But Which Is Best?

- Manual pen and ink style landscape illustrations usually depict low noise surfaces
- Dense sampling models have lots of noise
- Some NPR techniques are sensitive to noise
  - Can generate numerous junk silhouettes
- Bezier surface models supress noise and are good candidates for NPR support

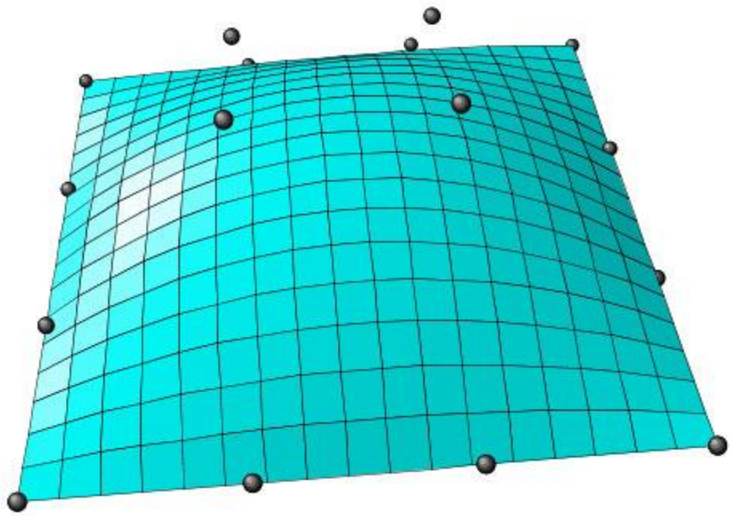
Surface Noise and Silhouettes



Bezier Surface Models

- A Bezier surface is described by control points
- Its order in u and v equals the number of control points along the respective axes
- Each control point is associated with a basis function
- The basis function determines the control point's influence on the surface at position u,v

A Bezier Surface



A degree 3 by degree 3 Bezier Surface

Generated from a Java applet created by David Little, Department of Mathematics, Penn State

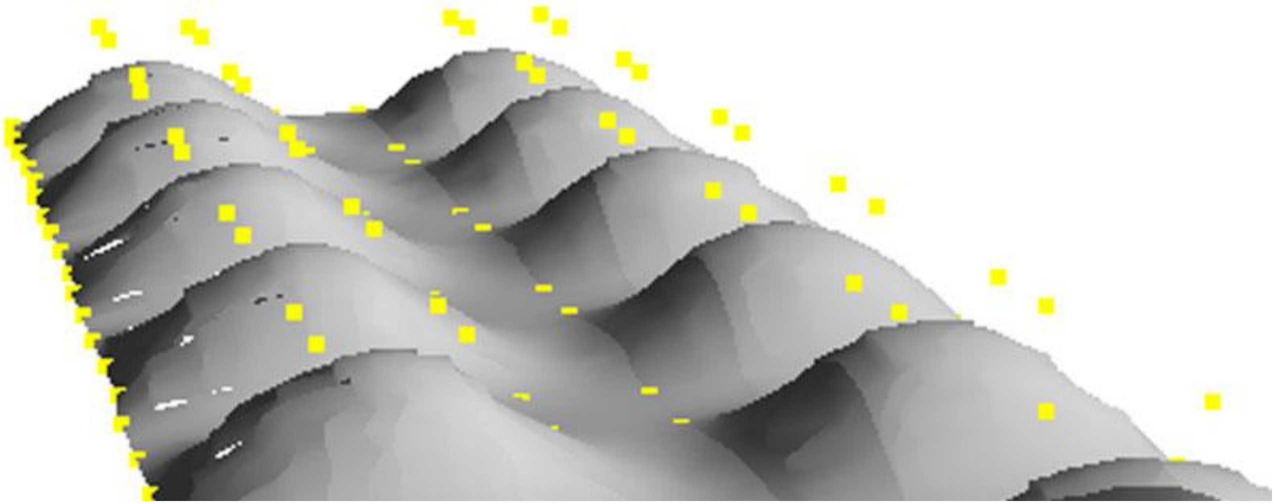
A Problem with Bezier Surfaces

- Evaluation times increase exponentially with the number of control points
- Computations on large numbers of control points can lead to numerical overflow
- Solution—B-Spline surfaces
  - A patchwork of low order Bezier surfaces
  - Stitched together at their edges with continuous joins

B-Spline Surface Model

- Composed of local ‘basis’ functions that only contribute within a given ‘knot span’
- The continuity at the joins is determined by:
  - The degree of the basis functions in u and v
  - The number of duplicate knot values at the join
- This project uses degree 3 basis functions with 2 times differentiability at the joins

