Focus+Context

Lecture 12 CPSC 533C, Spring 2004

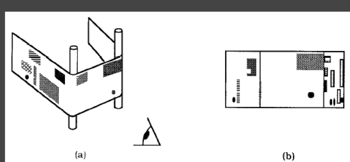
25 Feb 2003

Focus+Context

- Leung and Apperly taxonomy
  A Review and Taxonomy of Distortion-Oriented Presentation Techniques. Y.K. Leung and M.D. Apperley, ACM Transactions on Computer-Human Interaction, Vol. 1, No. 2, June 1994, pp. 126-160. [http://www.ai.mit.edu/people/jimmylin/papers/Leung94.pdf]
- Nonlinear Magnification Fields
  Nonlinear Magnification Fields. Alan Keahey, Proc InfoVis 1997 [http://citeseer.nj.nec.com/keahey97nonlinear.html]
- 2D Hyperbolic Trees
  The Hyperbolic Browser: A Focus + Context Technique for Visualizing Large Hierarchies. John Lamping and Ramana Rao, Proc SIGCHI '95. [http://citeseer.nj.nec.com/lamping95focuscontext.html]
- 3D Hyperbolic Graphs
  H3: Laying Out Large Directed Graphs in 3D Hyperbolic Space. Tamara Munzner, Proc InfoVis 97 [http://graphics.stanford.edu/papers/h3/]
- TreeJuxtaposer
  TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. Munzner, Guimbretiere, Tasiran, Zhang, and Zhou. SIGGRAPH 2003. [http://www.cs.ubc.ca/~tmm/papers/tj/]
- hyperbolic geometry background, if time

Intuition

- move part of surface closer to eye

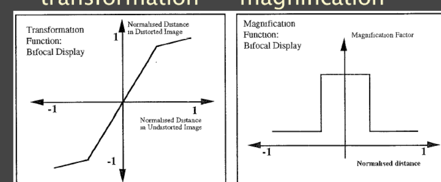


- stretchable rubber sheet
- borders tacked down

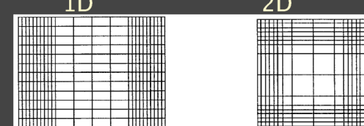
- merge overview and detail into combined view

