Focus + Context

Lecture 13 CPSC 533C, Fall 2004

1 Nov 2004
Focus + Context

Leung and Apperley taxonomy

Nonlinear Magnification Fields

2D Hyperbolic Trees

3D Hyperbolic Graphs

TreeJuxtaposer

hyperbolic geometry background, if time
Intuition

move part of surface closer to eye

stretchable rubber sheet borders tacked down

merge overview and detail into combined view
Bifocal transformation magnification

Transformation Function: Bifocal Display

Magnification Function: Bifocal Display

Normalised Distance in Distorted Image

Normalised Distance in Undistorted Image

Magnification Factor

1D

2D
Perspective Wall

**Transformation**

Transformation Function: Perspective Wall

Normalized Distance in Distorted Image

-1

1

Normalized Distance in Undistorted Image

-1

1

**Magnification**

Magnification Function: Perspective Wall

Magnification Factor

-1

1

Normalized Distance

**1D**

**2D**
Polyfocal: Continuous Mag

transformation

magnification

1D

2D
Fisheye Views: Continuous Mag

transformation

Magnification Function:
Fisheye View

magnification

Magnification Function:
Fisheye View

1D

2D rect

polar

norm polar
Multiple Foci

same params

diff params

polyfocal magnification function dips allow this
Nonlinear Magnification Functions

transformation
  · distortion
magnification
  · derivative of transformation

directionality
  · easy: compute transformation given magnification derivative
  · hard: compute magnification given transformation integration

new mathematical framework
  · approximate integration, iterative refinement
  · minimize "error mesh"
Expressiveness

magnification is more intuitive control

- allow expressiveness, data-driven expansion
2D Hyperbolic Trees

fisheye effect from hyperbolic geometry

[video]
3D Hyperbolic Graphs: H3

- task
  - browsing large quasi-hierarchical graphs

Previous work: graph drawing

scalability bottleneck
layout
avoiding disorientation
Previous work: graph drawing

- scalability bottleneck
- layout
- avoiding disorientation

H3 [Munzner 97,98]

dot [Gansner et al 93]

node count, log scale
Previous work: graph drawing

scalability bottleneck
layout
avoiding disorientation

H3 [Munzner 97,98]
Gem3D [Frick et al 95]
dot [Gansner et al 93]

node count, log scale
Graph layout criteria

minimize

- crossings, area, bends/curves
Graph layout criteria

minimize
  · crossings, area, bends/curves

maximize
  · angular resolution, symmetry
Graph layout criteria

minimize
  · crossings, area, bends/curves

maximize
  · angular resolution, symmetry

most criteria NP-hard
  · edge crossings [Garey and Johnson 83]
Graph layout criteria

minimize
  ∙ crossings, area, bends/curves

maximize
  ∙ angular resolution, symmetry

most criteria NP-hard
  ∙ edge crossings [Garey and Johnson 83]

incompatible
  ∙ [Brandenburg 88]
Layout

problem

- general problem is NP-hard
**Layout**

**problem**
- general problem is NP-hard

**solution**
- tractable spanning tree backbone
- match mental model "quasi-hierarchical"
- use domain knowledge to construct select parent from incoming links
Layout

problem
  · general problem is NP-hard

solution
  · tractable spanning tree backbone
  · match mental model "quasi-hierarchical"
  · use domain knowledge to construct select parent from incoming links

· non-tree links on demand
Avoiding disorientation

problem
  - maintain user orientation when showing detail
  - hard for big datasets

exponential in depth: node count, space needed

global overview

local detail
Overview and detail

two windows: add linked overview
  • cognitive load to correlate

solution
  • merge overview, detail
  • "focus+context"
Previous work: focus + context
fisheye views [Furnas 86], [Sarkar et al 94]
Previous work: focus+context

fisheye views [Furnas 86], [Sarkar et al 94]
nonlinear magnification [Keahey 96]
Previous work: focus + context

fisheye views [Furnas 86], [Sarkar et al 94]
nonlinear magnification [Keahey 96]
pliable surfaces [Carpendale et al 95]
Previous work: focus + context trees

H3 [Munzner 97,98]

Cone Trees [Robertson et al 91]

node count, log scale
Previous work: focus + context trees

- H3 [Munzner 97, 98]
- Fractal trees [Koike & Yoshihara 93]
- Cone Trees [Robertson et al 91]
Previous work: focus + context trees

- H3 [Munzner 97,98]
- 2D Hyp Trees [Lamping et al. 94,95]
- Fractal trees [Koike & Yoshihara 93]
- Cone Trees [Robertson et al. 91]
Hyperbolic space background

geometry with exponential "amount of room"
· good match for exponential node count of trees

2D hyperbolic plane

hemisphere area

hyperbolic: exponential
\[2\pi \sinh^2(r)\]

euclidean: polynomial
\[2\pi r^2\]

[Thurston and Weeks 84]
1D hyperbolic space

hyperbola projects to line
2D hyperbolic space
hyperboloid projects to disk
2D hyperbolic space

hyperboloid projects to disk

[Lamping et al 95]
3D hyperbolic space

3-hyperboloid projects to solid ball
3D hyperbolic space

3-hyperboloid projects to solid ball

webviz [Munzner and Burchard 95]

- straightforward cone tree + 3D hyperbolic space
- poor information density
Contribution: focus + context graphs