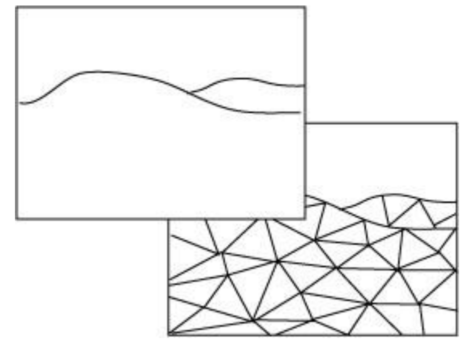
A B-Spline Surface



10 degree 3 by degree 3 patches are stitched together with 2 times differentiability at patch borders

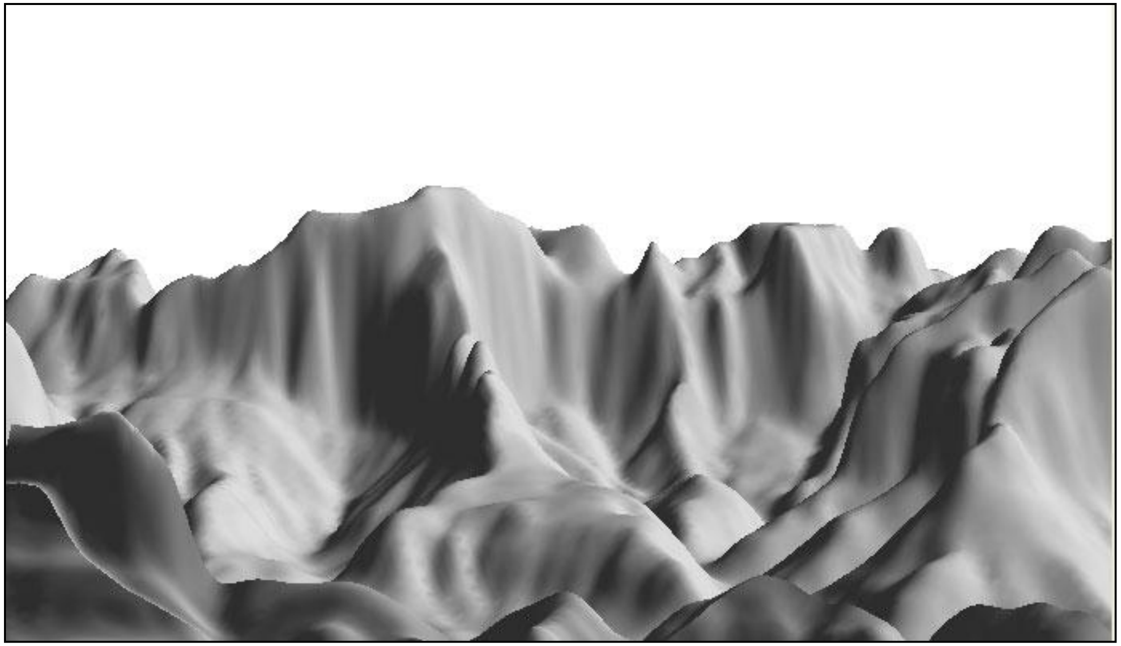
Surface Tessellation

- Polynomial surfaces are rendered as a set of planar facets (a tessellation)
- The facets should cover about the same screen space, regardless of their position in the world



