Focus+Context

Lecture 13 CPSC 533C, Fall 2004

1 Nov 2004

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/]

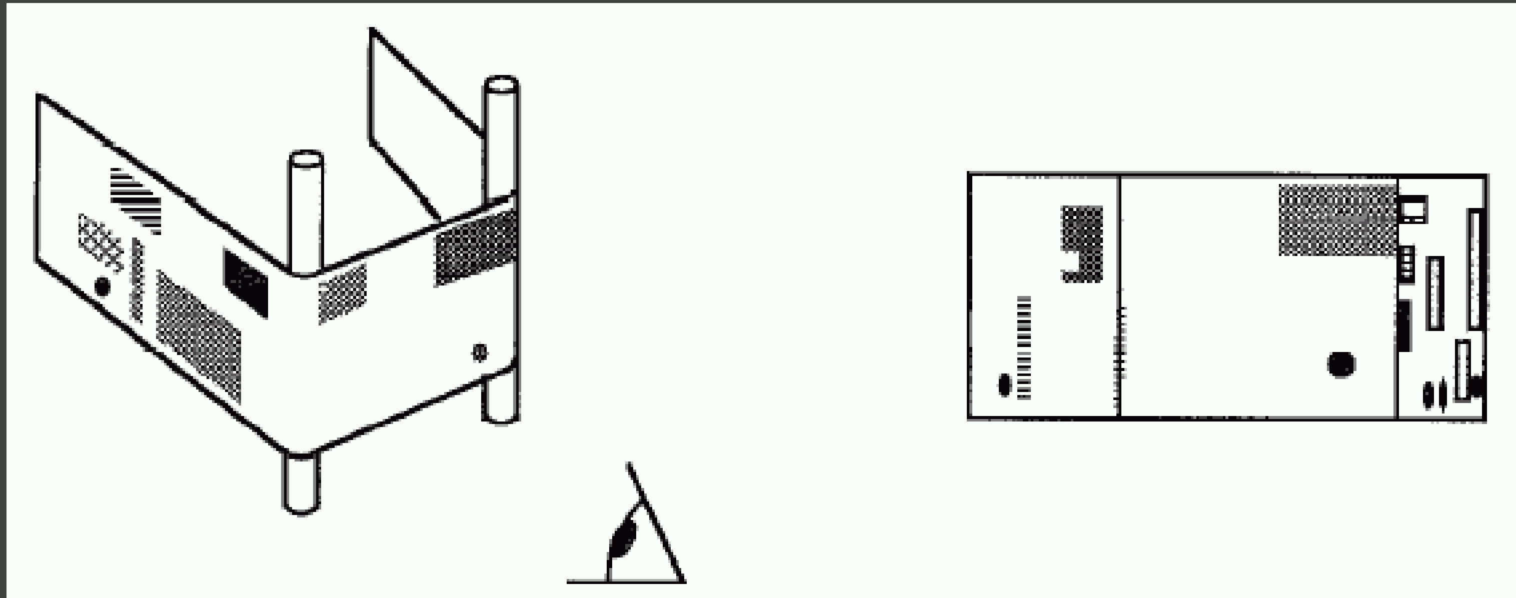
TreeJuxtaposer

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



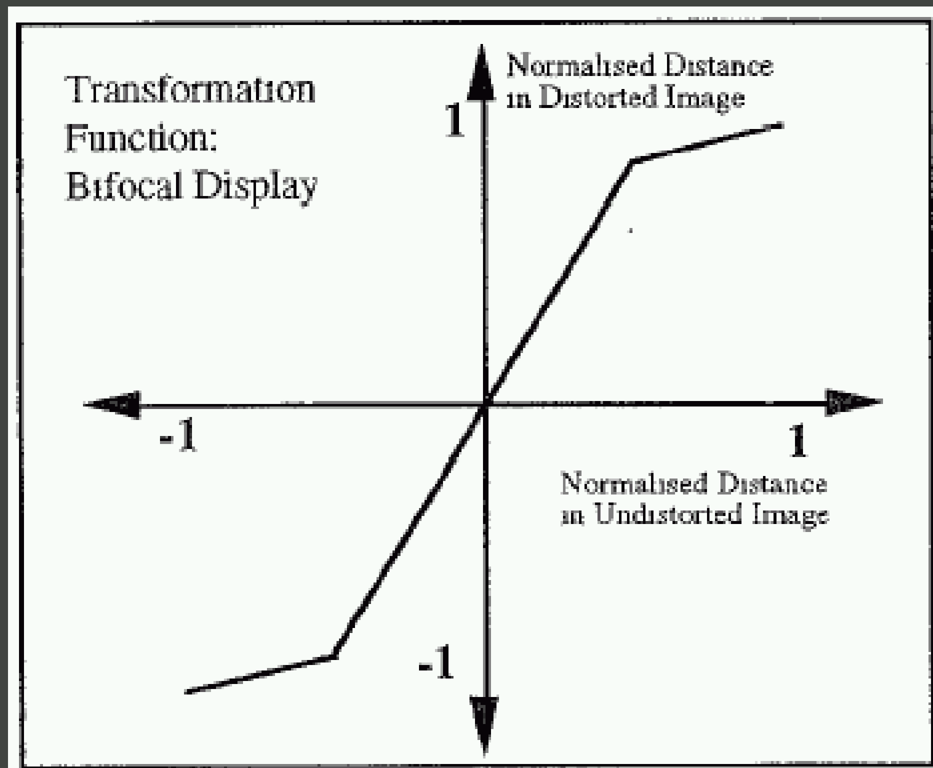
(a) (b)

stretchable rubber sheet
borders tacked down

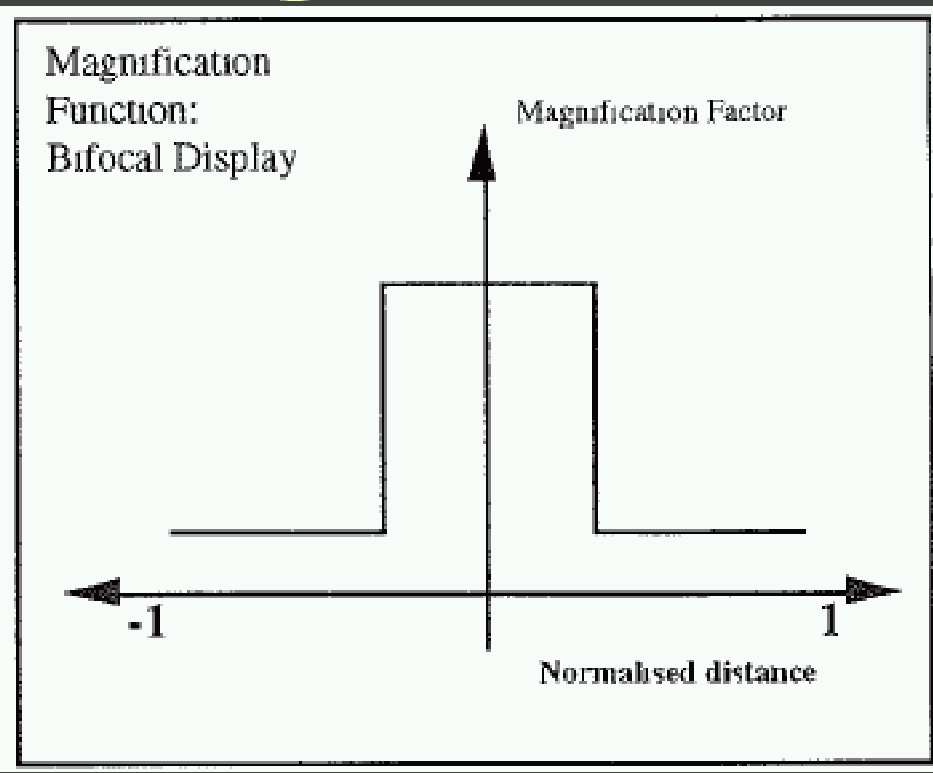
merge overview and detail into combined view