Bifocal

transformation magnification

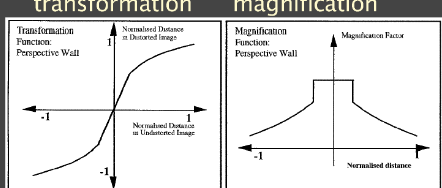


1D 2D

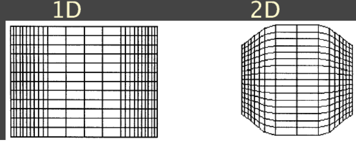


Perspective Wall

transformation magnification

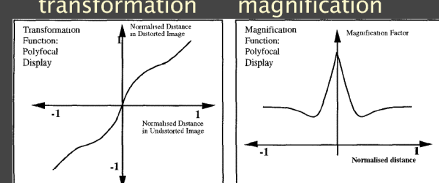


1D 2D

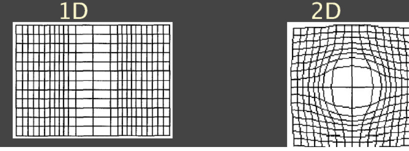


Polyfocal: Continuous Mag

transformation magnification

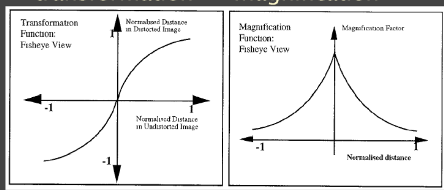


1D 2D

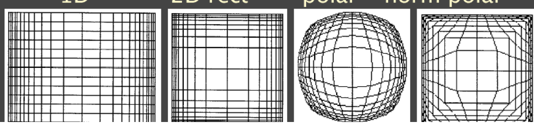


Fisheye Views: Continuous Mag

transformation magnification

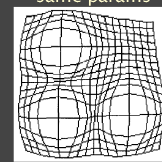


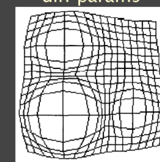
1D 2D rect polar norm polar



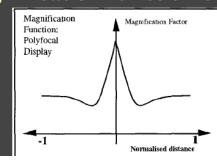
Multiple Foci

same params diff params





polyfocal magnification function dips allow this



Nonlinear Magnification Functions

transformation
- distortion

magnification
- derivative of transformation

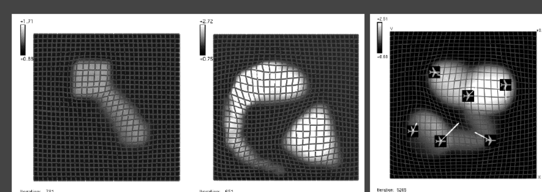
directionality
- easy: compute transformation given magnification
  - derivative
- hard: compute magnification given transformation
  - integration

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

Expressiveness

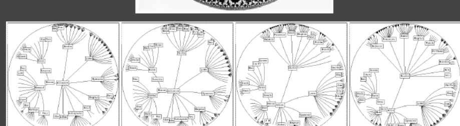
magnification is more intuitive control

- allow expressiveness, data-driven expansion



2D Hyperbolic Trees

fisheye effect from hyperbolic geometry



[video]

3D Hyperbolic Graphs: H3

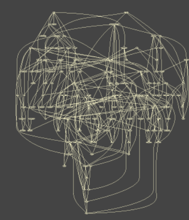
task
- browsing large quasi-hierarchical graphs

[Munzner 1997, 1998a, 1998b]

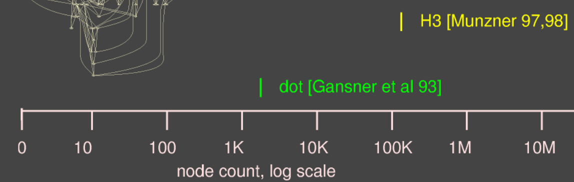
Previous work: graph drawing

scalability bottleneck
- layout
- avoiding disorientation

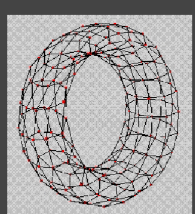
Previous work: graph drawing



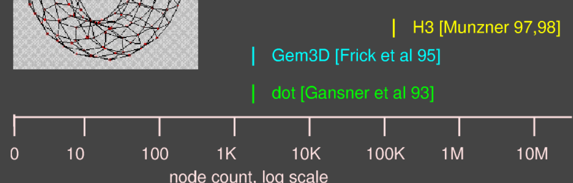
scalability bottleneck
- layout
- avoiding disorientation



Previous work: graph drawing

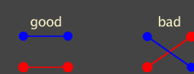


scalability bottleneck
- layout
- avoiding disorientation



Graph layout criteria

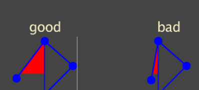
minimize
- crossings, area, bends/curves



Graph layout criteria

minimize
- crossings, area, bends/curves

maximize
- angular resolution, symmetry



Graph layout criteria

minimize
- crossings, area, bends/curves

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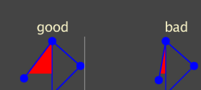
- angular resolution, symmetry



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

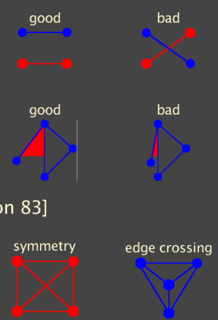
Graph layout criteria

minimize
- crossings, area, bends/curves

maximize
- angular resolution, symmetry

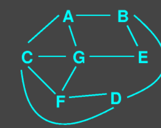
most criteria NP-hard
- edge crossings [Garey and Johnson 83]

incompatible
- [Brandenburg 88]



Layout

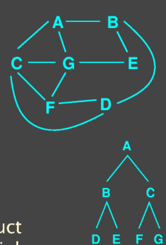
problem
- general problem is NP-hard



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

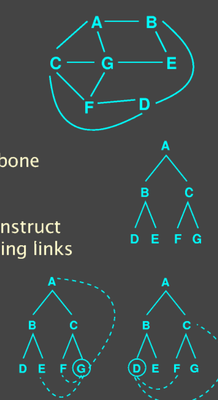


Layout

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

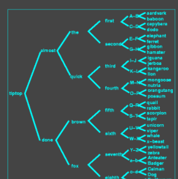
- non-tree links on demand



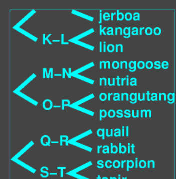
Avoiding disorientation

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

exponential in depth: node count, space needed



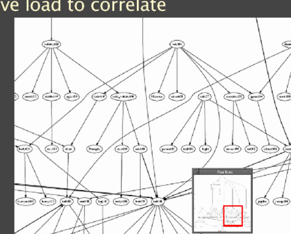
global overview



local detail

Overview and detail

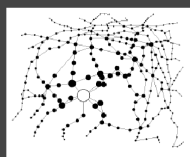
two windows: add linked overview
- cognitive load to correlate