- The OpenGL B-spline rendering functions enforce this criterion

Gray Shaded B-Spline Surface

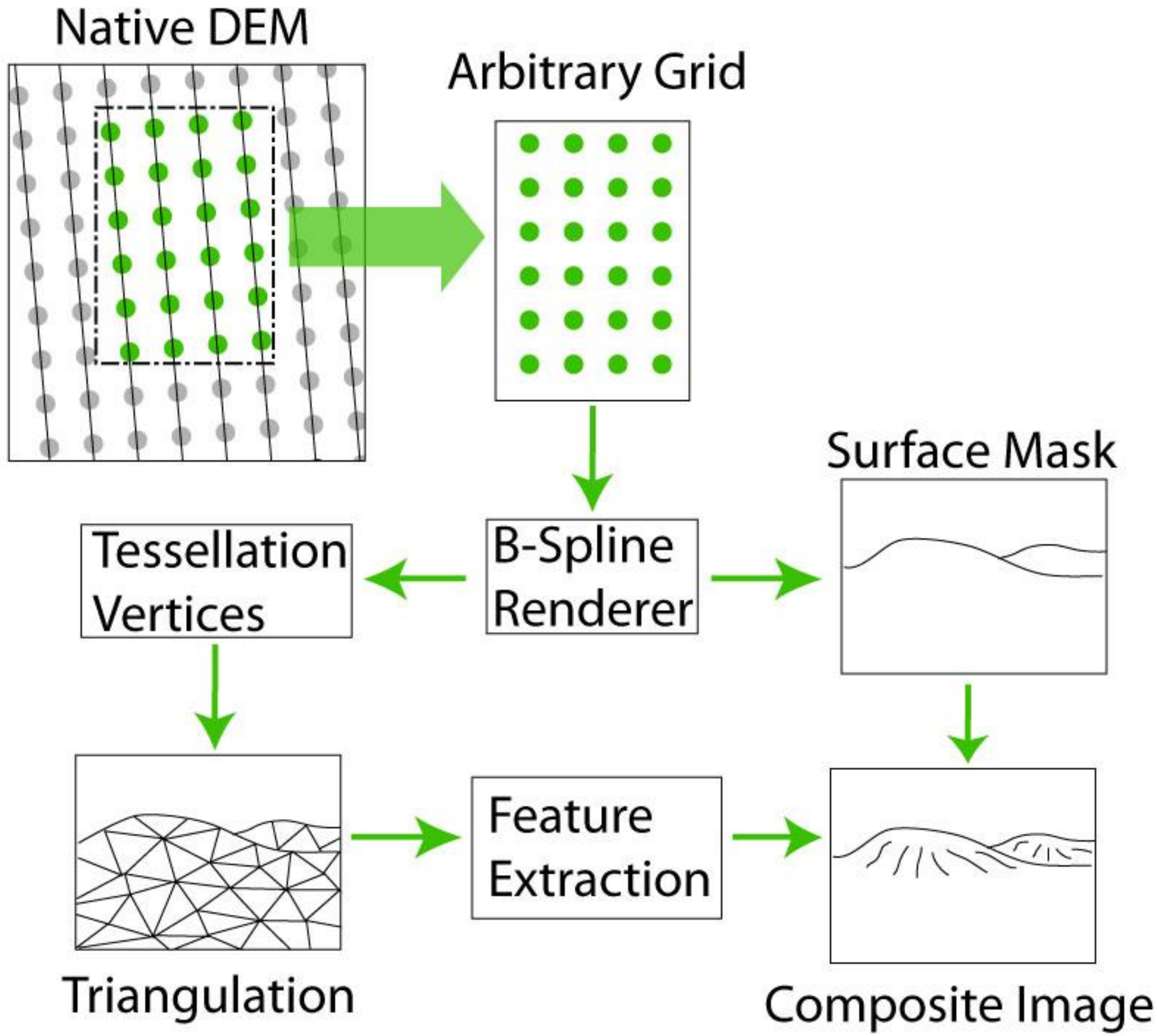


Rendering this surface in emissive white makes it a useful surface mask for silhouette and form line rendering