Bifocal

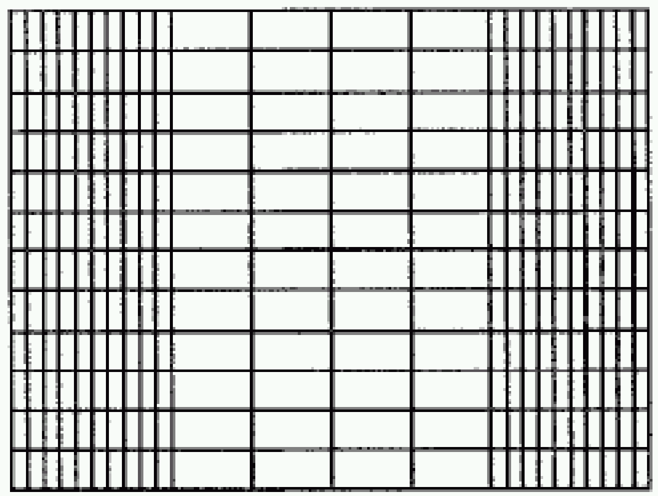
transformation



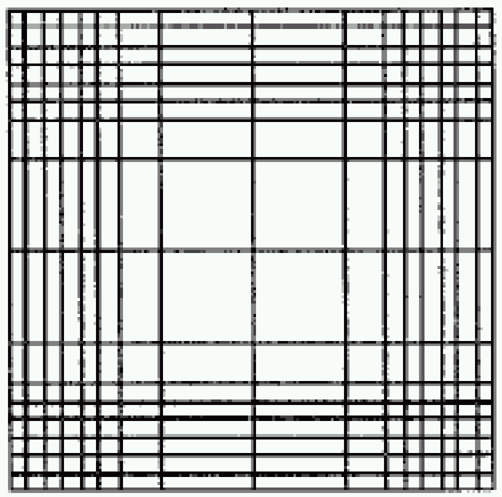
magnification



1D

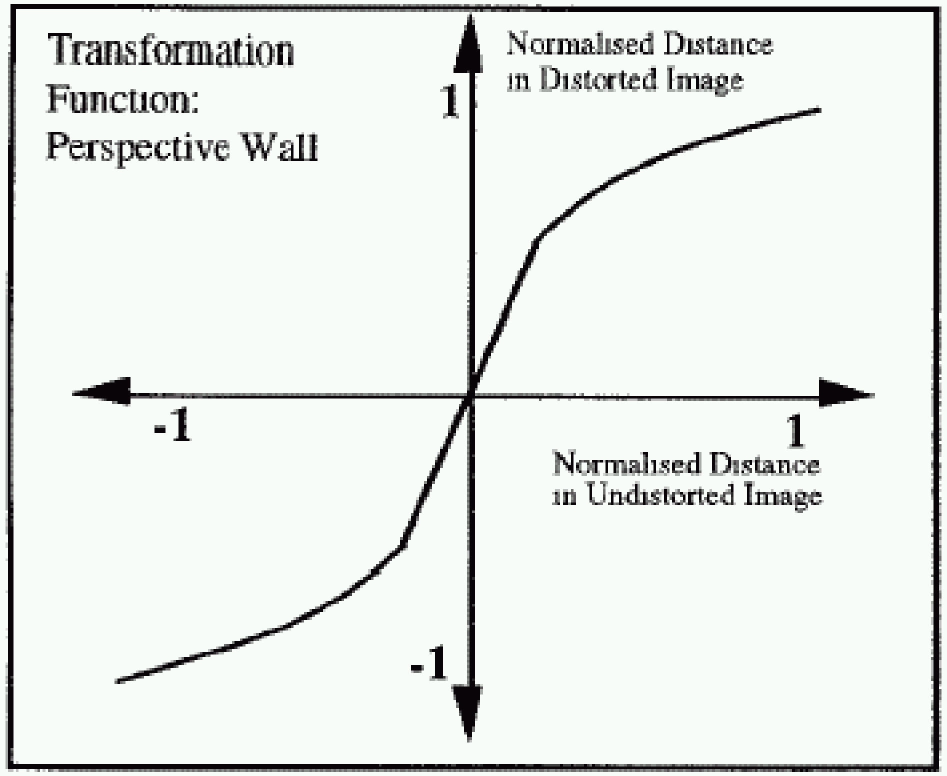


2D

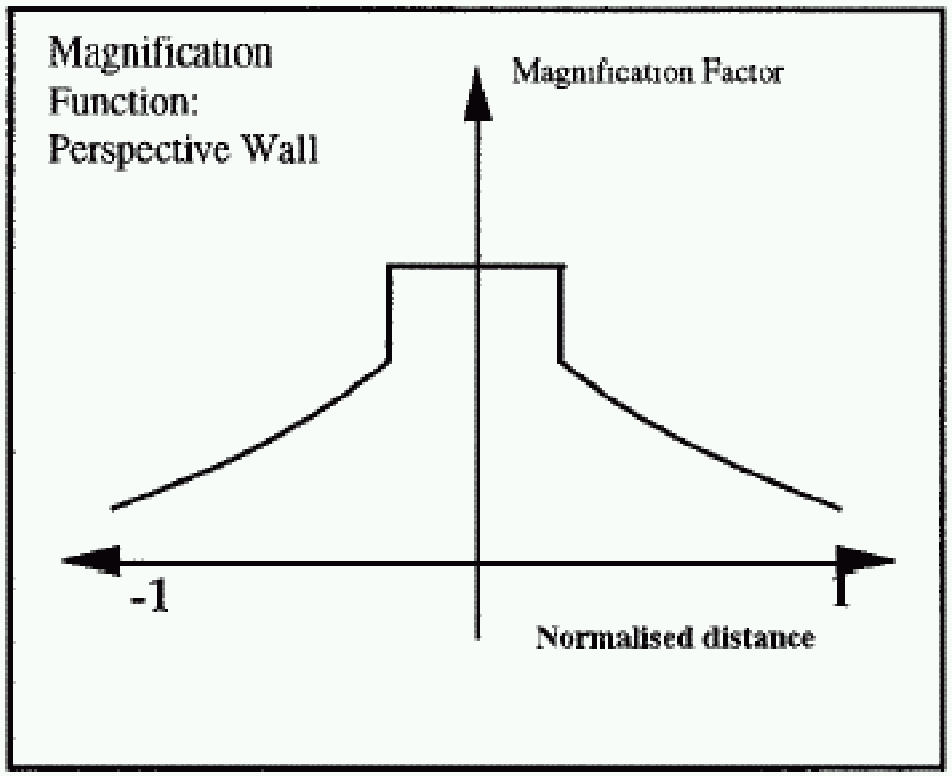


Perspective Wall

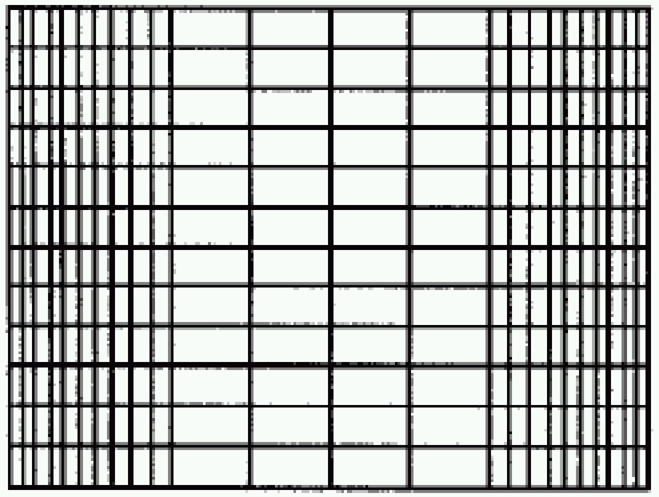
transformation



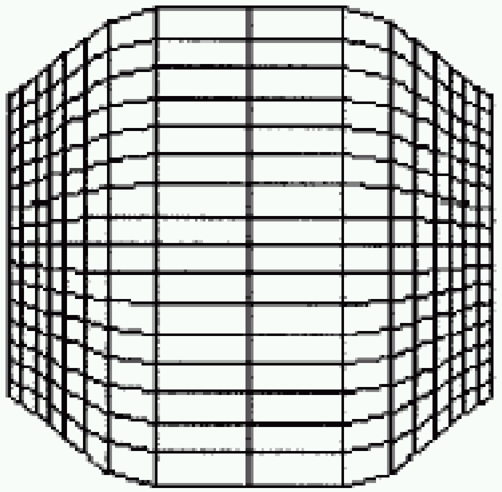
magnification



1D

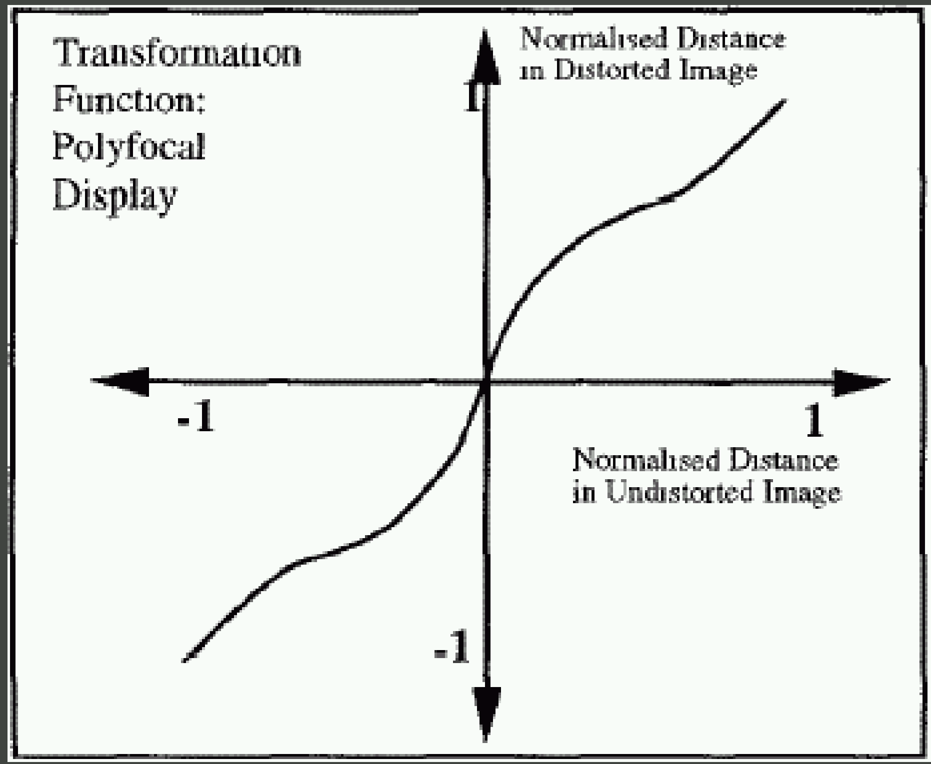


2D

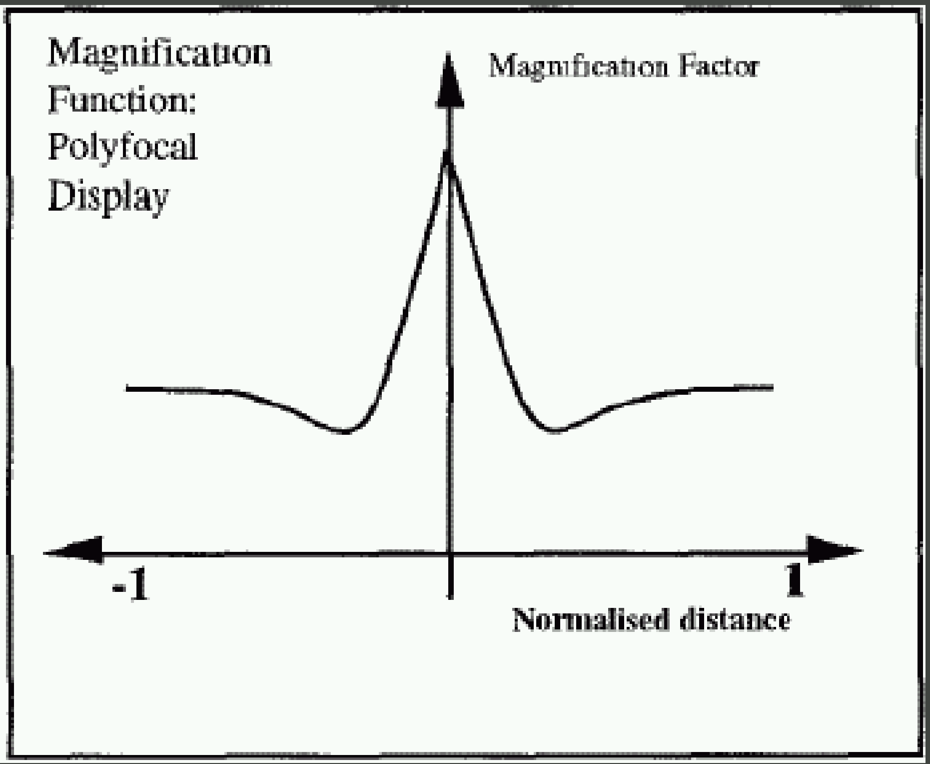


Polyfocal: Continuous Mag

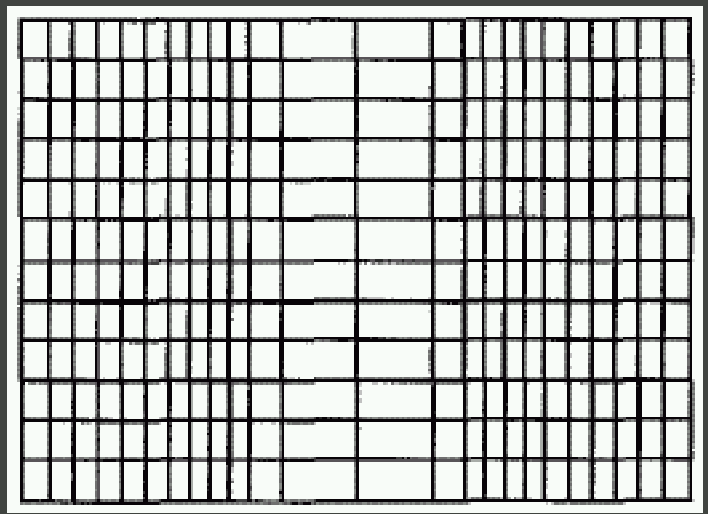
transformation



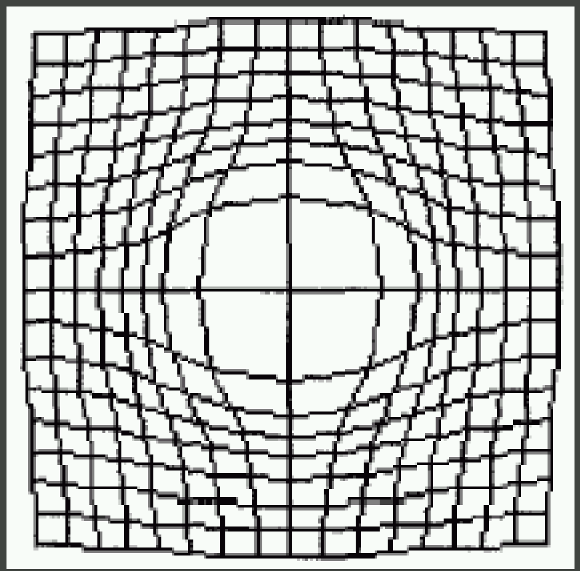
magnification



1D

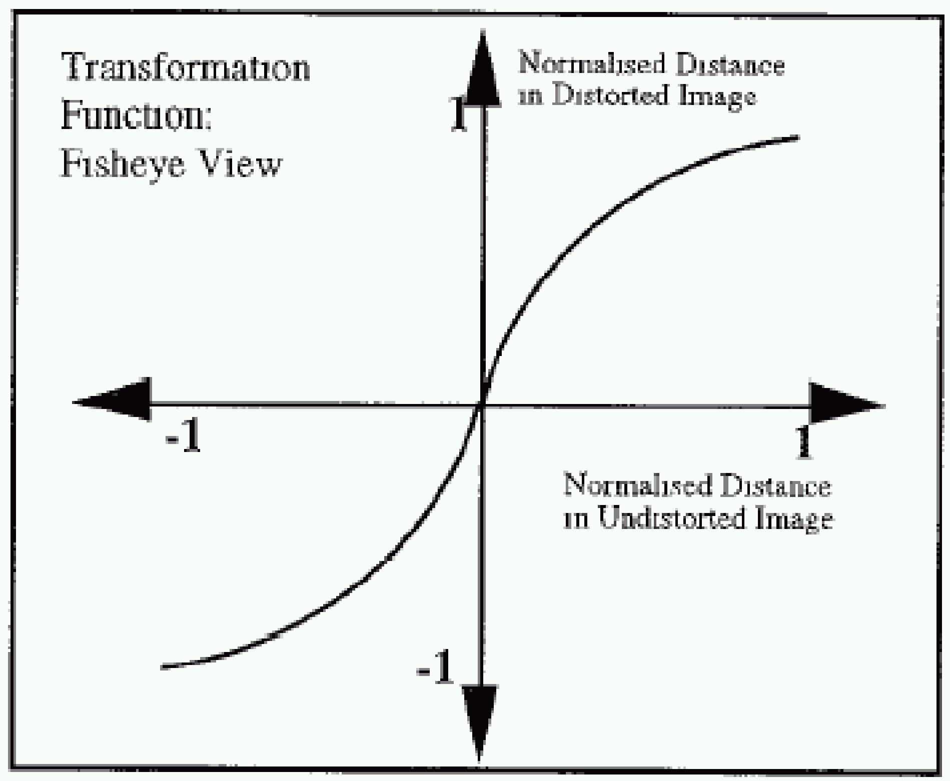


2D

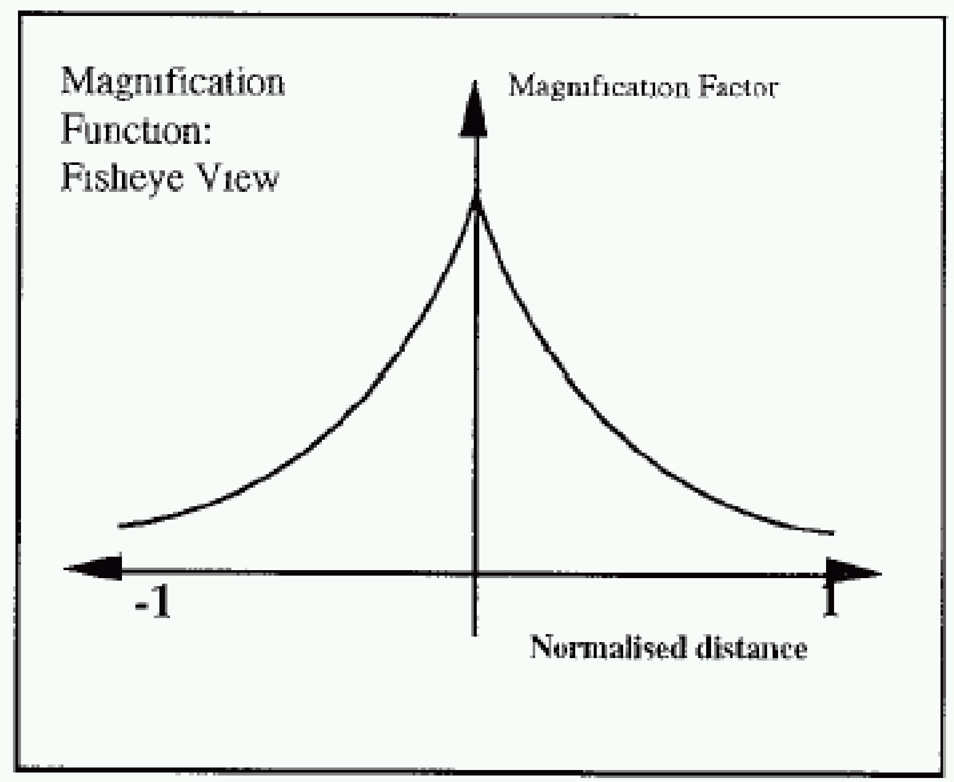


Fisheye Views: Continuous Mag

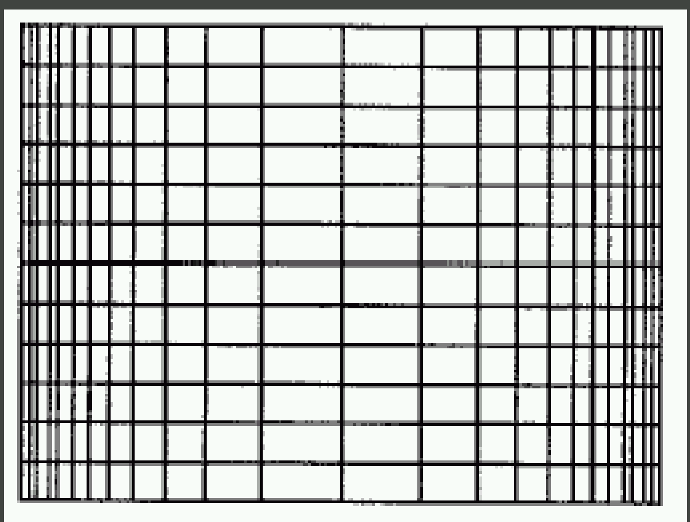
transformation



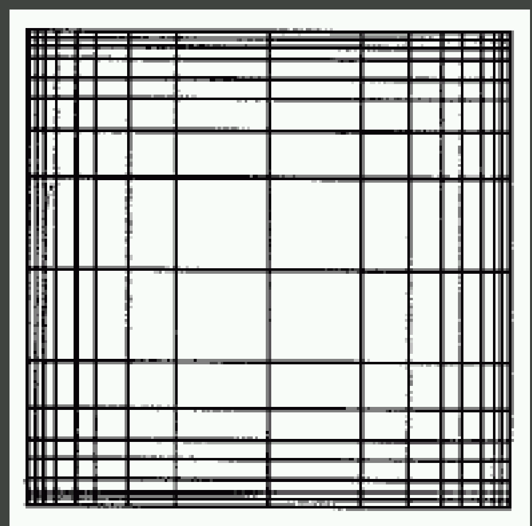
magnification



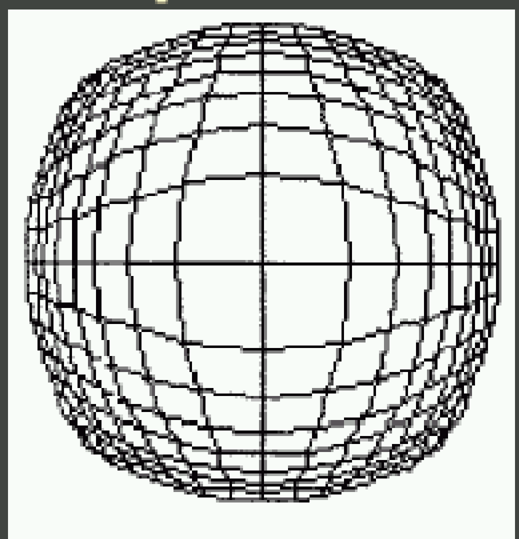
1D



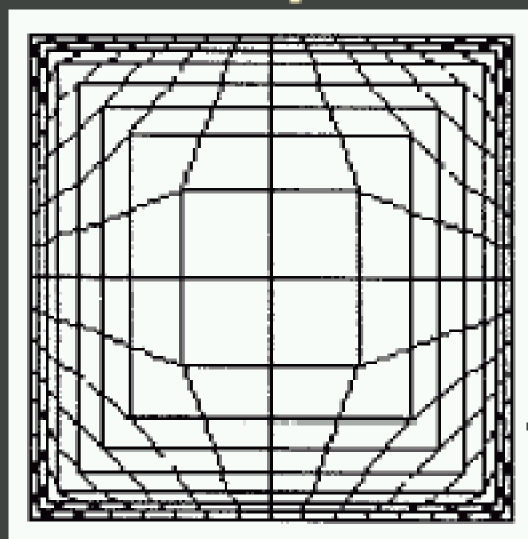
2D rect



polar

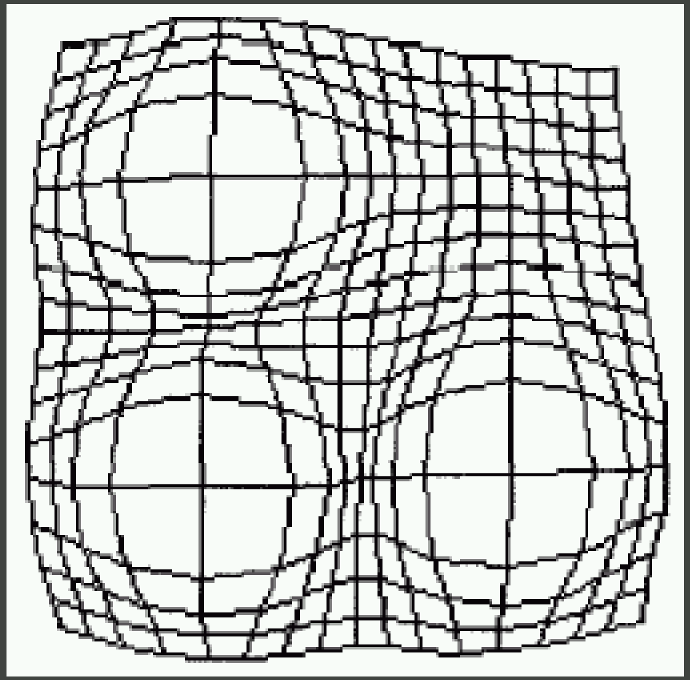


norm polar