solution
- merge overview, detail
- "focus+context"

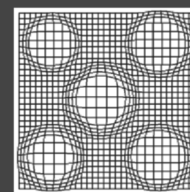
Previous work: focus+context

fisheye views [Furnas 86], [Sarkar et al 94]



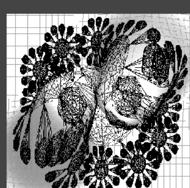
Previous work: focus+context

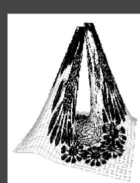
fisheye views [Furnas 86], [Sarkar et al 94]
nonlinear magnification [Keahey 96]



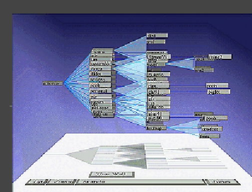
Previous work: focus+context

fisheye views [Furnas 86], [Sarkar et al 94]
nonlinear magnification [Keahey 96]
pliable surfaces [Carpendale et al 95]





Previous work: focus+context trees



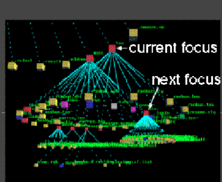
H3 [Munzner 97,98]

Cone Trees [Robertson et al 91]

0 10 100 1K 10K 100K 1M 10M

node count, log scale

Previous work: focus+context trees



H3 [Munzner 97,98]

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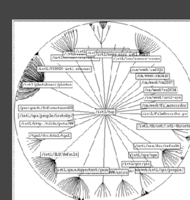


H3 [Munzner 97,98]

2D Hyp Trees [Lamping et al 94,95]

Fractal trees [Koike & Yoshihara 93]

Cone Trees [Robertson et al 91]

0 10 100 1K 10K 100K 1M 10M

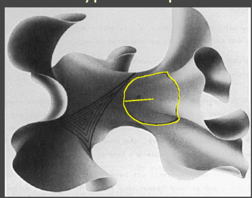
node count, log scale

Hyperbolic space background

geometry with exponential "amount of room"

- good match for exponential node count of trees

2D hyperbolic plane



[Thurston and Weeks 84]

hemisphere area

hyperbolic: exponential

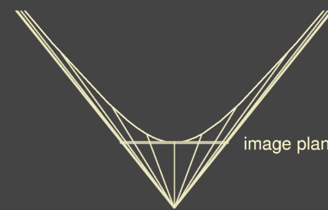
$$2\pi \sinh^2(r)$$

euclidean: polynomial

$$2\pi r^2$$

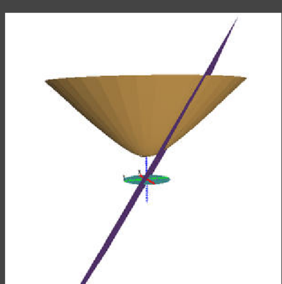
1D hyperbolic space

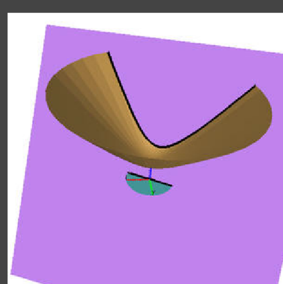
hyperbola projects to line



2D hyperbolic space

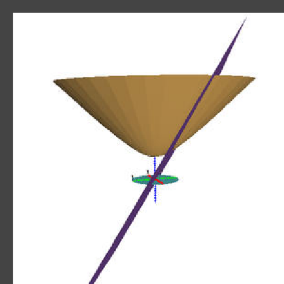
hyperboloid projects to disk

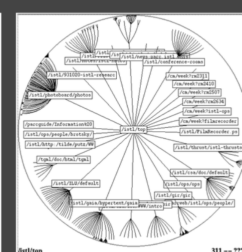




2D hyperbolic space

hyperboloid projects to disk

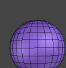




[Lamping et al 95]