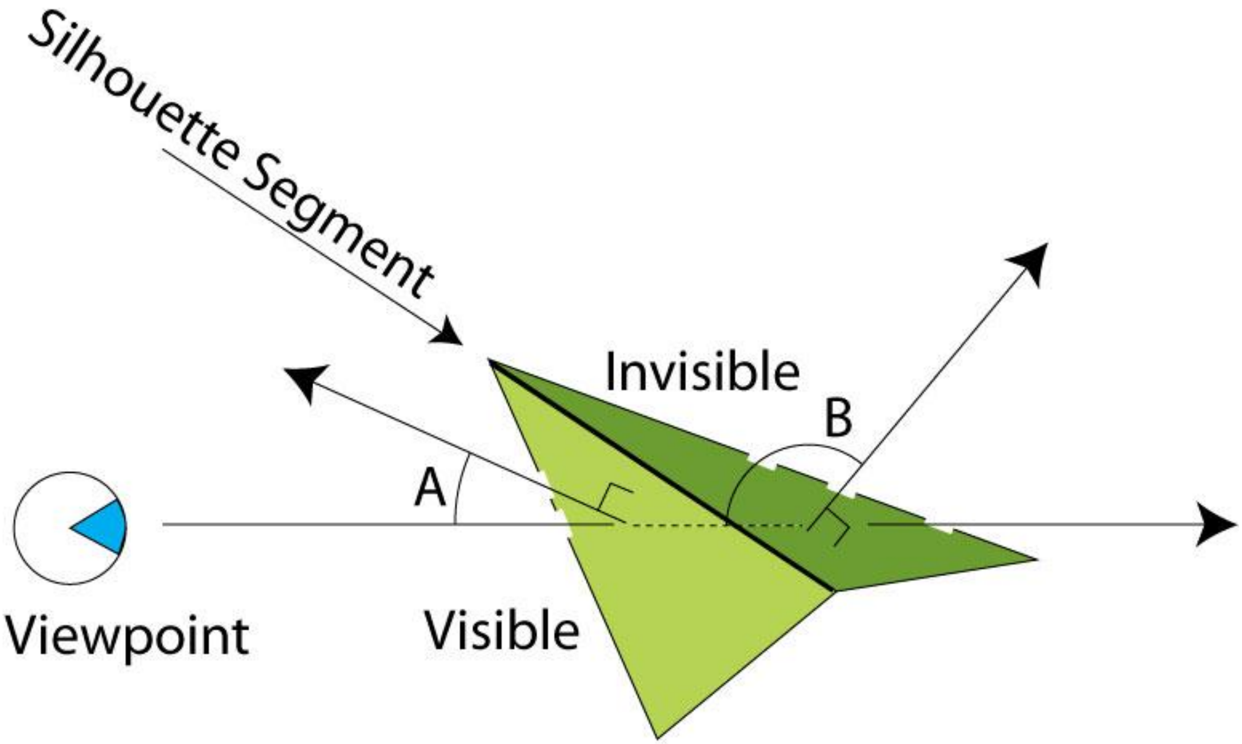
Surface Processing Environment

- OpenGL
  - NURBS (non-uniform, rational B-spline) package
- CGAL
  - Computational Geometry and Algorithms Library
  - Triangulation facilities
  - Useful geometric modeling operations and primitives
- Written in C++ for MS Windows