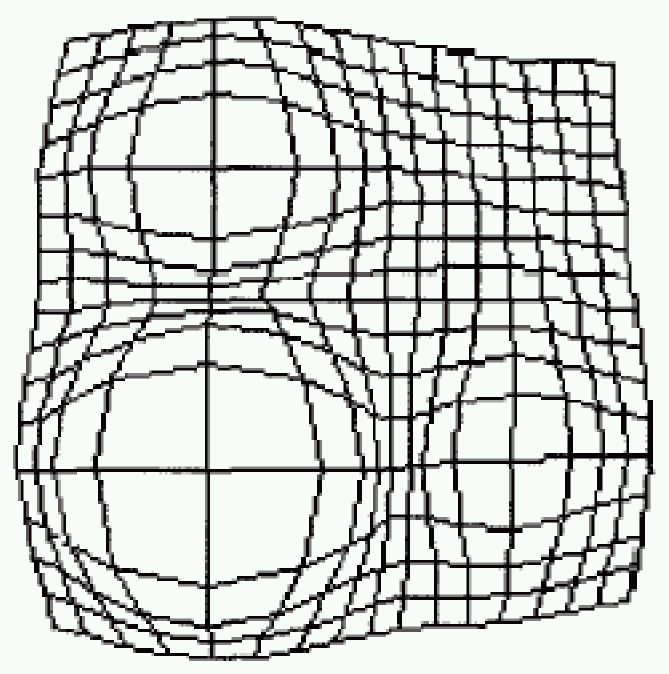


Multiple Foci

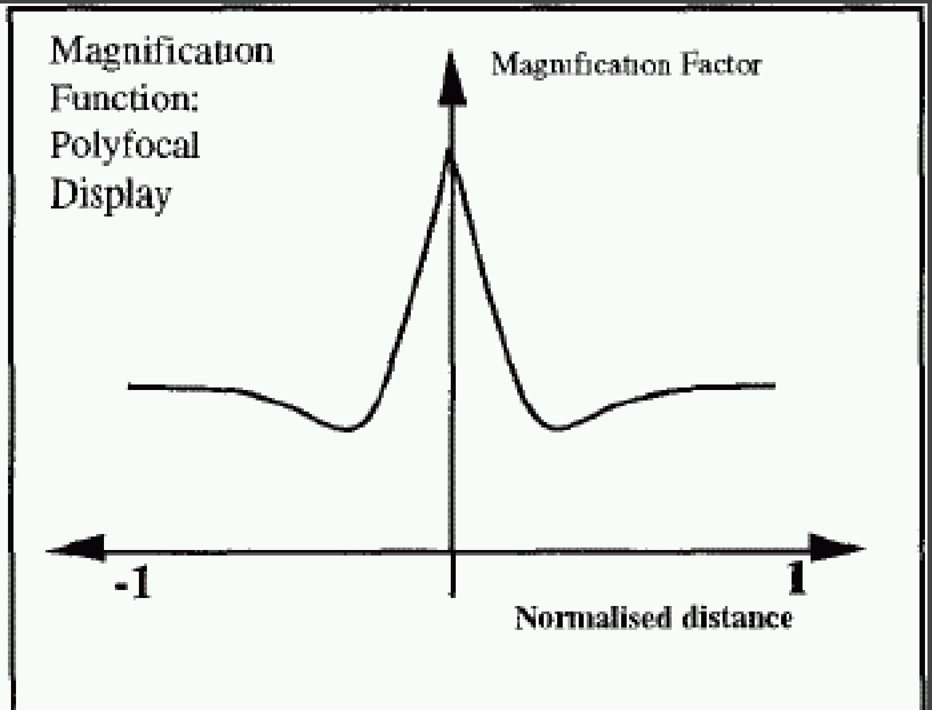
same params



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

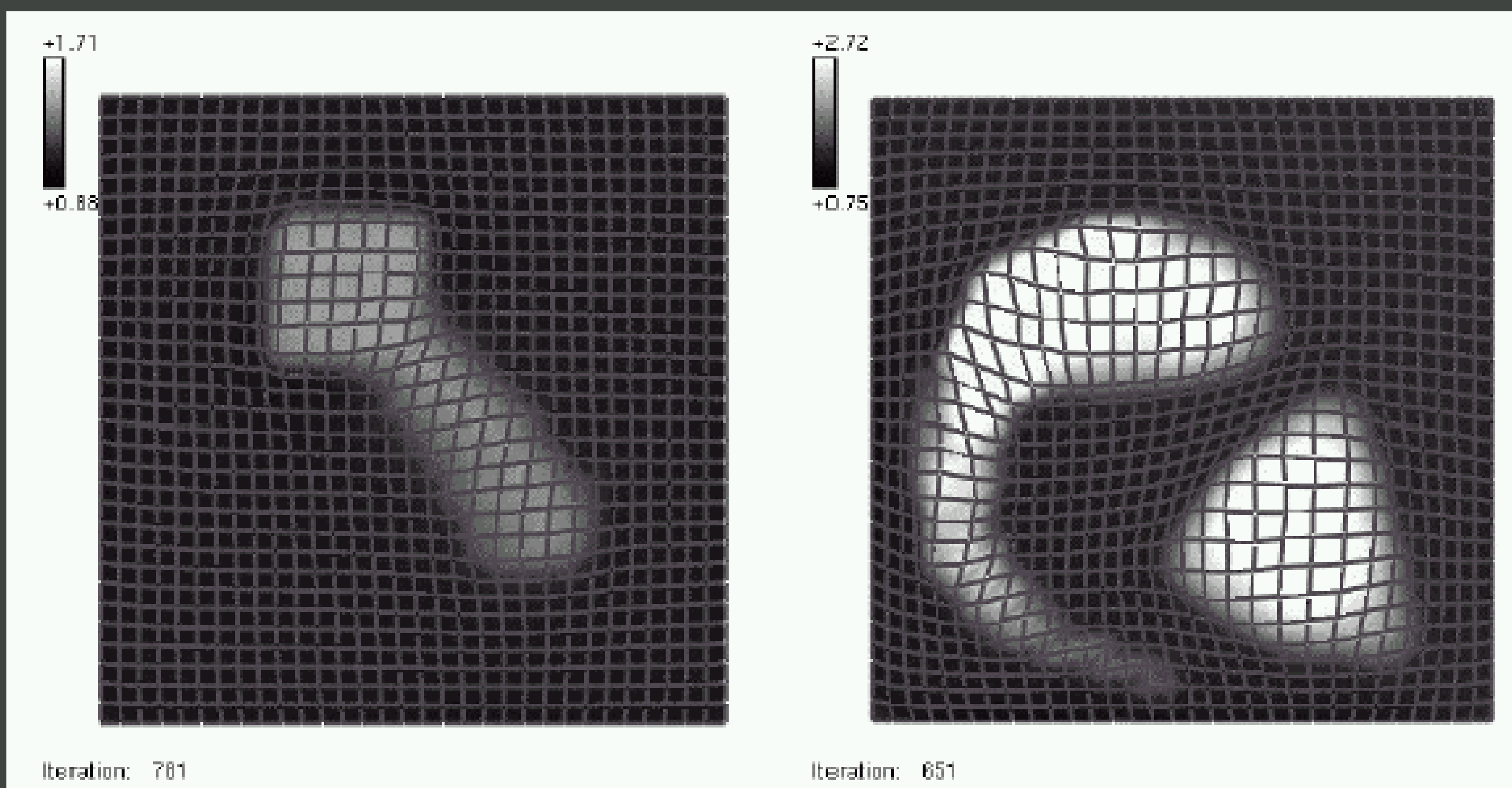
new mathematical framework

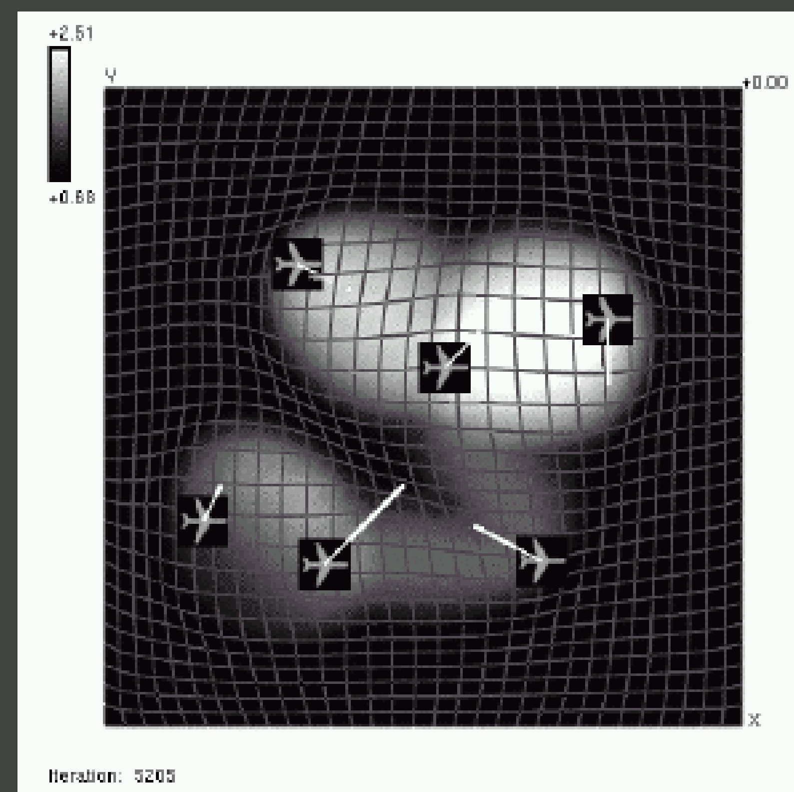
- approximate integration, iterative refinement
- minimize "error mesh"

Expressiveness

magnification is more intuitive control

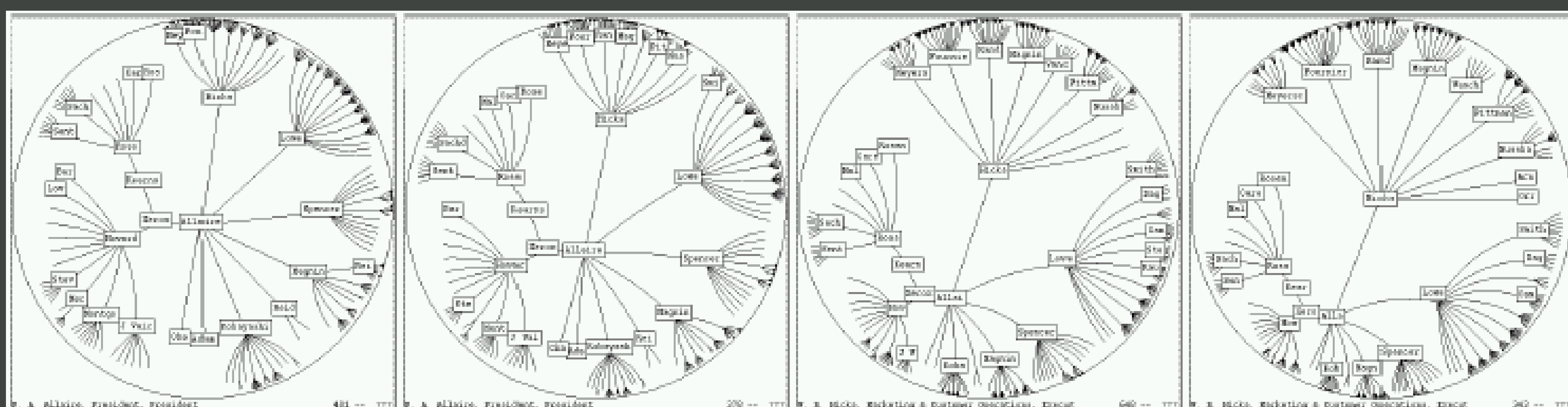
- allow expressiveness, data-driven expansion





2D Hyperbolic Trees

fisheye effect from hyperbolic geometry

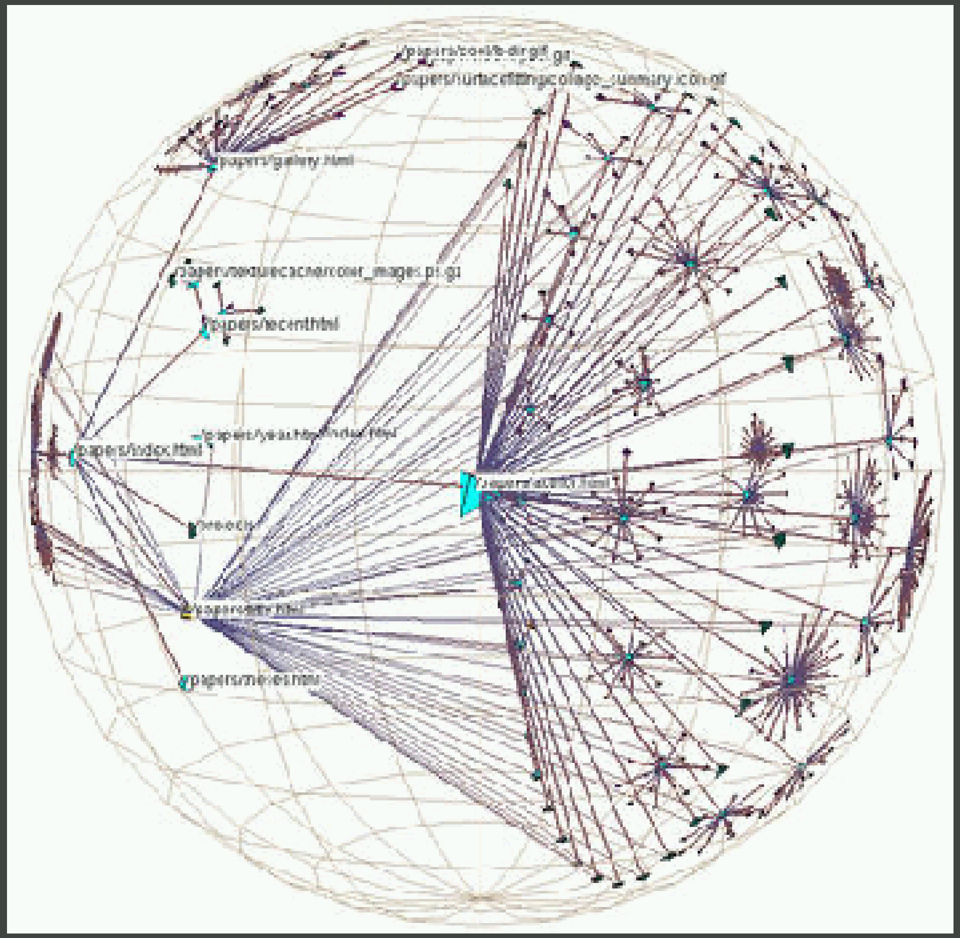


[video]

3D Hyperbolic Graphs: H3

task

- browsing large quasi-hierarchical graphs



[Munzner 1997, 1998a, 1998b]

Previous work: graph drawing

scalability bottleneck
- layout
- avoiding disorientation

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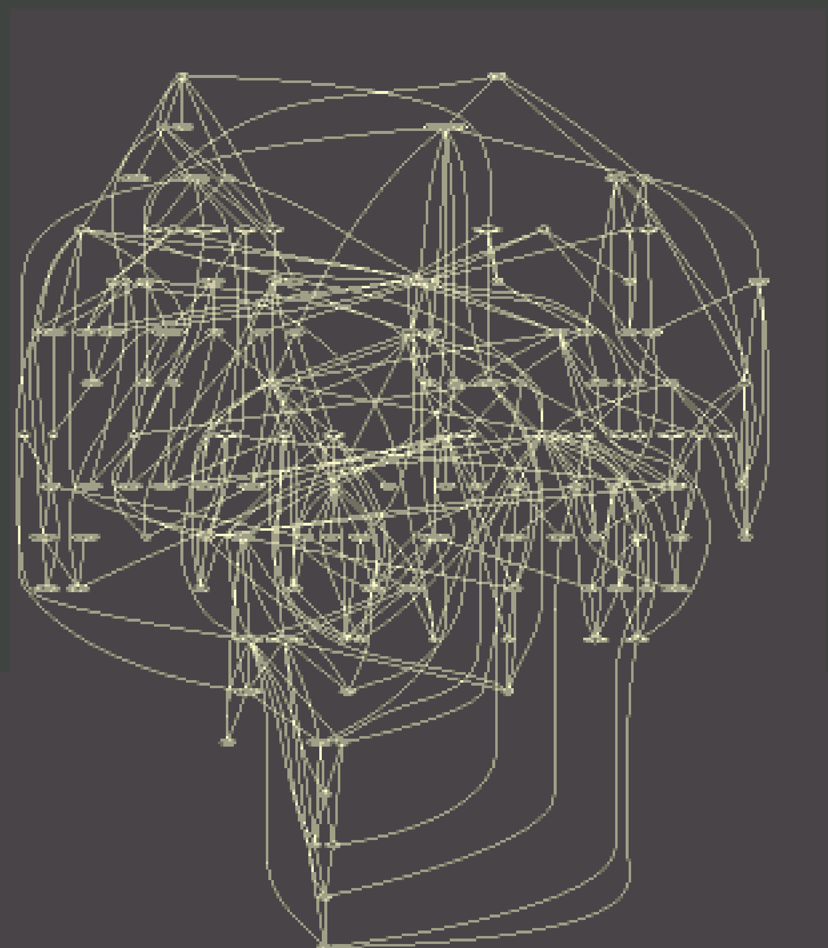
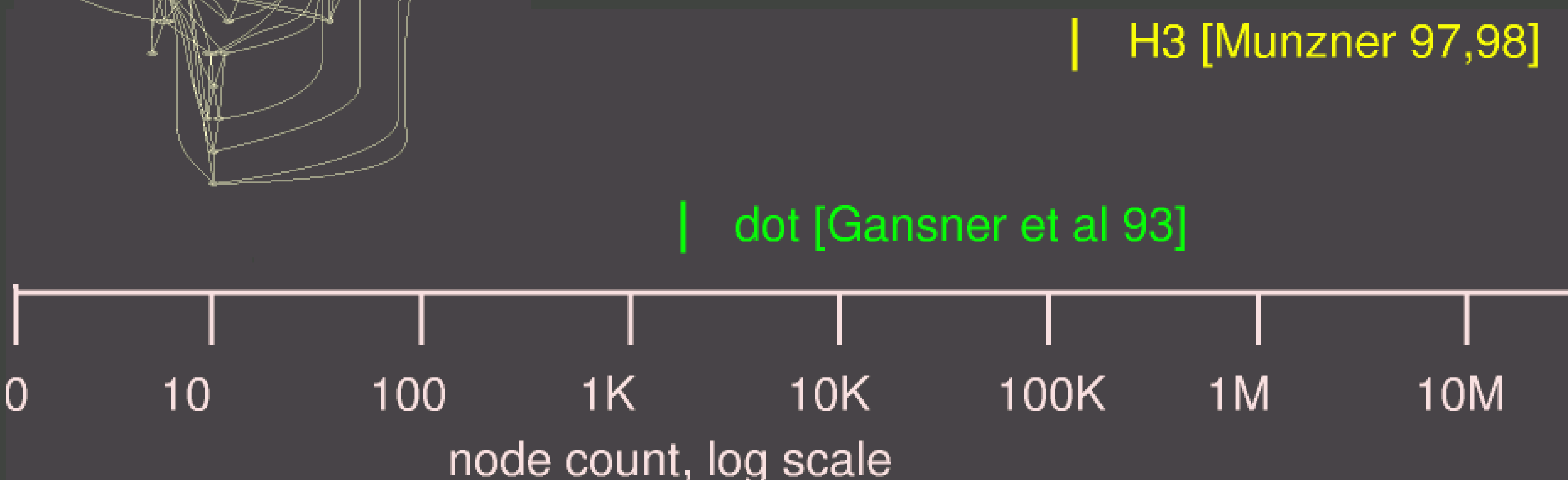
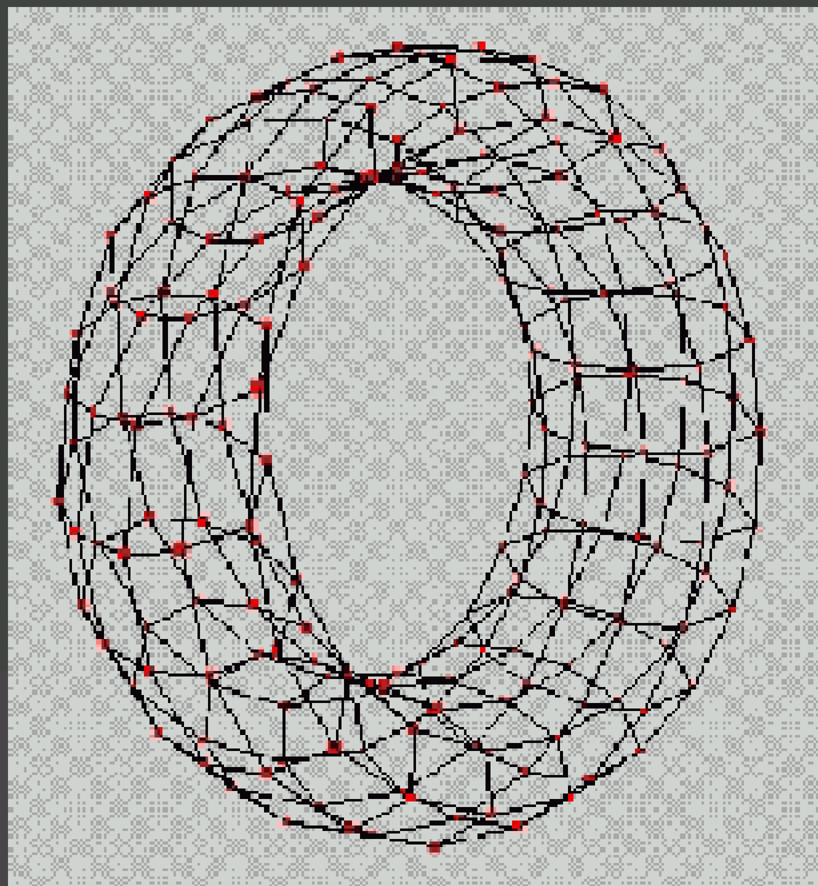
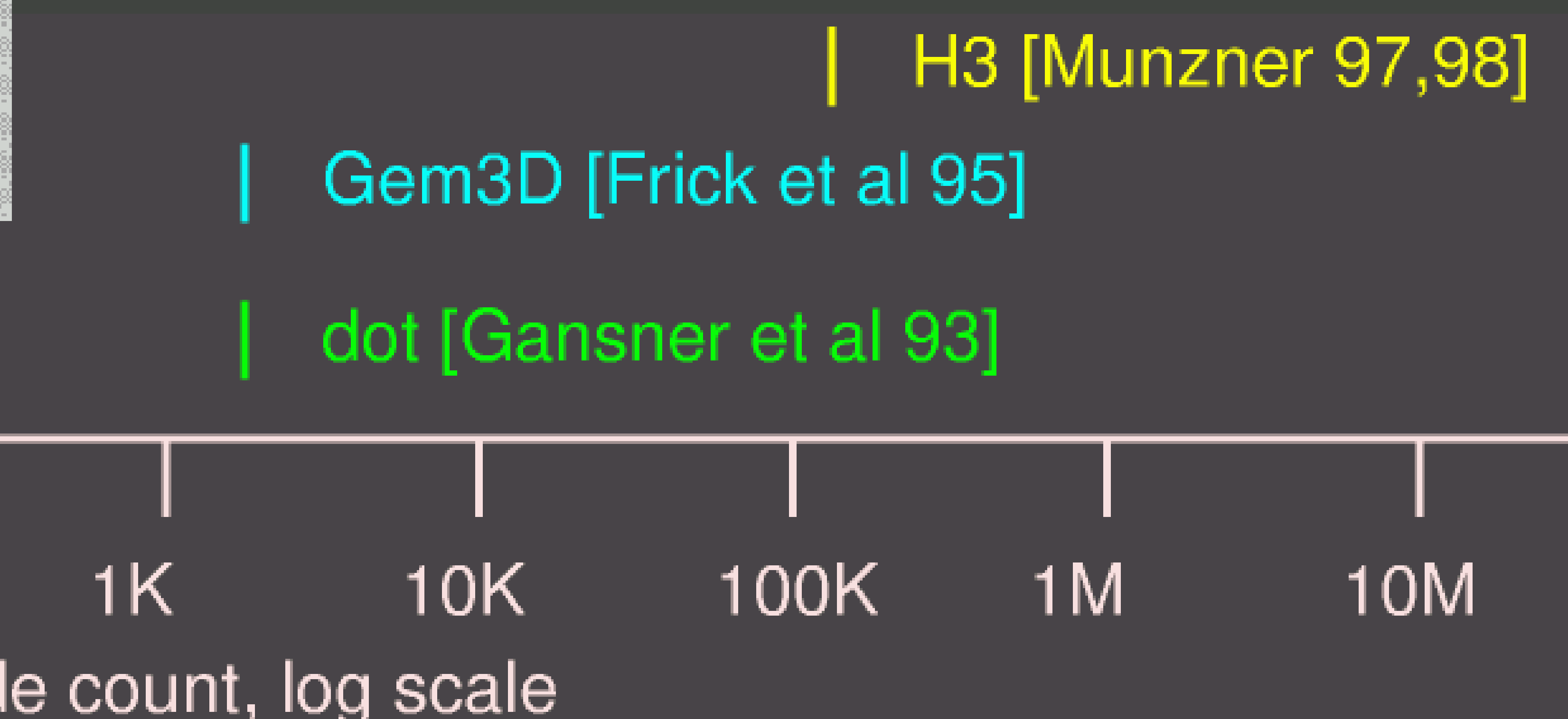