3D hyperbolic space

3-hyperboloid projects to solid ball



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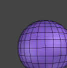
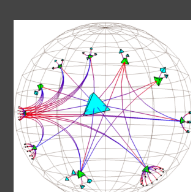
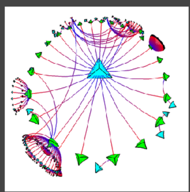


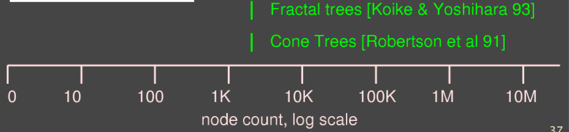
webviz [Munzner and Burchard 95]

- straightforward cone tree + 3D hyperbolic space
- poor information density



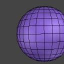
Contribution: focus+context graphs



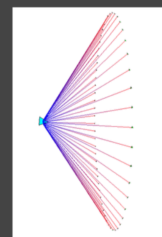


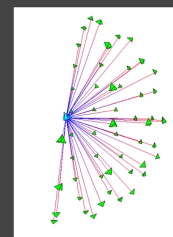
3D hyperbolic space

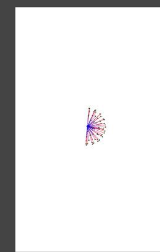
3-hyperboloid projects to solid ball



H3 layout
- circumference -> hemisphere

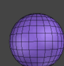






3D hyperbolic space

3-hyperboloid projects to solid ball



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

Formula	Euclidean	Hyperbolic
right-angle triangle	$\tan\theta = \frac{opp}{adj}$	$\tan\theta = \frac{\tanh(opp)}{\sinh(adj)}$
right-angle triangle	$\sin\theta = \frac{opp}{hyp}$	$\sin\theta = \frac{\sinh(opp)}{\sinh(hyp)}$
circle area	πr^2	$2\pi(\cosh(r) - 1)$
hemisphere area	$2\pi r^2$	$2\pi \sinh^2(r)$
spherical cap area	$2\pi r^2(1 - \cos\phi)$	$2\pi \sinh^2 r(1 - \cos\phi)$

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

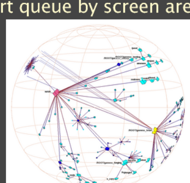
progressive refinement
- gradually improve image vs. standard Z-buffer
- common in graphics [Bergman et al 86]
- far less attention in infovis

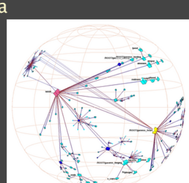
H3Viewer algorithm

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

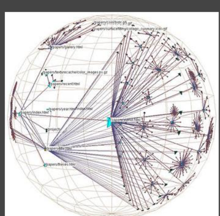
performance

- 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

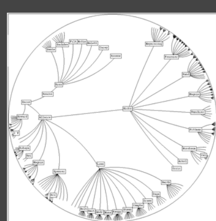
H3 results: scalability

information density: 10x better

H3



2D PARC Tree

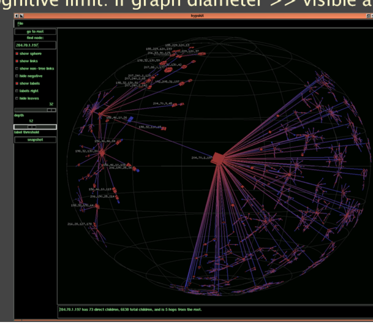


	center	fringe
3D	dozens	thousands
2D	dozens	hundreds

H3 discussion: scalability

focus+context layout

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



TreeJuxtaposer

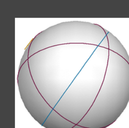
extend cognitive limit

- move from local F+C to global F+C

Noneuclidean geometry

Euclid's 5th Postulate

- exactly 1 parallel line



[torus.math.uiuc.edu/jms/java/dragsphere]

spherical

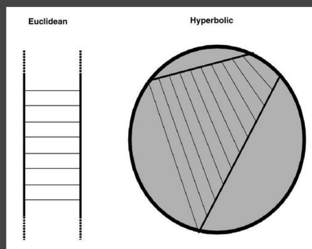
- geodesic = great circle
- no parallels

hyperbolic

- infinte parallels

Parallel vs. equidistant

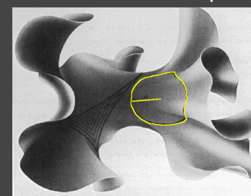
euclidean: inseparable
hyperbolic: different