Project Work Flow

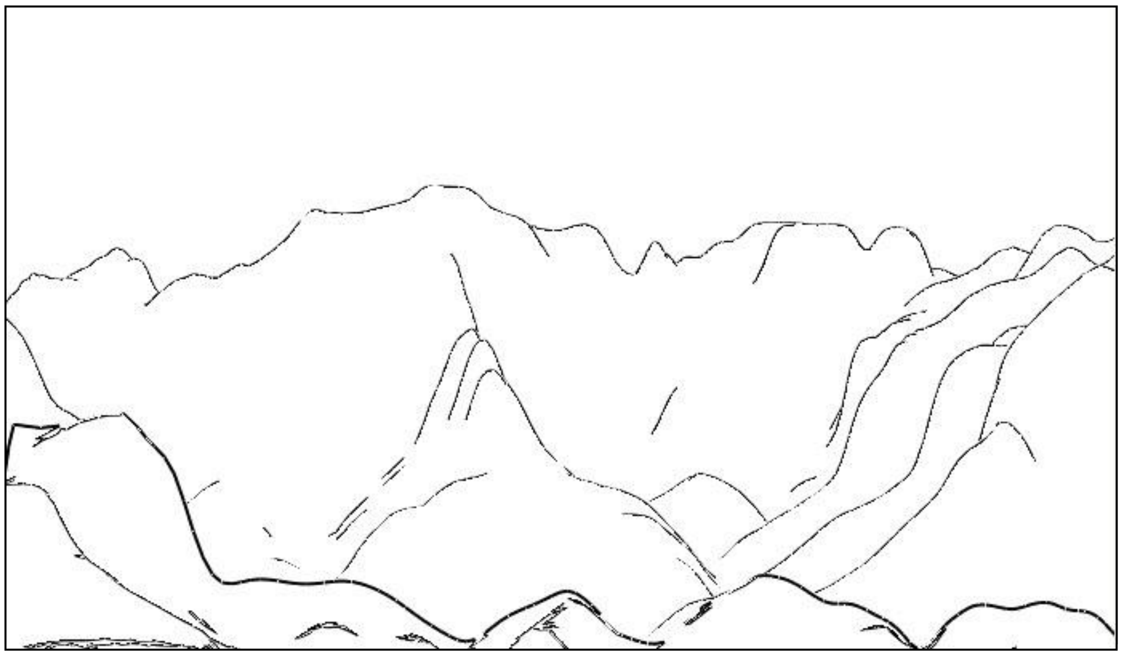


Extracting Silhouettes



A silhouette segment is a boundary between a visible and invisible facet

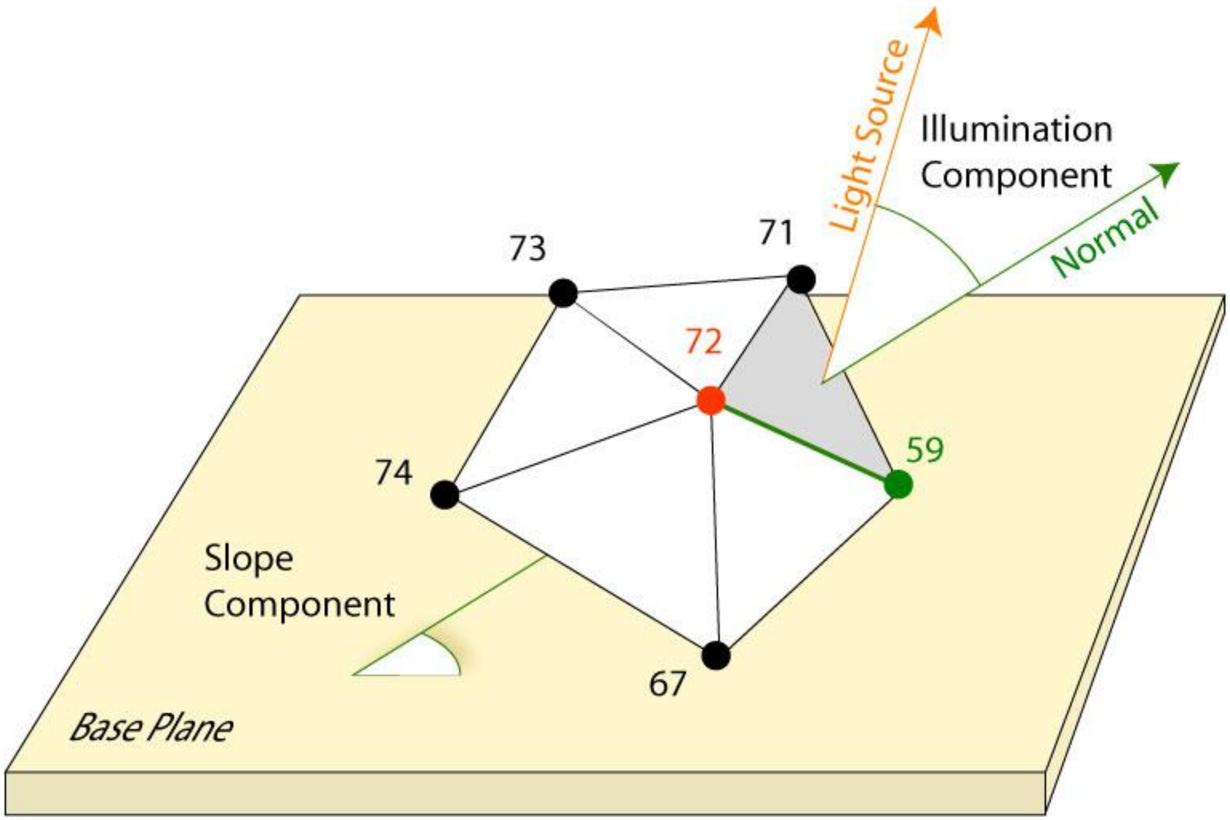
Silhouettes and a Masking Surface



Defining Form Lines

- A form line shows a surface trend
- Form lines can be defined globally or locally
- This project defines a form line segment as a line of steepest descent from one vertex to an adjacent neighbor
  - Form lines are visual composites of locally generated segments

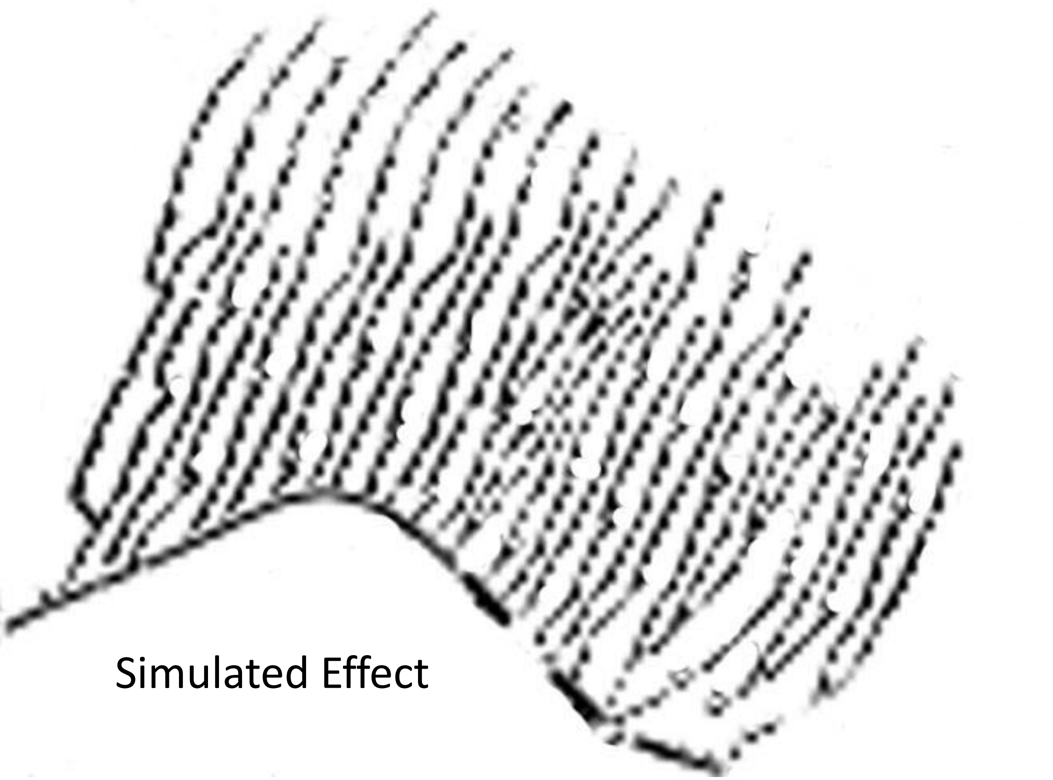
The Form Line Model



The weighted illumination and slope components control shading for a surface facet