Previous work: graph drawing



scalability bottleneck
- layout
- avoiding disorientation

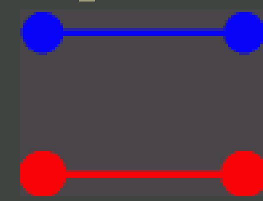


Graph layout criteria

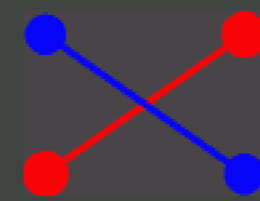
minimize

- crossings, area, bends/curves

good



bad



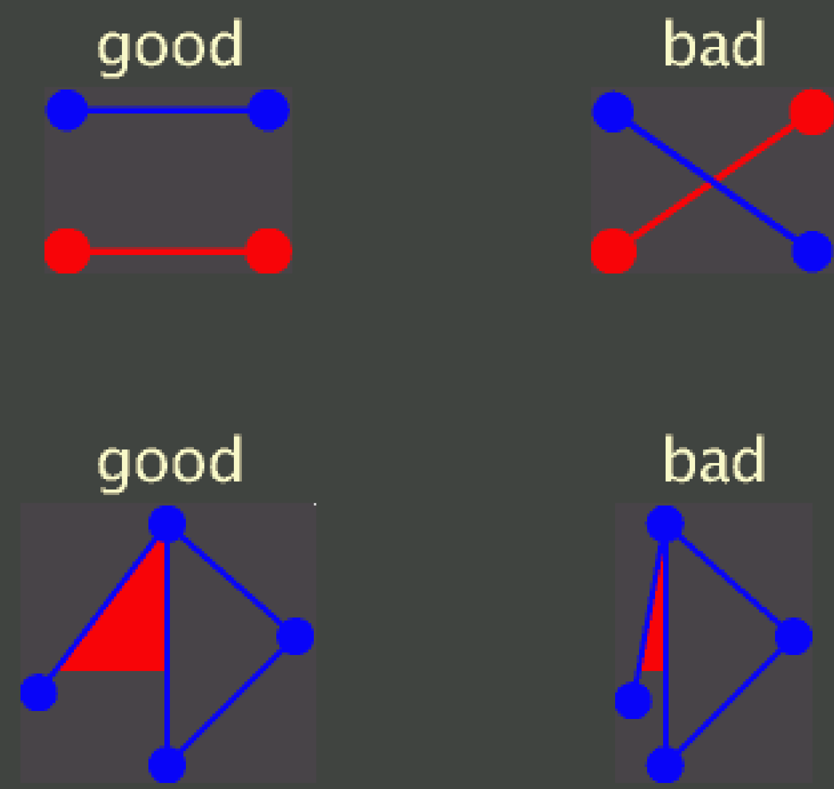
Graph layout criteria

minimize

- crossings, area, bends/curves

maximize

- angular resolution, symmetry



Graph layout criteria

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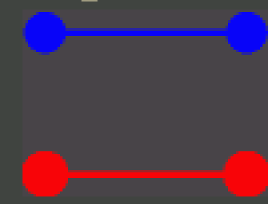

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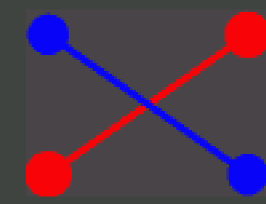

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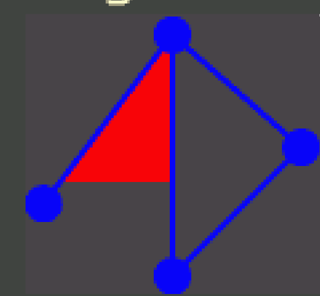

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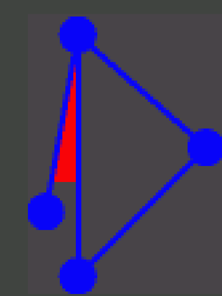


most criteria NP-hard

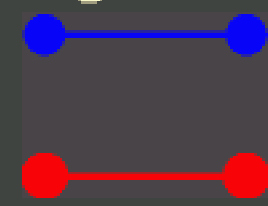
- edge crossings [Garey and Johnson 83]

Graph layout criteria

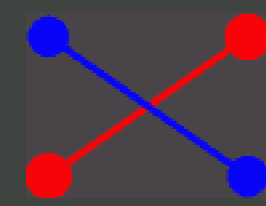
minimize

- crossings, area, bends/curves

good



bad



maximize

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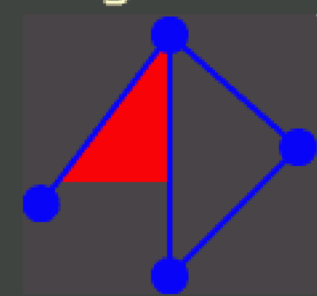
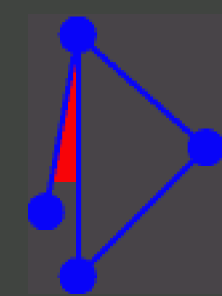
good



bad



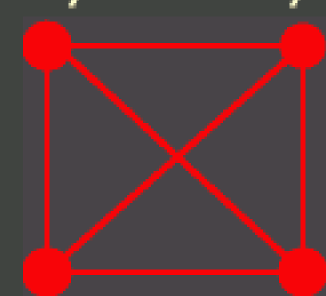
most criteria NP-hard

- edge crossings [Garey and Johnson 83]

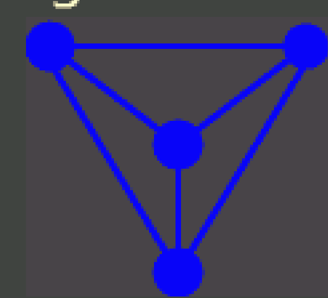
incompatible

- [Brandenburg 88]

symmetry



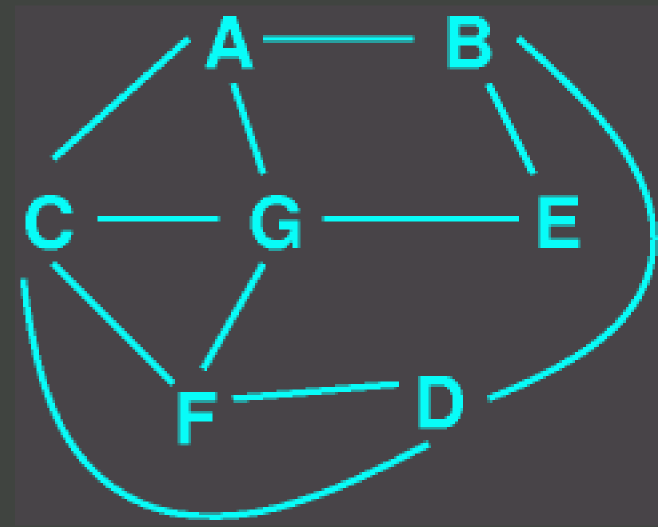
edge crossing



Layout

problem

- general problem is NP-hard



Layout

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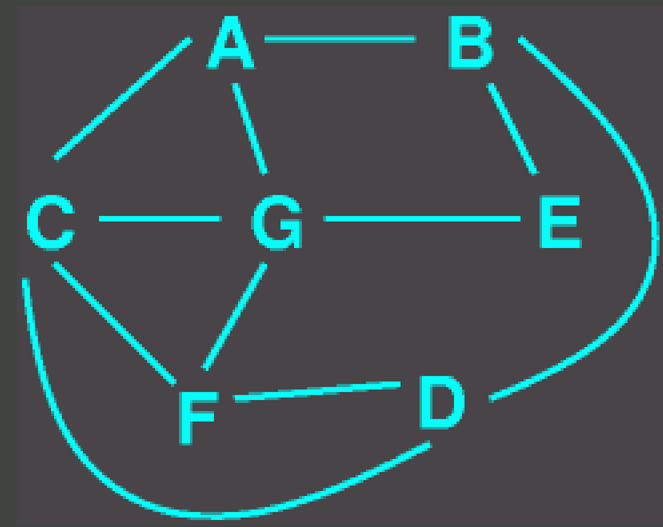
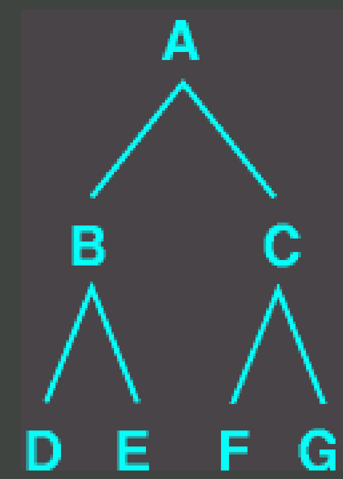
- general problem is NP-hard