Exponential "amount of room"

good match for exponential node count of trees

2D hyperbolic plane
embedded in 3D space



[Thurston and Weeks 84]

hemisphere area

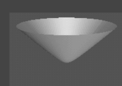
hyperbolic: exponential
$2\pi \sinh^2(r)$

euclidean: polynomial
$2\pi r^2$

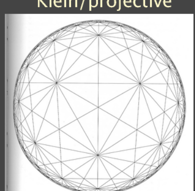
Models, 2D

not just round!

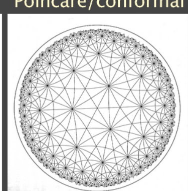
Minkowski



Klein/projective



Poincare/conformal

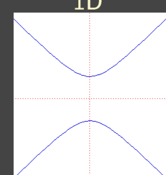


Upper Half Space

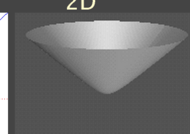
[Three Dimensional Geometry and Topology, William Thurston, Princeton University Press]

Minkowski

1D



2D

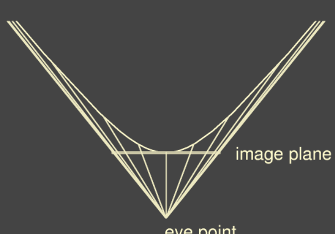


[www-gap.dcs.st-and.ac.uk/~history/Curves/Hyperbola.html]
[www.geom.umn.edu/~crobles/hyperbolic/hypr/modl/mnkw/]

the hyperboloid itself
embedded one dimension higher

1D Klein

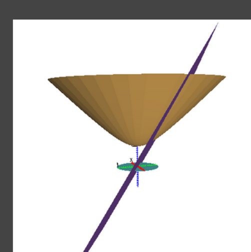
hyperbola projects to line

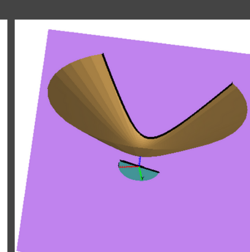


2D Klein

hyperboloid projects to disk

[demo: Geomview]
[video: www.geom.umn.edu/~crobles/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/]

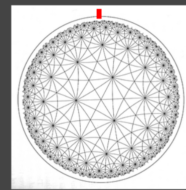
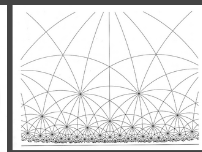
transformation from Klein to Poincare
- vertically project disc to hemisphere
- stereographically project hemisphere to Poincare disc

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

graphics
- Klein: 4x4 real matrix
- Poincare: 2x2 complex matrix

Upper Half Space

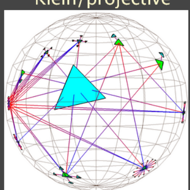
"cut and unroll" Poincare
- one point on circle goes to infinity

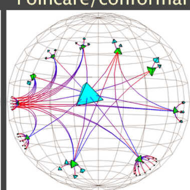
[demo: www.geom.umn.edu/~crobles/hyperbolic/hypr/modl/uhp/uhpjava.html

Models, 3D

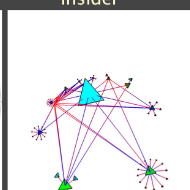
Klein/projective



Poincare/conformal



"insider"

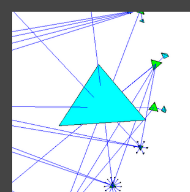
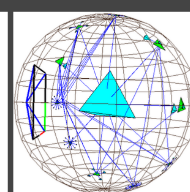


[http://graphics.stanford.edu/papers/webviz/]

- Upper Half Space
- Minkowski

3D Insider

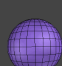
insider: camera also moves by hyperbolic rules
- cool, but limited visibility

[demo]

3D Klein

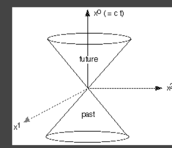
3-hyperboloid projects to solid ball



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]