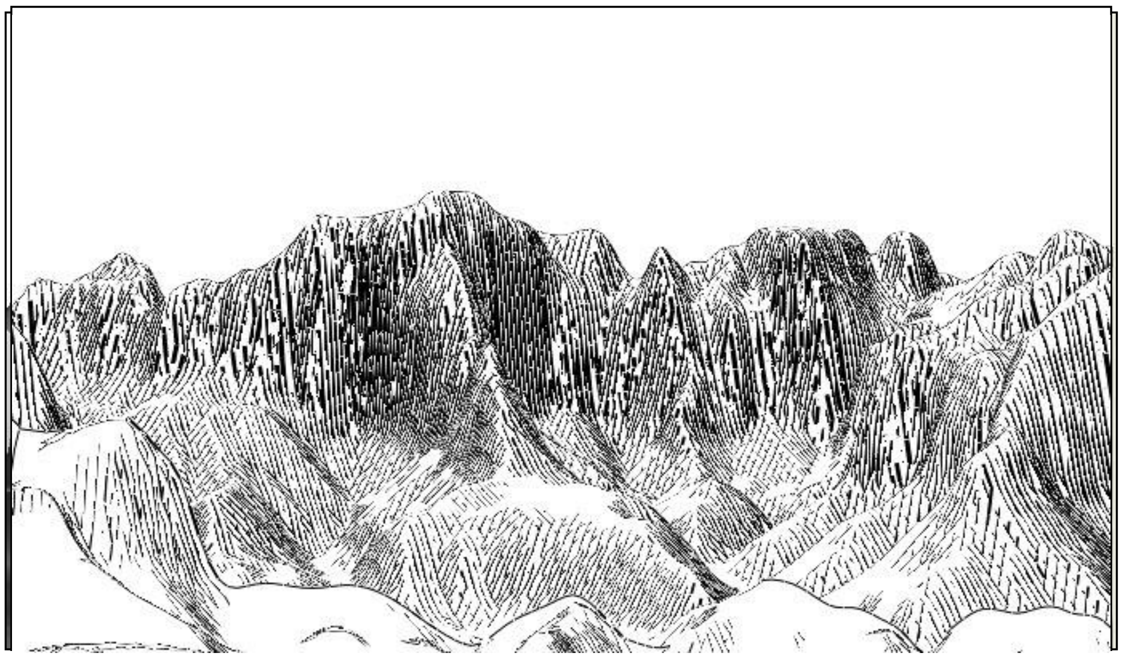
Using Drainage Accumulation Models

- Lines of steepest descent are assembled into a stream network
- Each branch of the network has a stream order
- Segments can be displayed or hidden by order