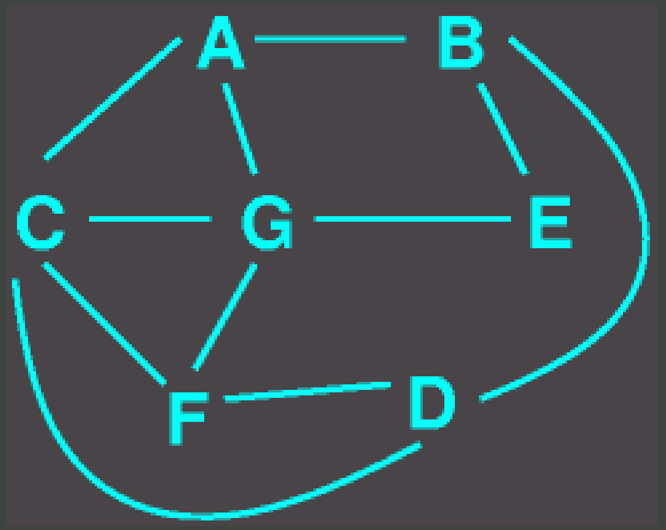


solution

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



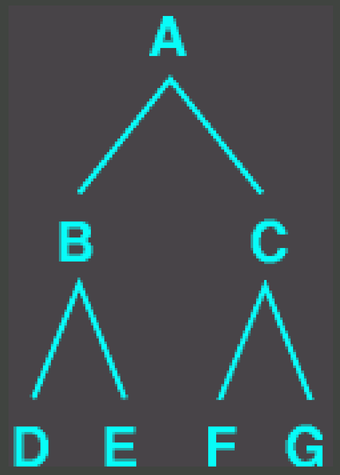
Layout



problem

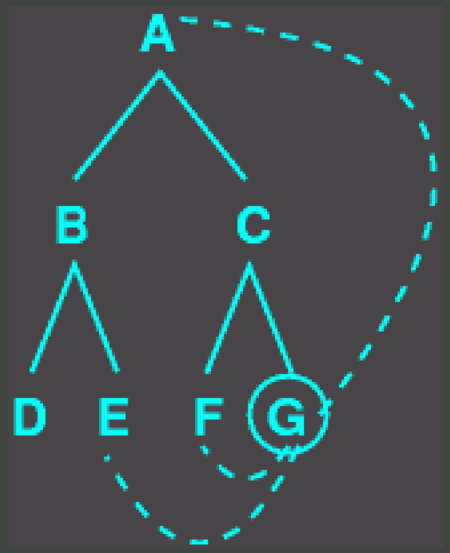
- general problem is NP-hard

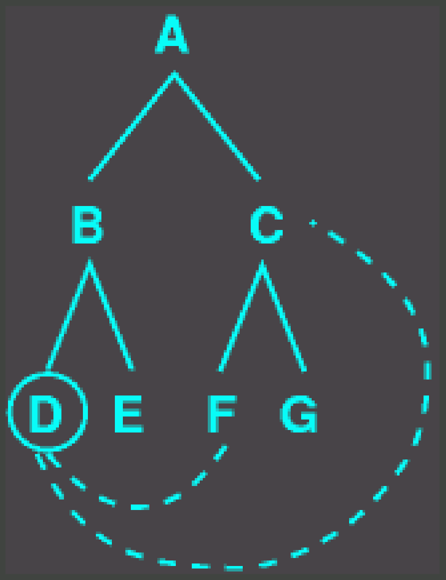
solution



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

- non-tree links on demand



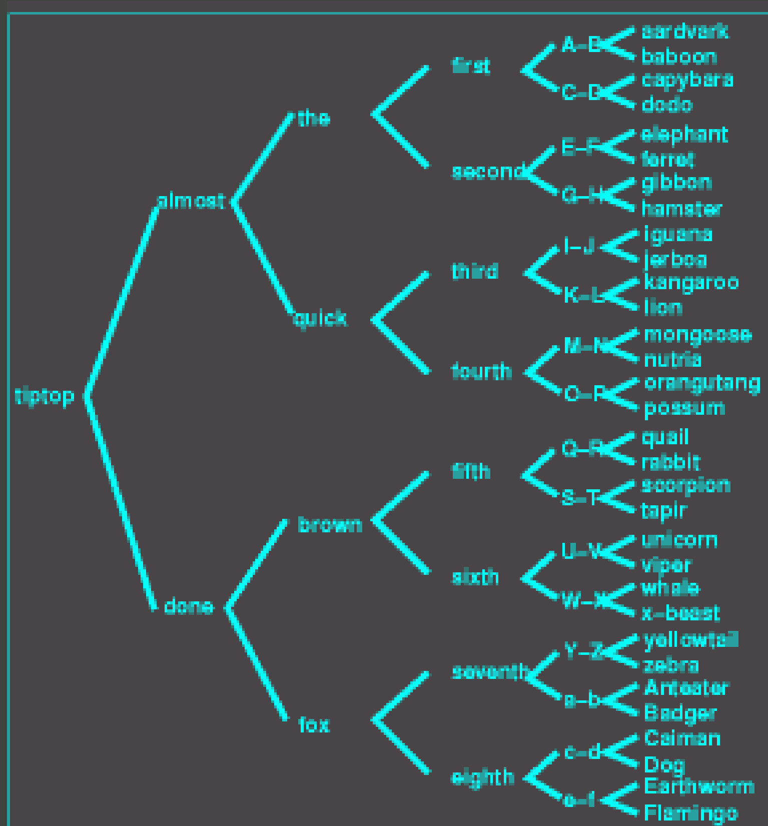


Avoiding disorientation

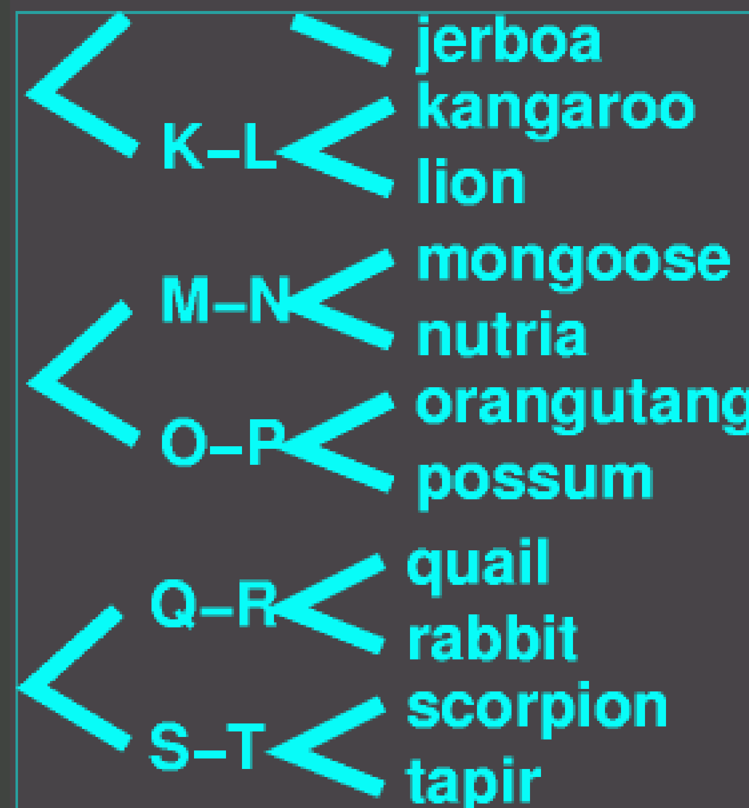
problem

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

exponential in depth: node count, space needed



global overview

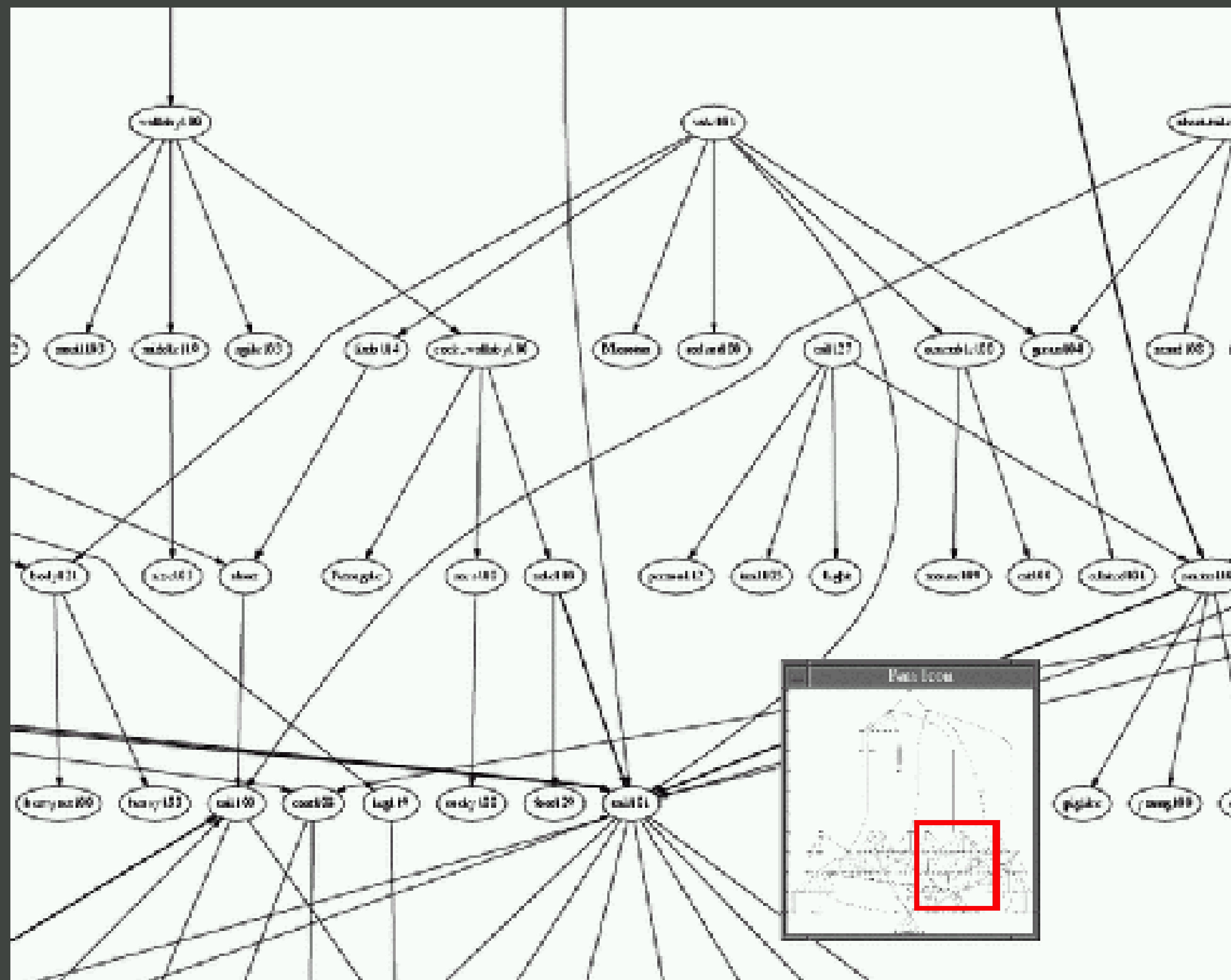


local detail

Overview and detail

two windows: add linked overview

- cognitive load to correlate

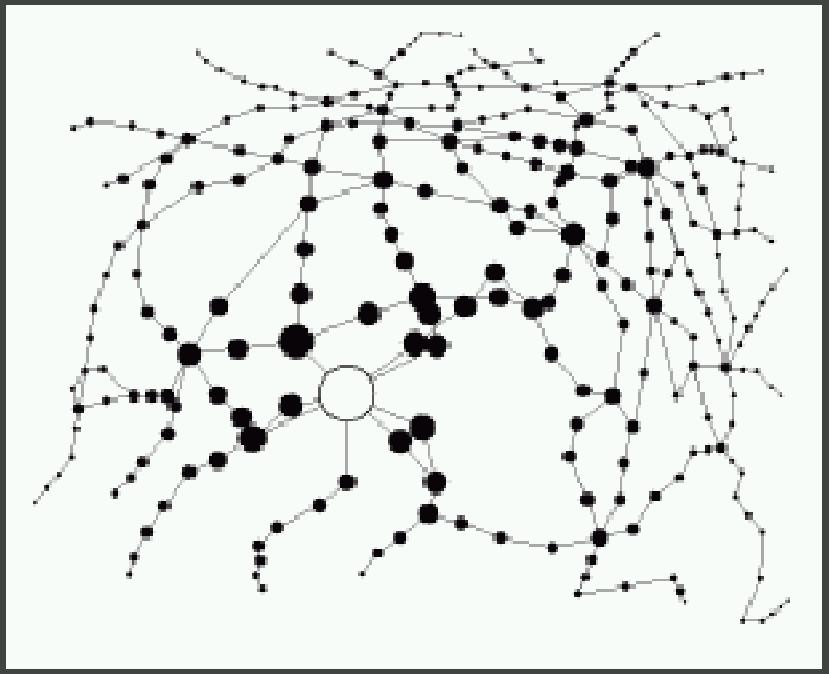


solution

- merge overview, detail
- "focus+context"

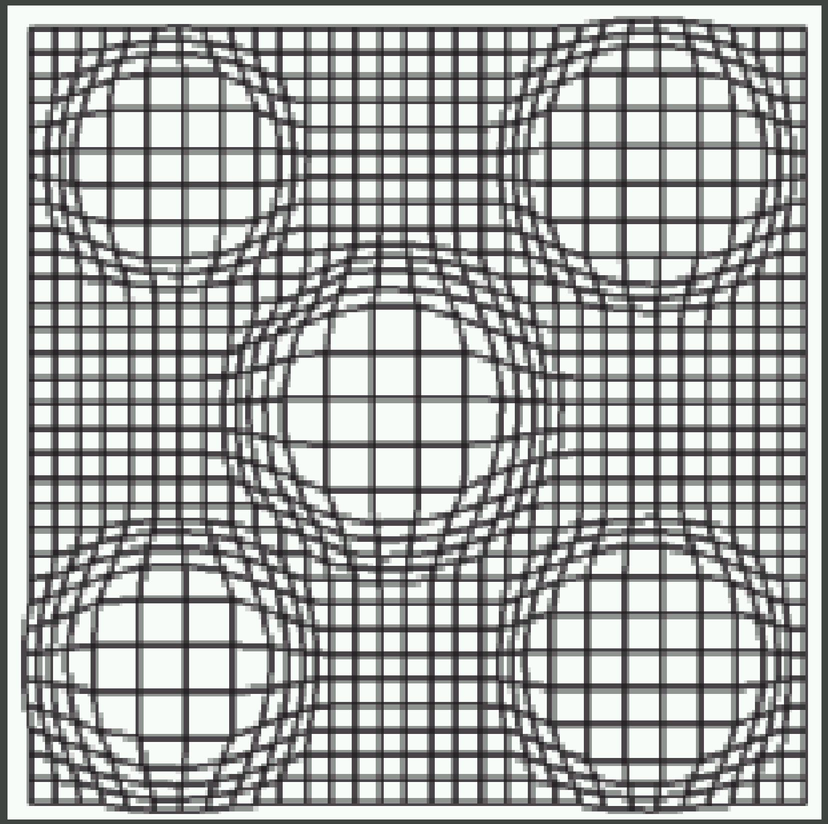
Previous work: focus+context

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



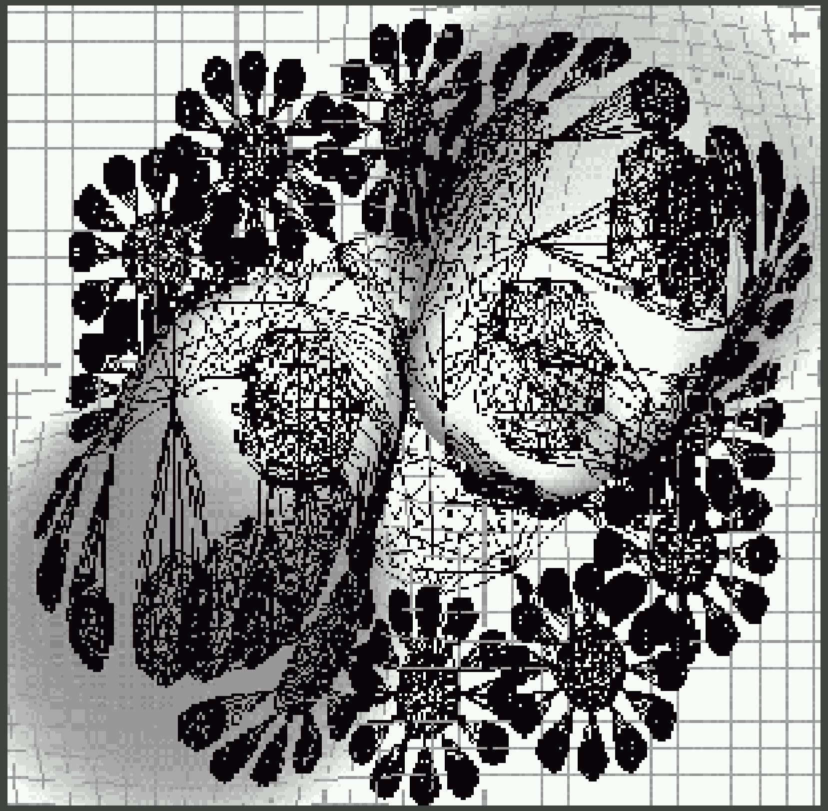
Previous work: focus+context

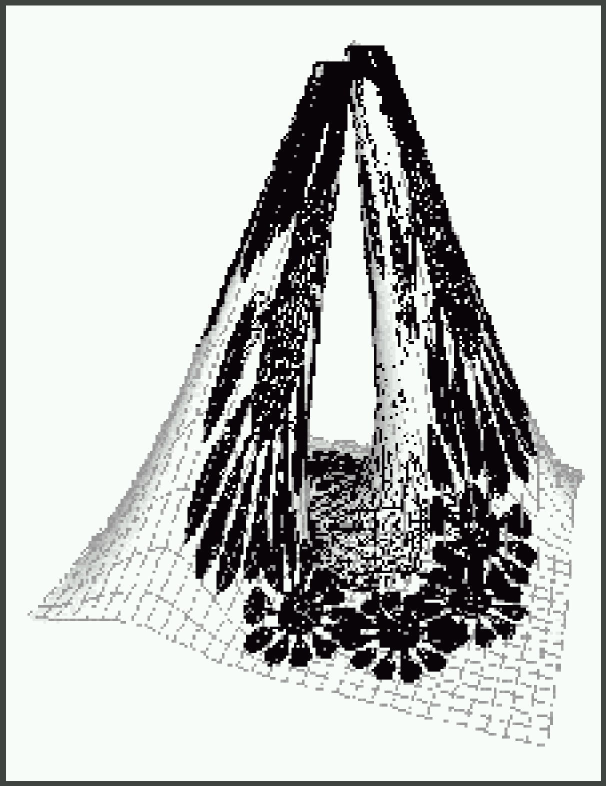
fisheye views [Furnas 86], [Sarkar et al 94]
nonlinear magnification [Keahey 96]