- H3 [Munzner 97, 98]
- webviz [Munzner & Burchard 95]
  - 2D Hyp Trees [Lamping et al 94, 95]
  - Fractal trees [Koike & Yoshihara 93]
  - Cone Trees [Robertson et al 91]

node count, log scale
3D hyperbolic space

3-hyperboloid projects to solid ball

H3 layout
  · circumference → hemisphere
3D hyperbolic space

3-hyperboloid projects to solid ball

**H3 layout**
- bottom-up: allocate space for nodes
- top-down: place child on parent hemisphere

<table>
<thead>
<tr>
<th>Formula</th>
<th>Euclidean</th>
<th>Hyperbolic</th>
</tr>
</thead>
<tbody>
<tr>
<td>right-angle triangle</td>
<td>$\tan \theta = \frac{opp}{adj}$</td>
<td>$\tan \theta = \frac{\tanh(opp)}{\sinh(adj)}$</td>
</tr>
<tr>
<td>right-angle triangle</td>
<td>$\sin \theta = \frac{opp}{hyp}$</td>
<td>$\sin \theta = \frac{\sinh(opp)}{\sinh(hyp)}$</td>
</tr>
<tr>
<td>circle area</td>
<td>$\pi r^2$</td>
<td>$2\pi (\cosh(r) - 1)$</td>
</tr>
<tr>
<td>hemisphere area</td>
<td>$2\pi r^2$</td>
<td>$2\pi \sinh^2(r)$</td>
</tr>
<tr>
<td>spherical cap area</td>
<td>$2\pi r^2(1 - \cos \phi)$</td>
<td>$2\pi \sinh^2 r(1 - \cos \phi)$</td>
</tr>
</tbody>
</table>
Progressive rendering

want fast update during user interaction
  · fill in details when user is idle

problem
  · dataset too big to draw in single frame

solution
  · guaranteed frame rate algorithm

progressive refinement
  · gradually improve image vs. standard Z-buffer
  · common in graphics [Bergman et al 86]
  · far less attention in infovis
H3Viewer algorithm

drawing queue for nodes

graph-theoretic
  · add parent, child nodes to queue

view-dependent
  · sort queue by screen area
H3 video (excerpts)
H3 results

scalability

- performance
- information density
H3 results: scalability

performance

- layout
  110K edges, 12 seconds (1997: SGI IR2)
  300K edges, 16 seconds (2002: Intel P3)

- drawing
  constant time: guaranteed frame rate

- limited by main memory size
H3 results: scalability

information density: 10x better

<table>
<thead>
<tr>
<th></th>
<th>center</th>
<th>fringe</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D</td>
<td>dozens</td>
<td>thousands</td>
</tr>
<tr>
<td>2D</td>
<td>dozens</td>
<td>hundreds</td>
</tr>
</tbody>
</table>
H3 discussion: scalability

focus+context layout

- success: large local neighborhood visible, 5–9 hops
- cognitive limit: if graph diameter >> visible area
TreeJuxtaposer

extend cognitive limit
  · move from local F+C to global F+C
Noneuclidean geometry

Euclid's 5th Postulate
  · exactly 1 parallel line

spherical
  · geodesic = great circle
  · no parallels

hyperbolic
  · infinite parallels

[torus.math.uiuc.edu/jms/java/dragsphere]
Parallel vs. equidistant

euclidean: inseparable
hyperbolic: different

[Diagram showing the difference between Euclidean and Hyperbolic parallel lines]
Exponential "amount of room"

good match for exponential node count of trees

2D hyperbolic plane embedded in 3D space

hemisphere area

hyperbolic: exponential
\[ 2\pi \sinh^2(r) \]

euclidean: polynomial
\[ 2\pi r^2 \]

[Thurston and Weeks 84]
Models, 2D

not just round!  Minkowski

Klein/projective  Poincare/conformal  Upper Half Space

[Three Dimensional Geometry and Topology, William Thurston, Princeton University Press]
Minkowski

1D

2D

[www-gap.dcs.st-and.ac.uk/~history/Curves/Hyperbola.html]
[www.geom.umn.edu/~crobles/hyperbolic/hypr/modl/mnkw/]

the hyperboloid itself
embedded one dimension higher
1D Klein

hyperbola projects to line

image plane

eye point
2D Klein

hyperboloid projects to disk

demo: Geomview
video: www.geom.umn.edu/~crobes/hyperbolic/hypr/ibm/mkb/M2K.mpg

[graphics.stanford.edu/papers/munzner_thesis/html/node8.html#hyp2Dfig]
Klein vs Poincare

stereographic projection
  · transparent sphere
  · plane at south pole
  · light at north pole

[demo: torus.math.uiuc.edu/jms/java/stereop/]

transformation from Klein to Poincare
  · vertically project disc to hemisphere
  · stereographically project hemisphere to Poincare disc

[video: www.geom.umn.edu/~crobes/hyperbolic/hypr/ibm/mkb/K2P.mpg]

graphics
  · Klein: 4x4 real matrix
  · Poincare: 2x2 complex matrix
Upper Half Space

"cut and unroll" Poincare
  · one point on circle goes to infinity

[demo: www.geom.umn.edu/~crobles/hyperbolic/hypr/modl/uhp/uhpjava.html]
Models, 3D

Klein/projective  Poincare/conformal  "insider"

[http://graphics.stanford.edu/papers/webviz/]

- Upper Half Space
- Minkowski
3D Insider

insider: camera also moves by hyperbolic rules
  · cool, but limited visibility

[demo]
3D Klein

3-hyperboloid projects to solid ball
3D Minkowski

3-hyperboloid embedded in 4D space
light cone: special relativity
  · diagrams in 2D for clarity

timelike: inside cone, speed < c
lightlike: on cone, speed = c
spacelike: outside cone, speed > c
  · can't affect

[appletree.mta.ca/courses/physics/4701/EText/LightCone.html]