Simulated Effect

Form Line Example

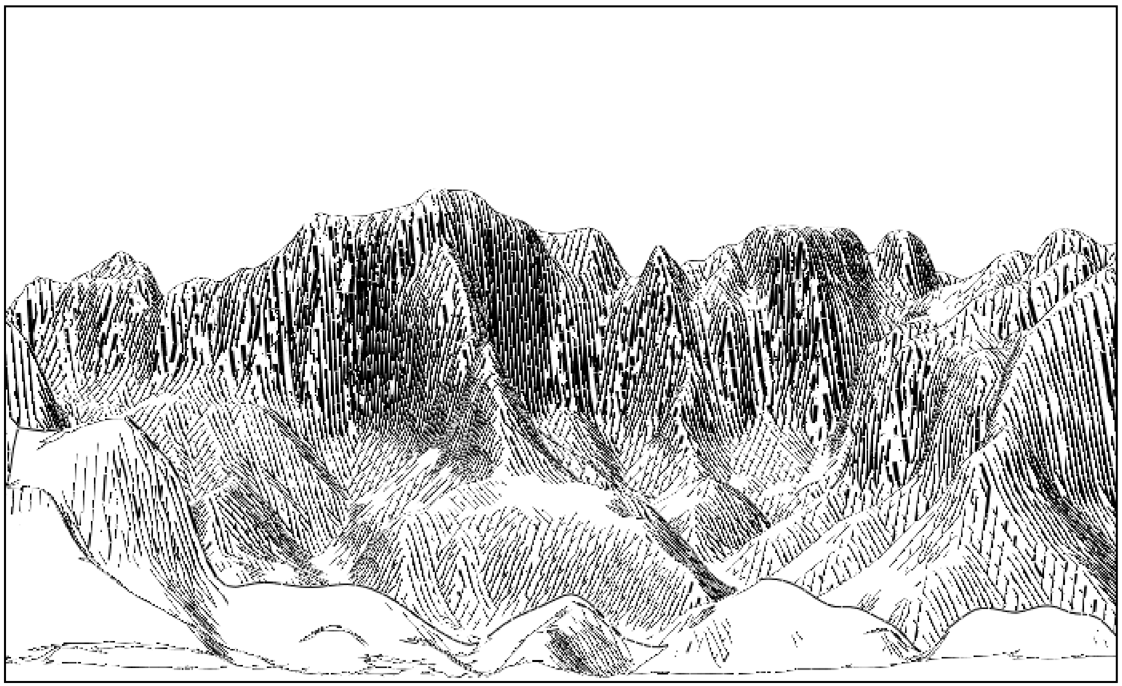


Rendering Parameters

- Illumination azimuth and altitude
- Position and attitude of the viewpoint
- Variable form line width with slope and illumination angles
- Form line display by stream order
- Adjustable weighting of all parameters

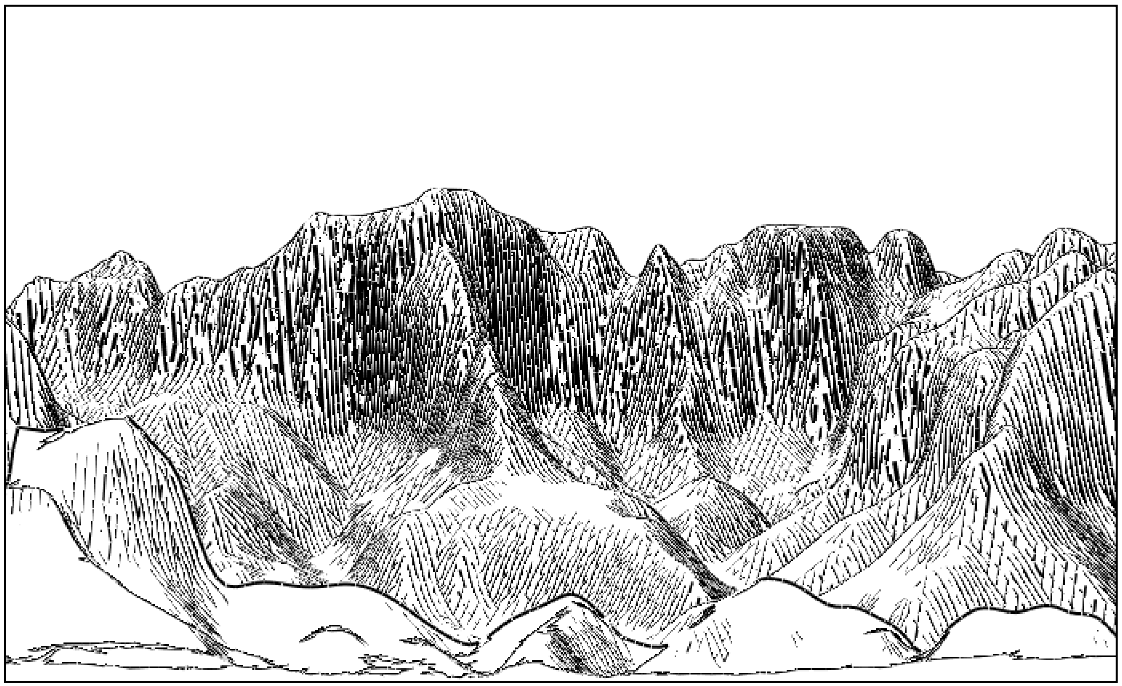
Varying Illumination Azimuth

West Temple feature, Zion National Park



72 images, illumination azimuth rotating through 360 degrees
at 5 degrees per image