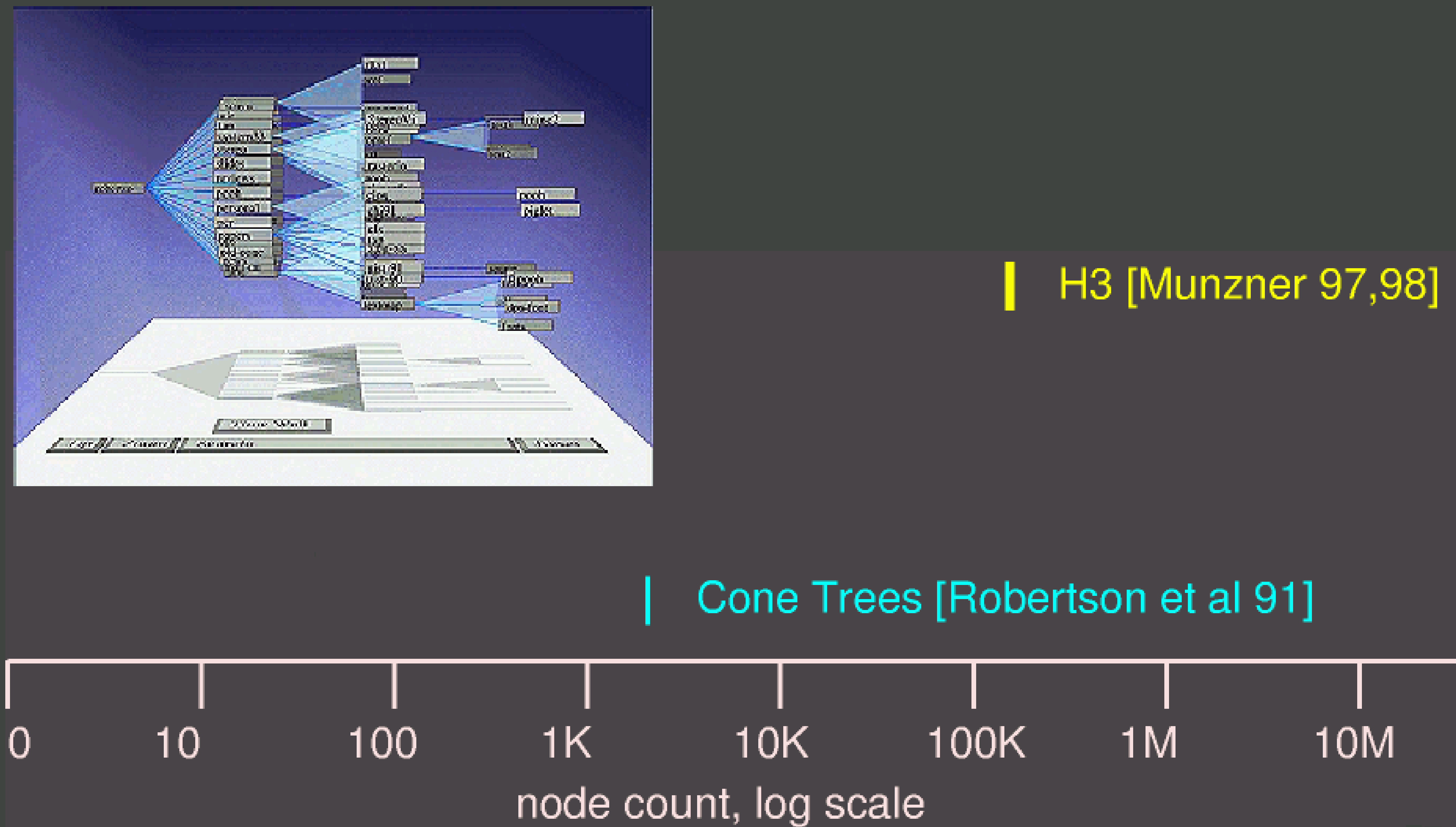
Previous work: focus+context

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





Previous work: focus+context trees



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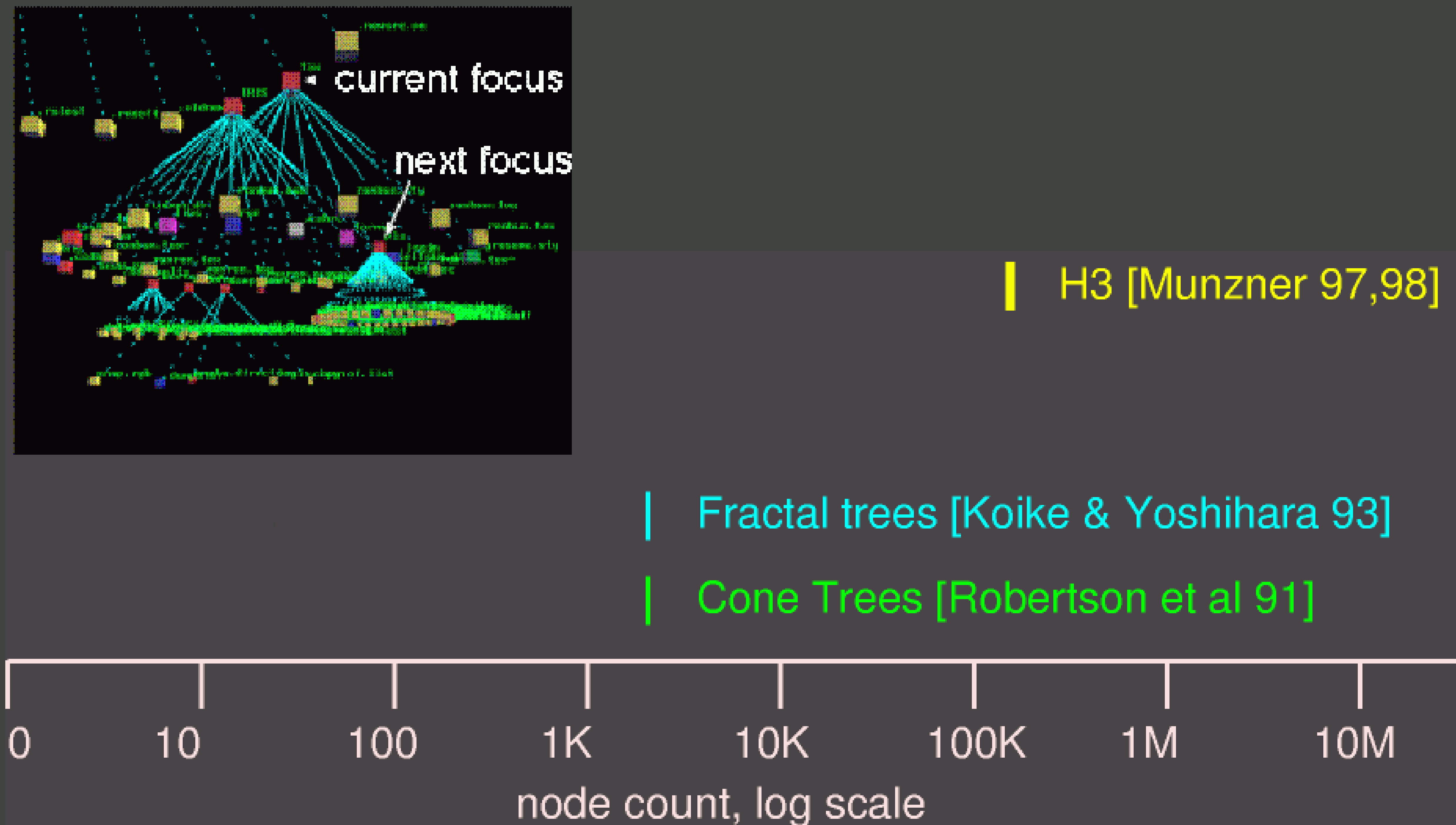
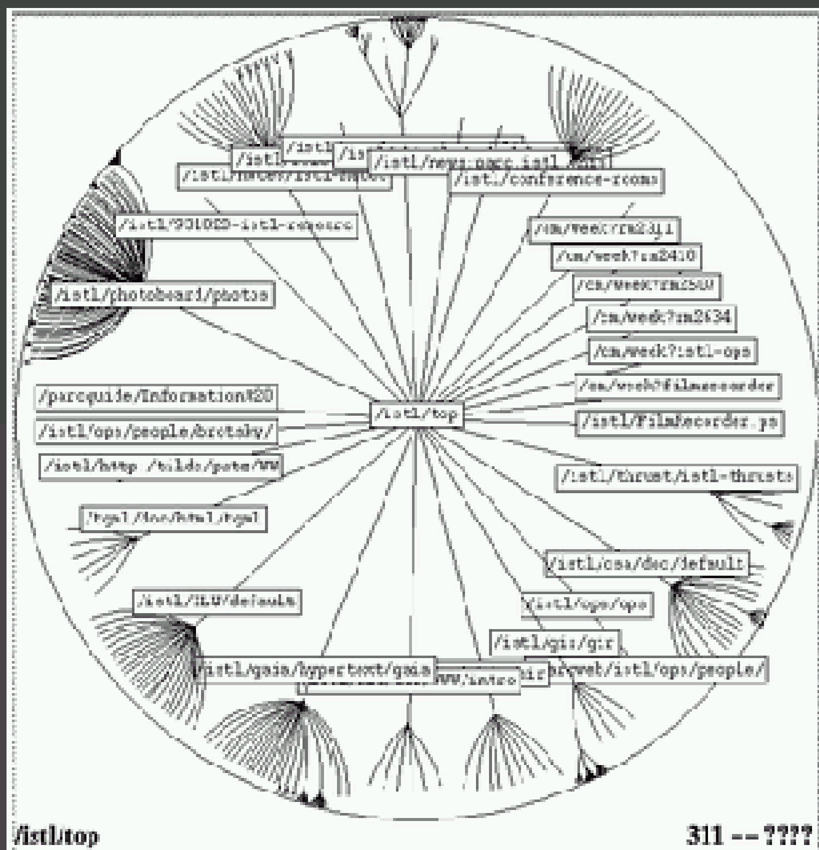


Previous work: focus+context trees



H3 [Munzner 97,98]

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

Fractal trees [Koike & Yoshihara 93]

Cone Trees [Robertson et al 91]

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

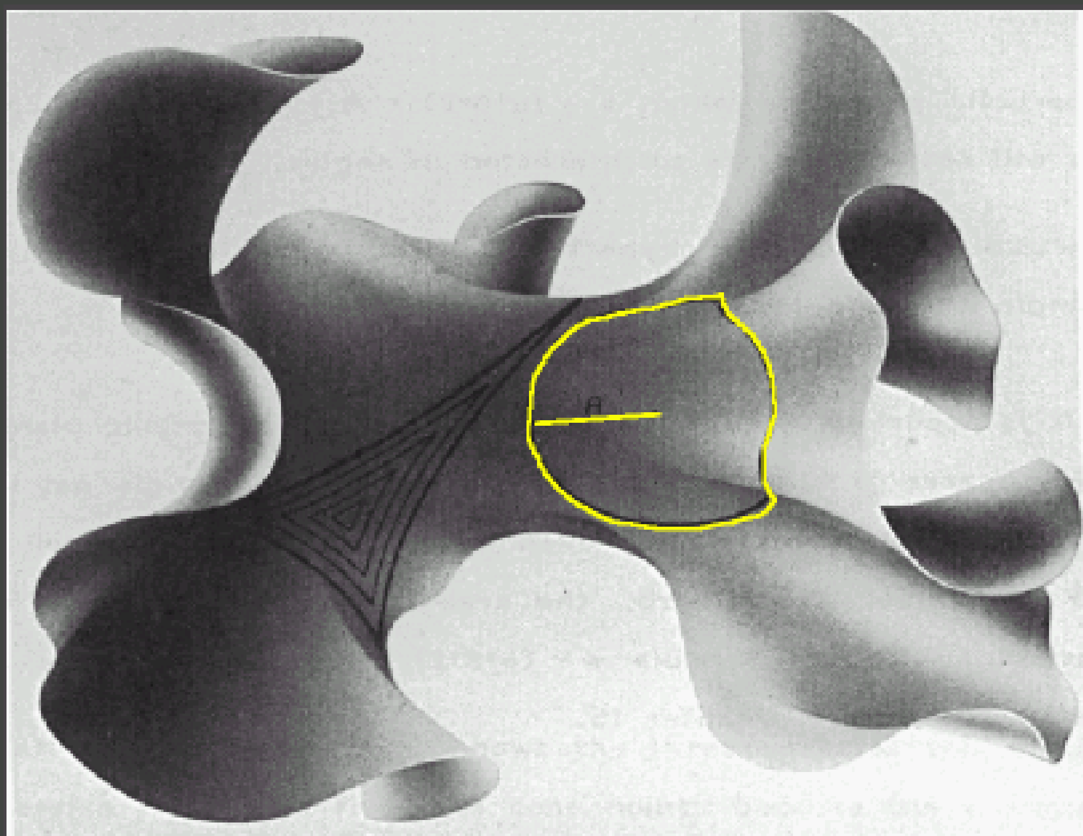
node count, log scale

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

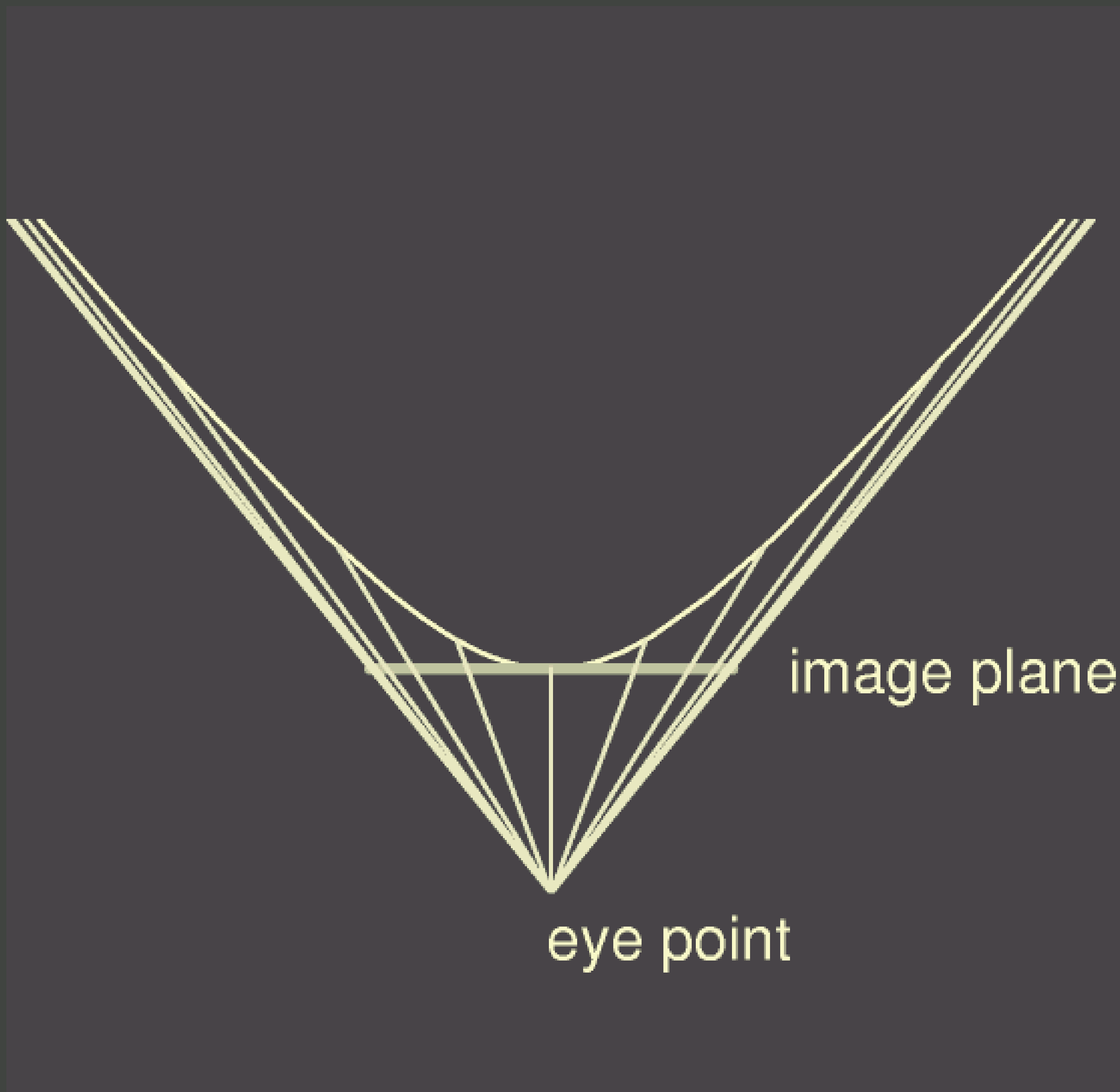
$$2\pi \sinh^2(r)$$

euclidean: polynomial

$$2\pi r^2$$

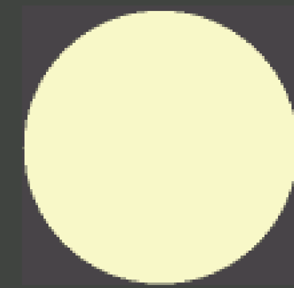
1D hyperbolic space

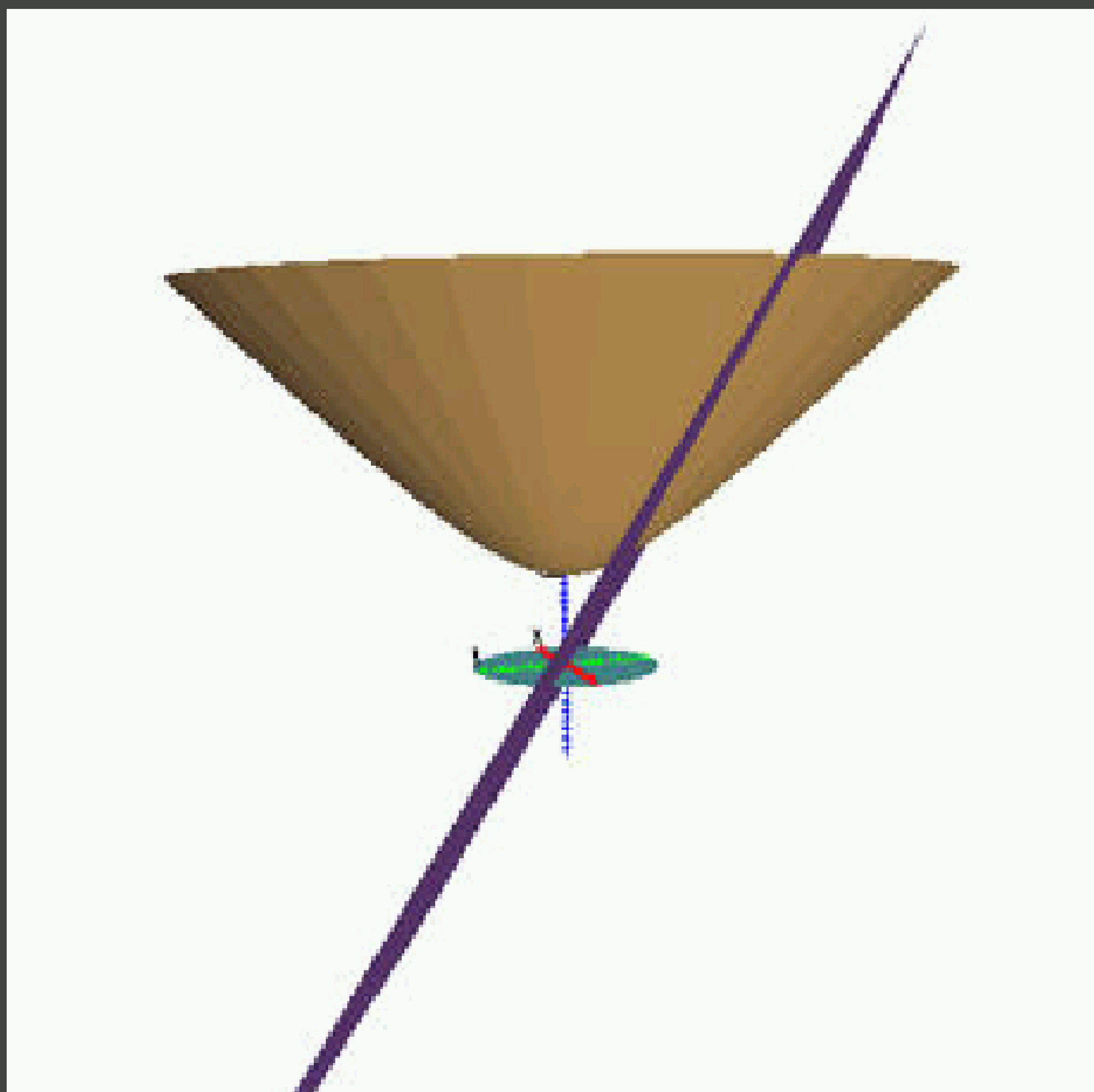
hyperbola projects to line

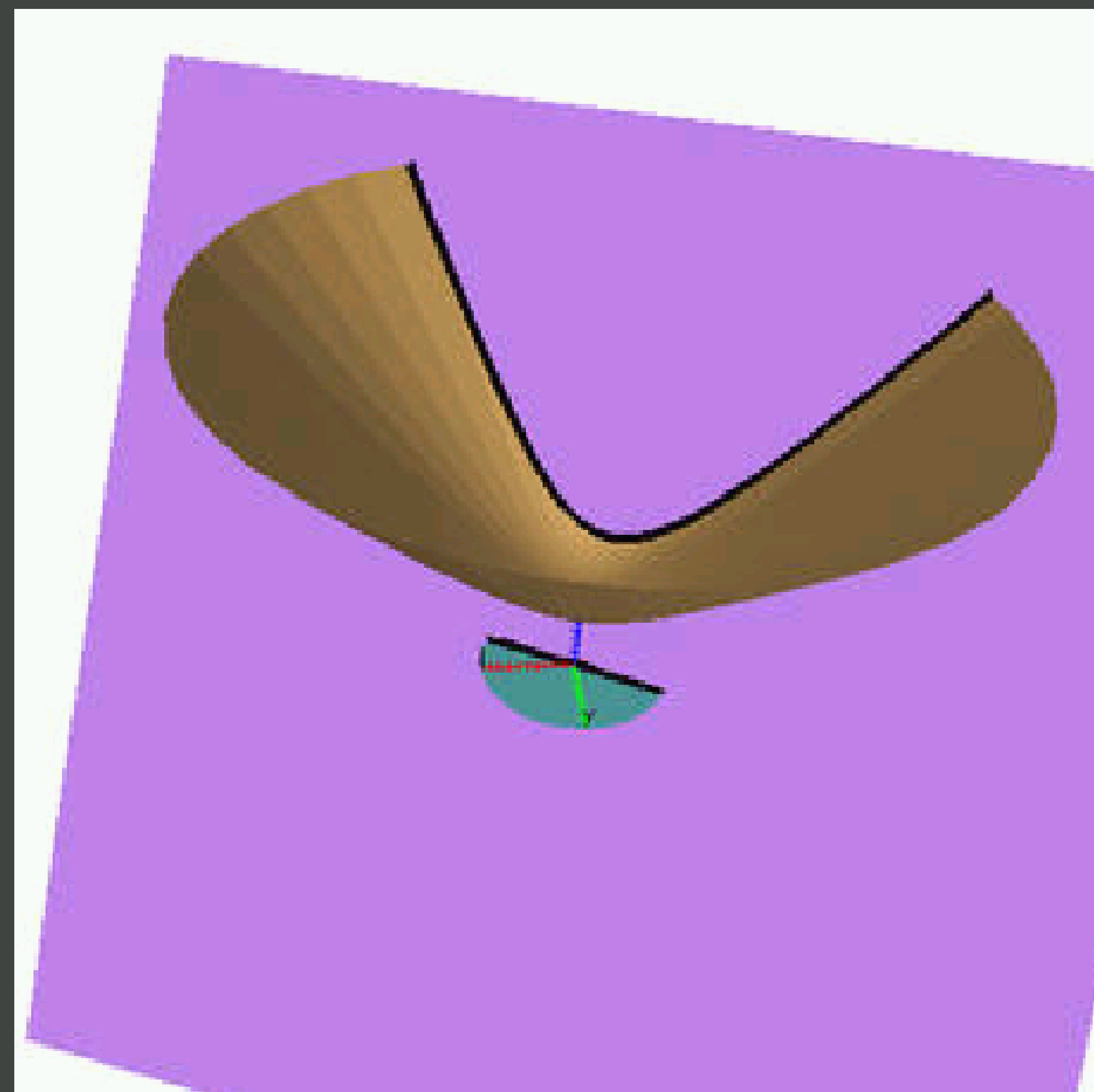


2D hyperbolic space

hyperboloid projects to disk

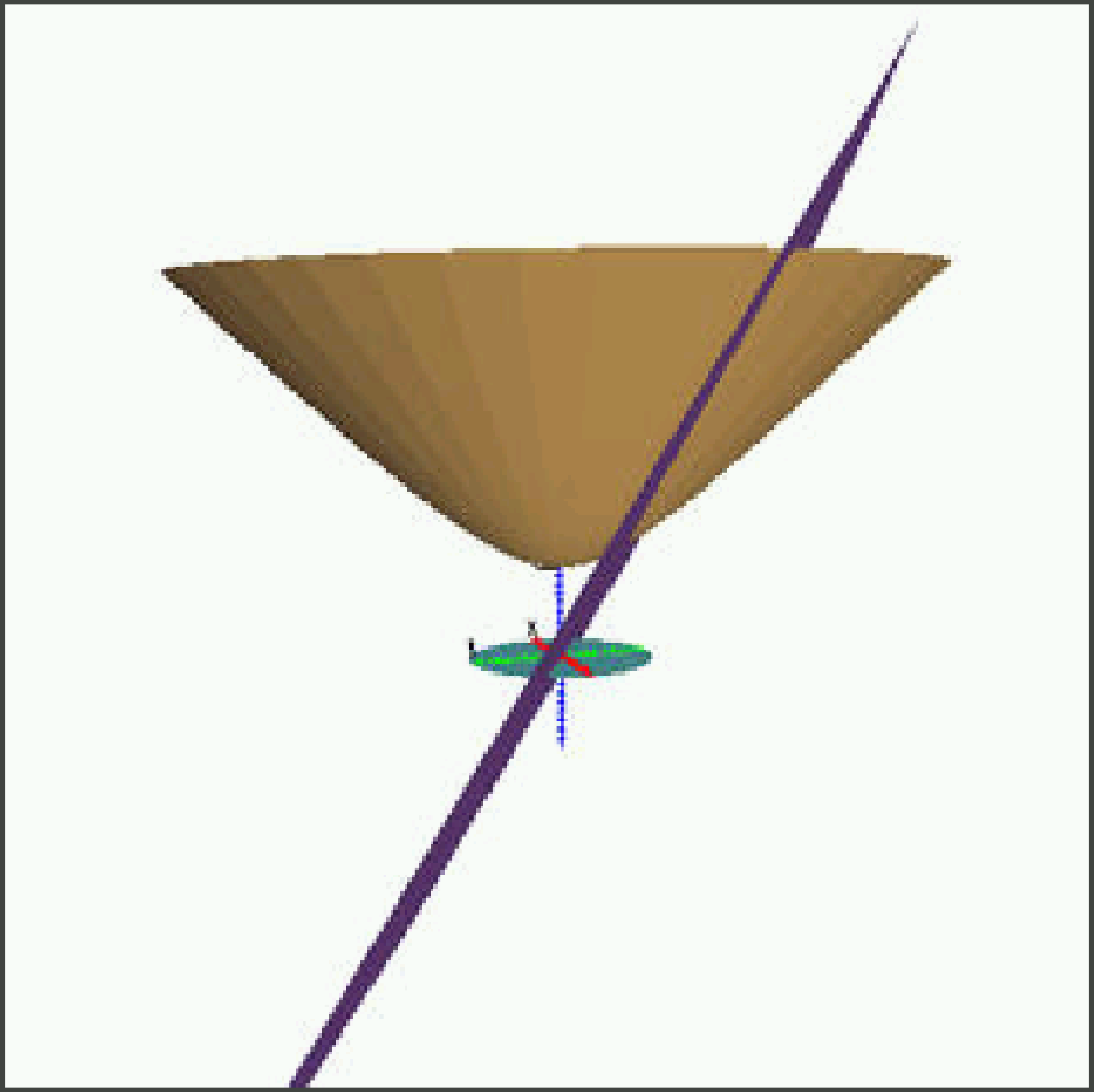


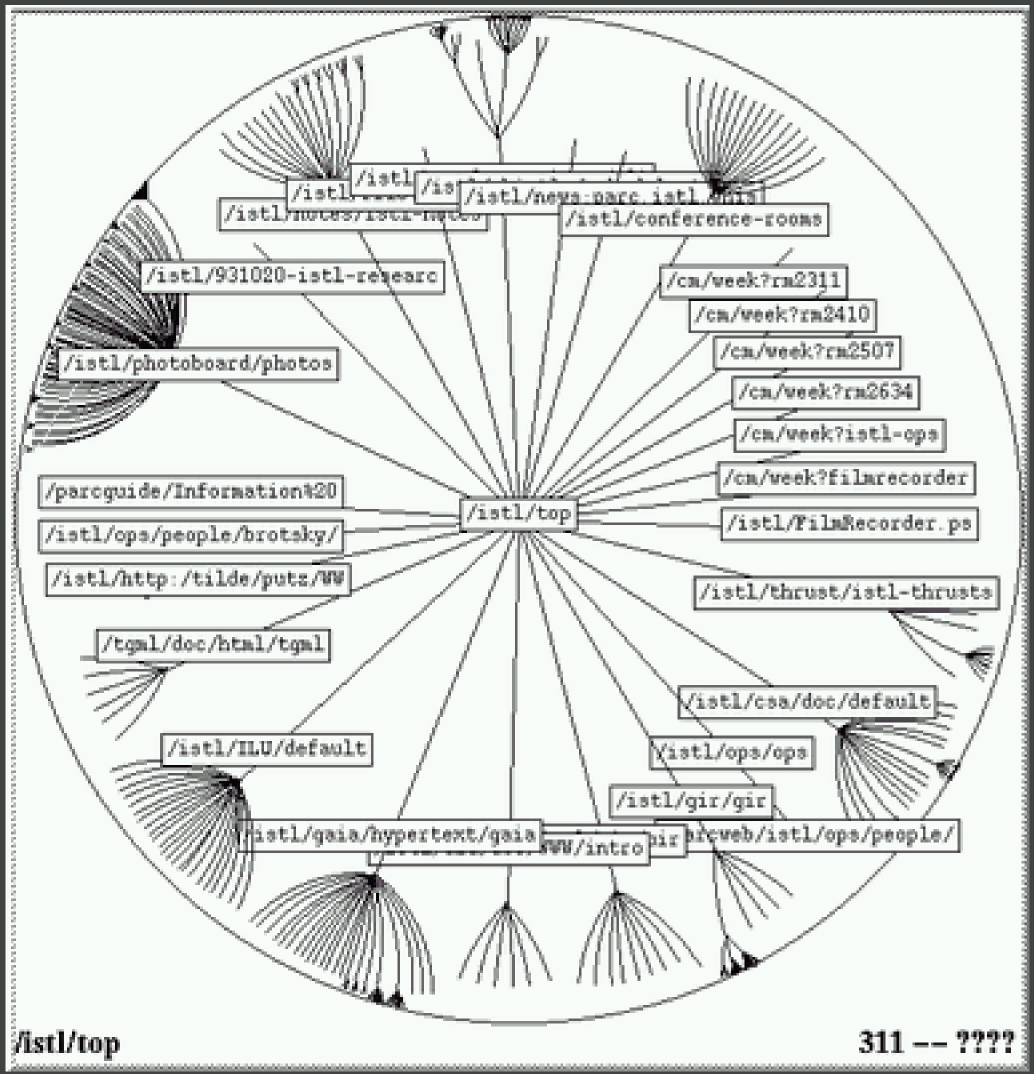




2D hyperbolic space

hyperboloid projects to disk

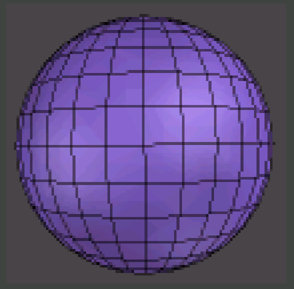




[Lamping et al 95]

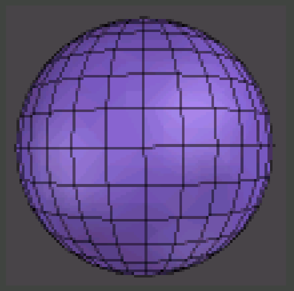
3D hyperbolic space

3-hyperboloid projects to solid ball



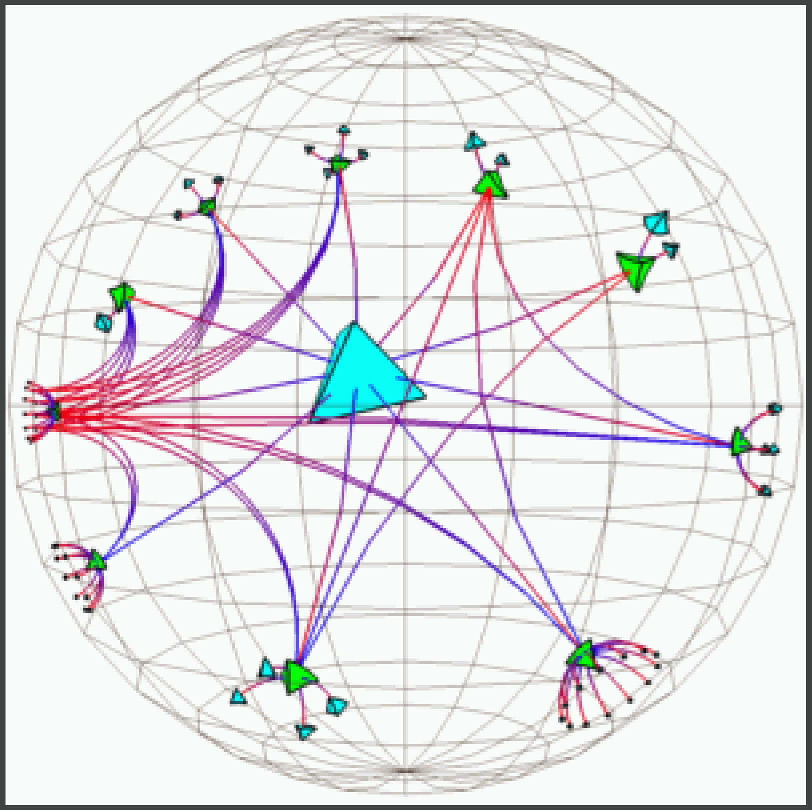
3D hyperbolic space

3-hyperboloid projects to solid ball

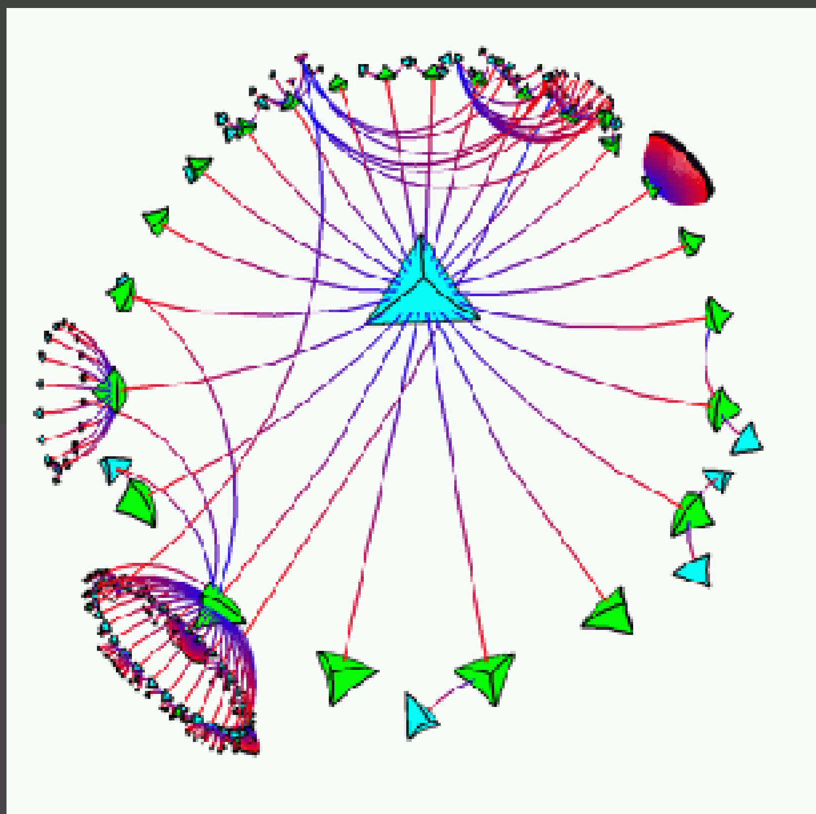


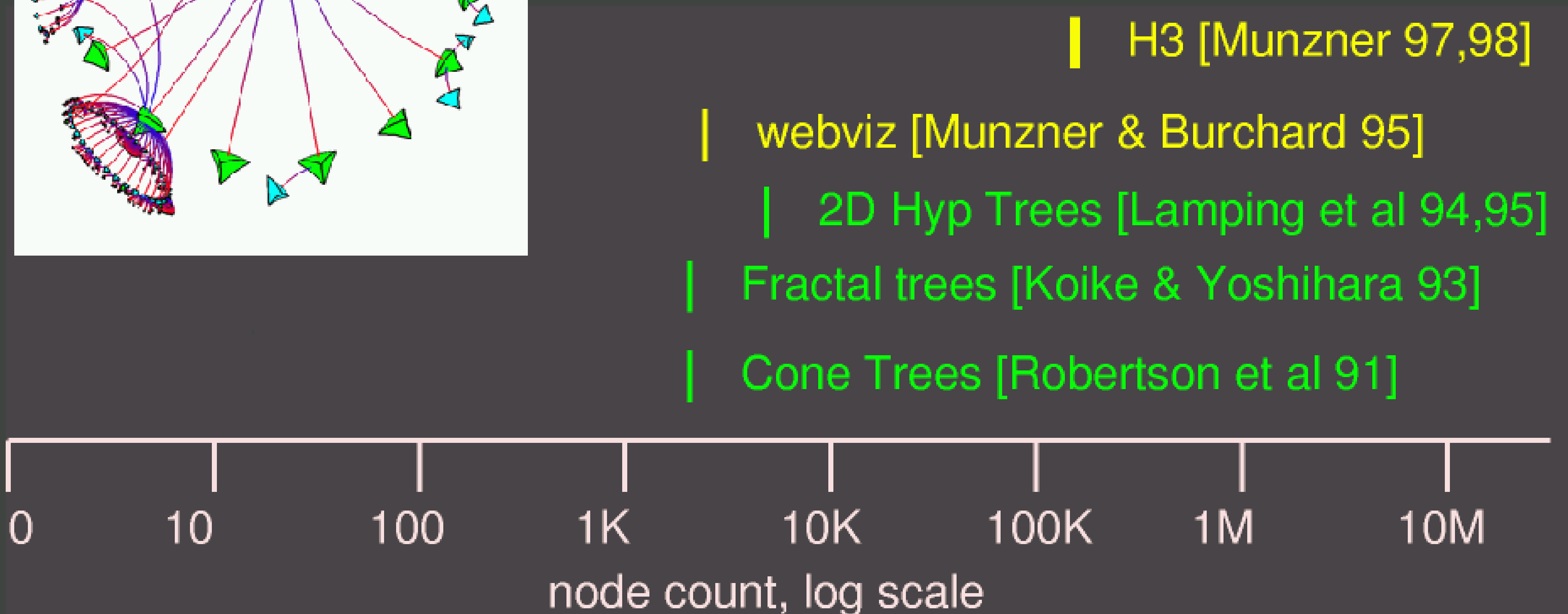
webviz [Munzner and Burchard 95]