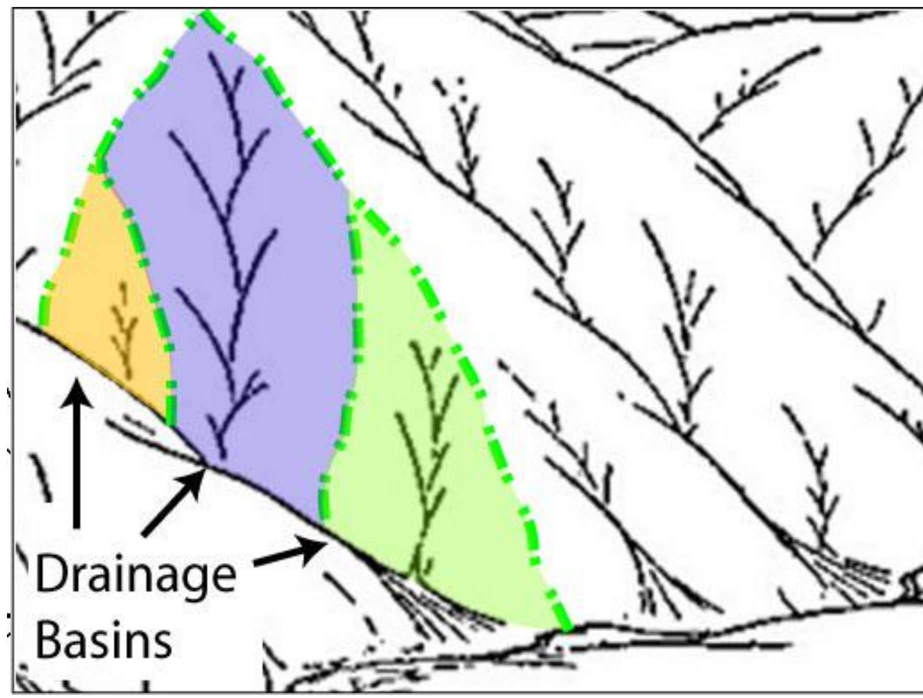
Level of Detail Varies with the Viewpoint Position



100 still images on an 8 km flight path

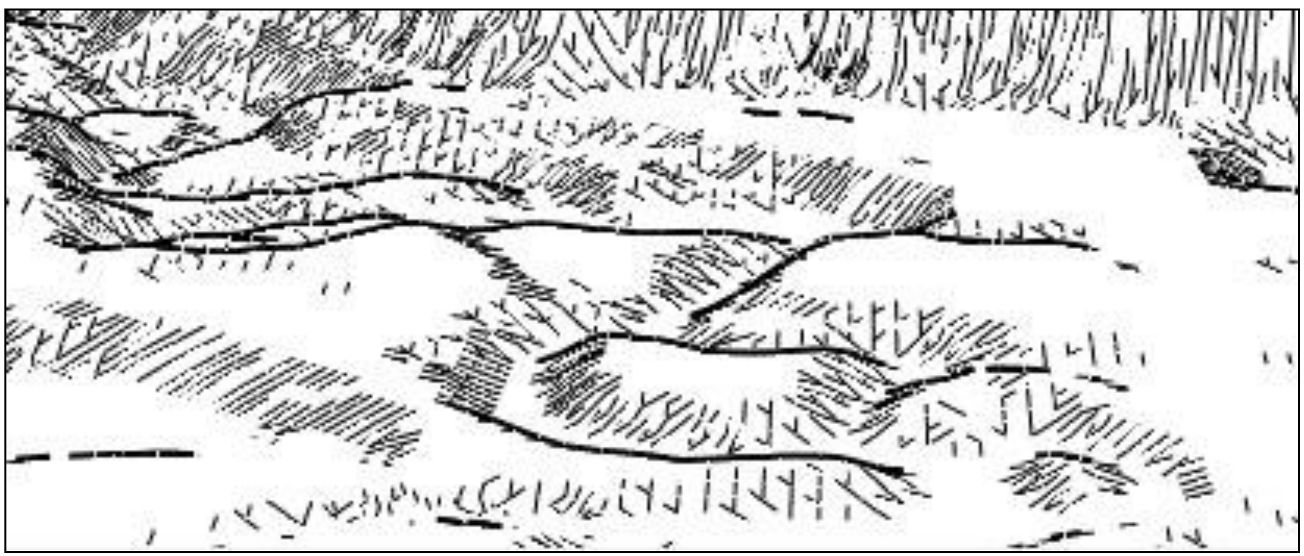
When Less is More

- This W.M. Davis image uses very few strokes
- The following slide shows how a landscape can be rendered with fewer strokes



A Low Relief Environment

- This is from a coastal scene in Labrador
  - DEM provided by Rudy Slingerlands at Penn State
- Not as minimal as Davis, but getting there…



Performance Issues and a New Approach

- Building silhouette and drainage models with CGAL from NURBS models is very slow
  - The Utah images take 5 to 10 minutes per frame
- New OpenGL versions allow tessellation control with shader programs
- Shader programs run on the GPU and can be very fast

Preliminary GPU Results

- Now doing B-spline modeling on the GPU
- Silhouettes are interpreted as borders between rendered pixels generated from non 3D-contiguous parent triangles
- Speeds are approaching animation time scale

Thanks for Coming!

- A couple recent papers are at http://www.albany.edu/faculty/jmower/geog/publications/

- Any questions?