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



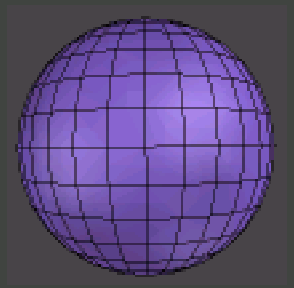
Contribution: focus+context graphs





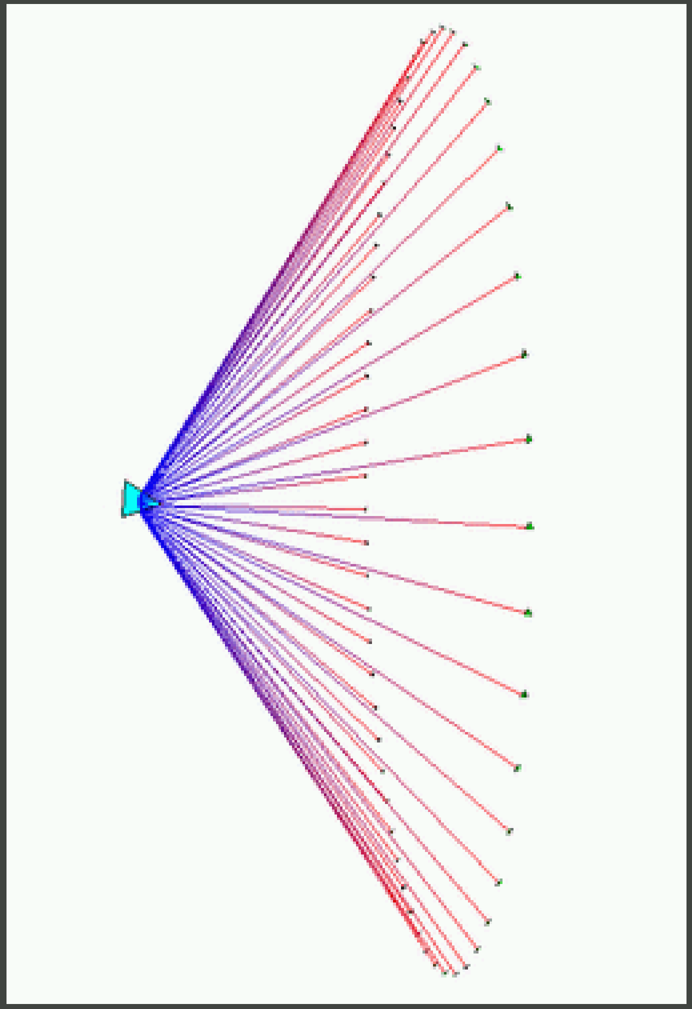
3D hyperbolic space

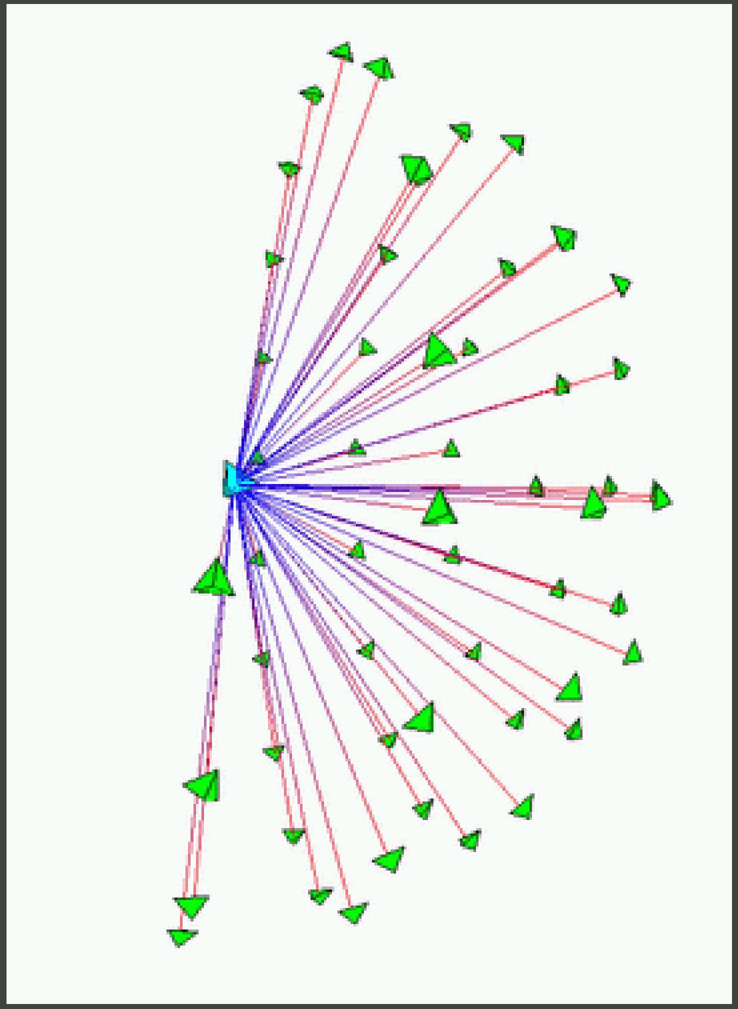
3-hyperboloid projects to solid ball

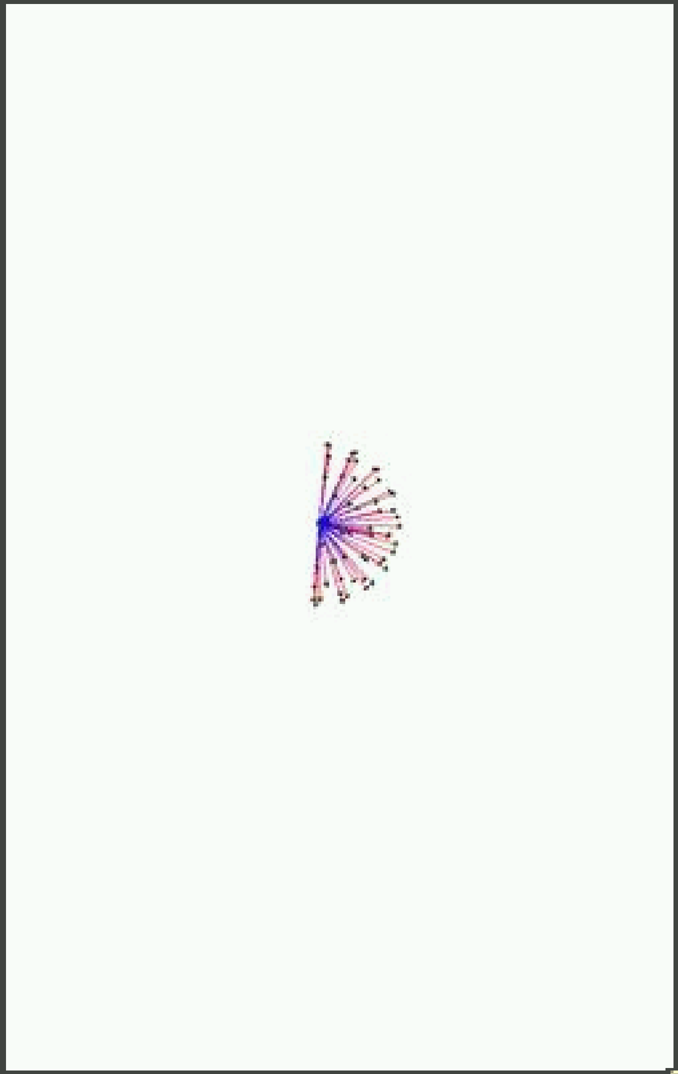


H3 layout

- circumference -> hemisphere

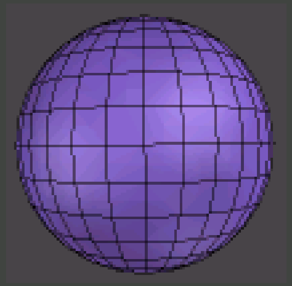






3D hyperbolic space

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

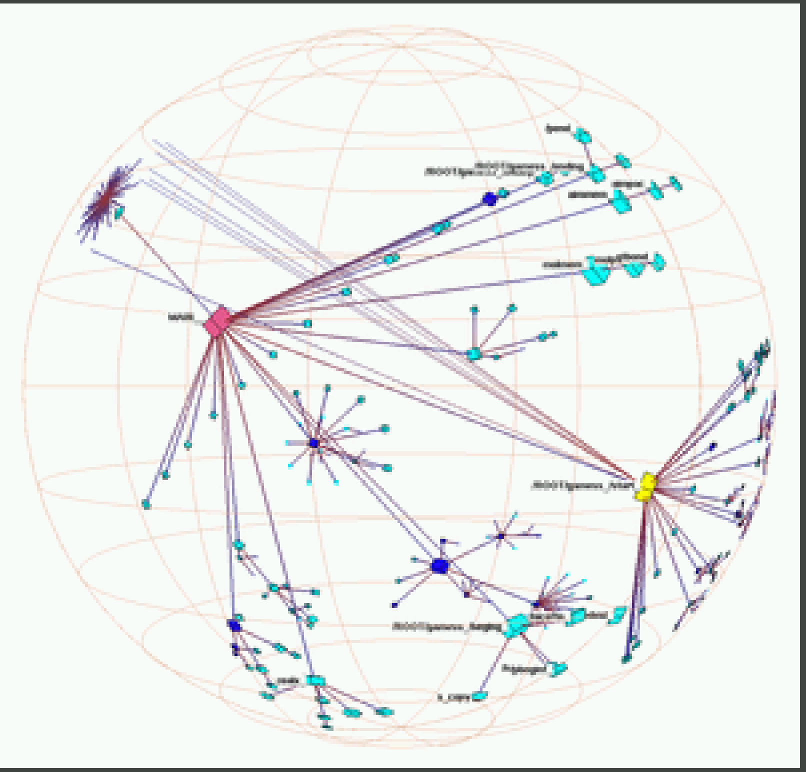
drawing queue for nodes

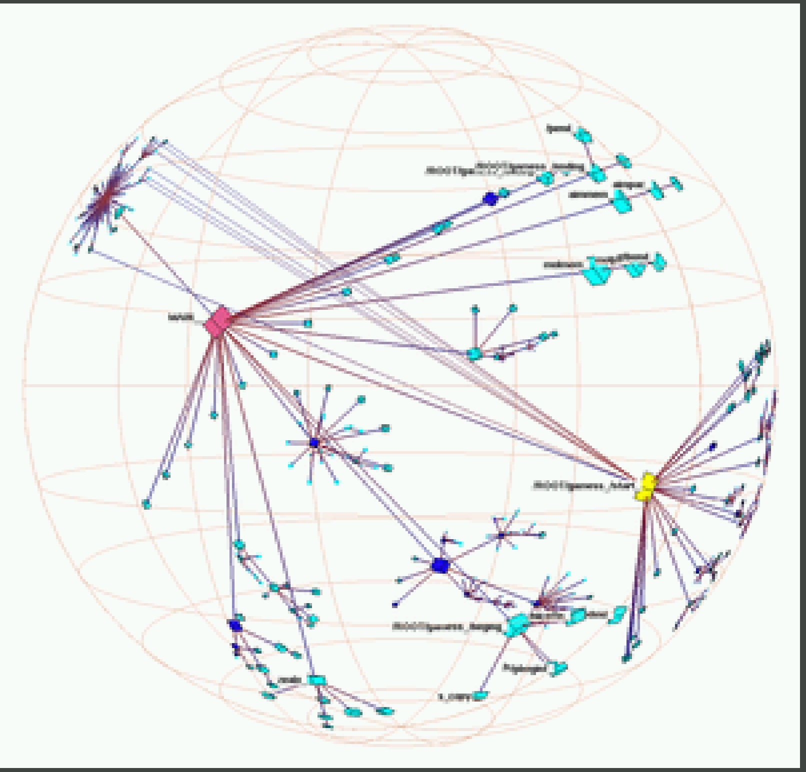
graph-theoretic

- 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)

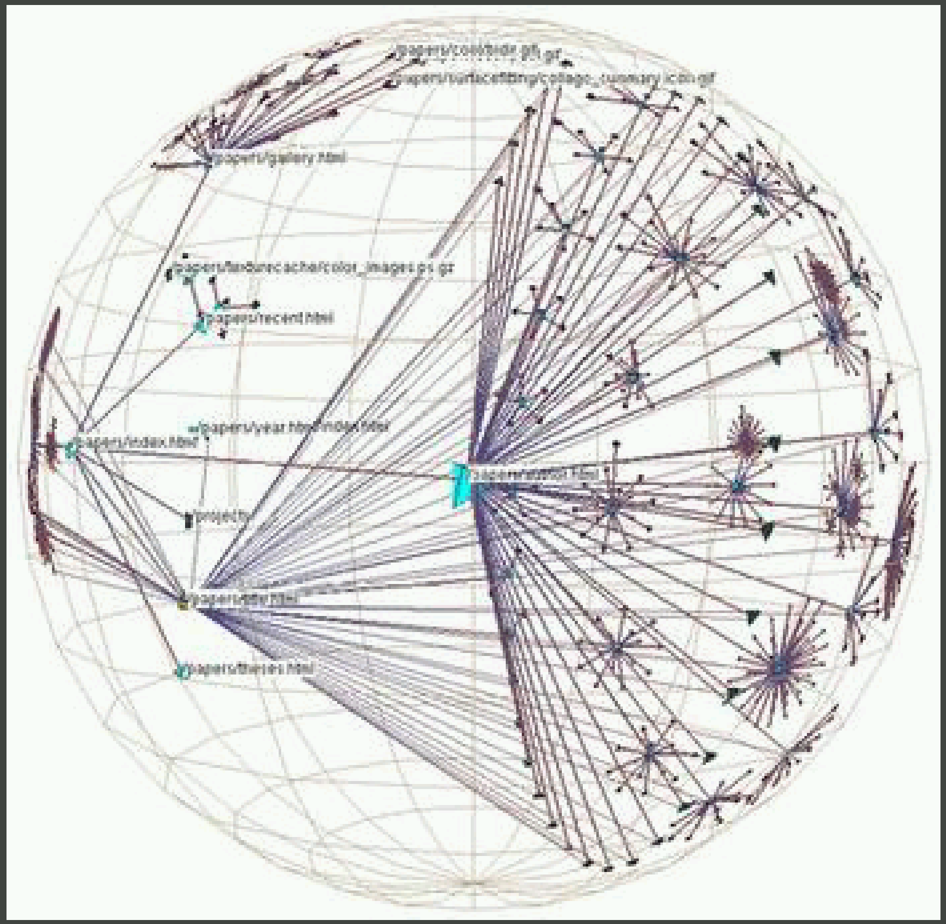
- drawing
  constant time: guaranteed frame rate

- limited by main memory size

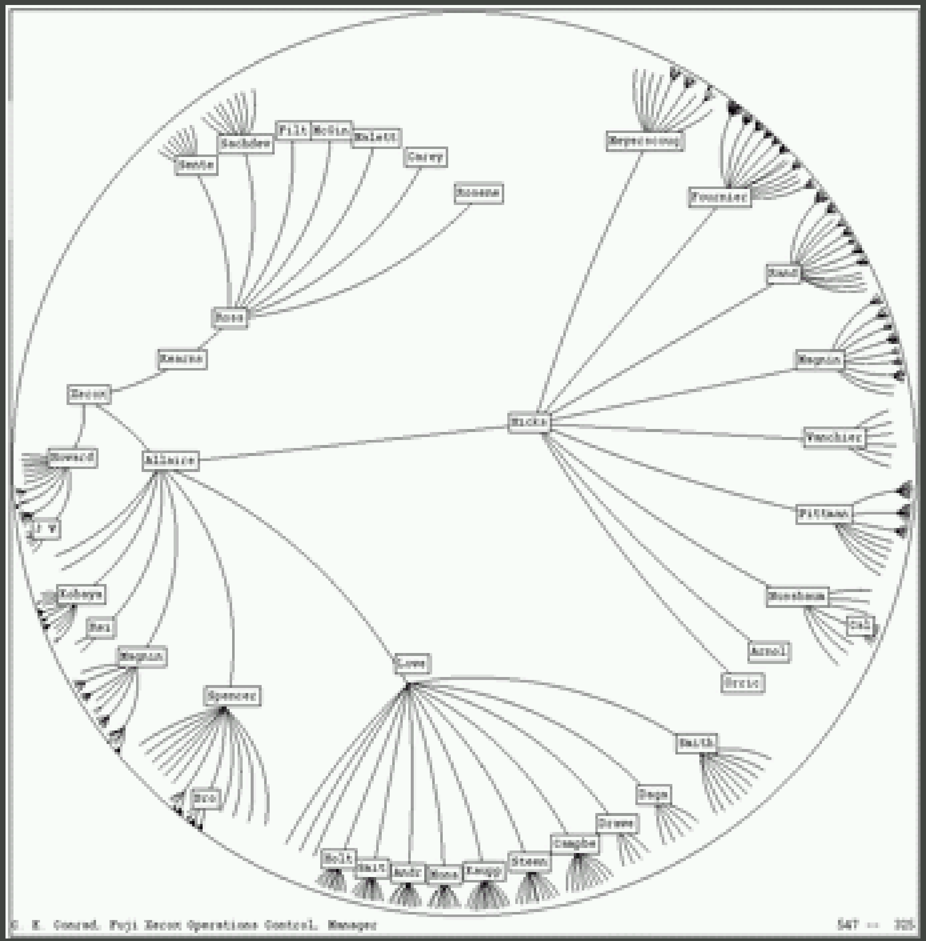
H3 results: scalability

information density: 10x better

H3



2D PARC Tree

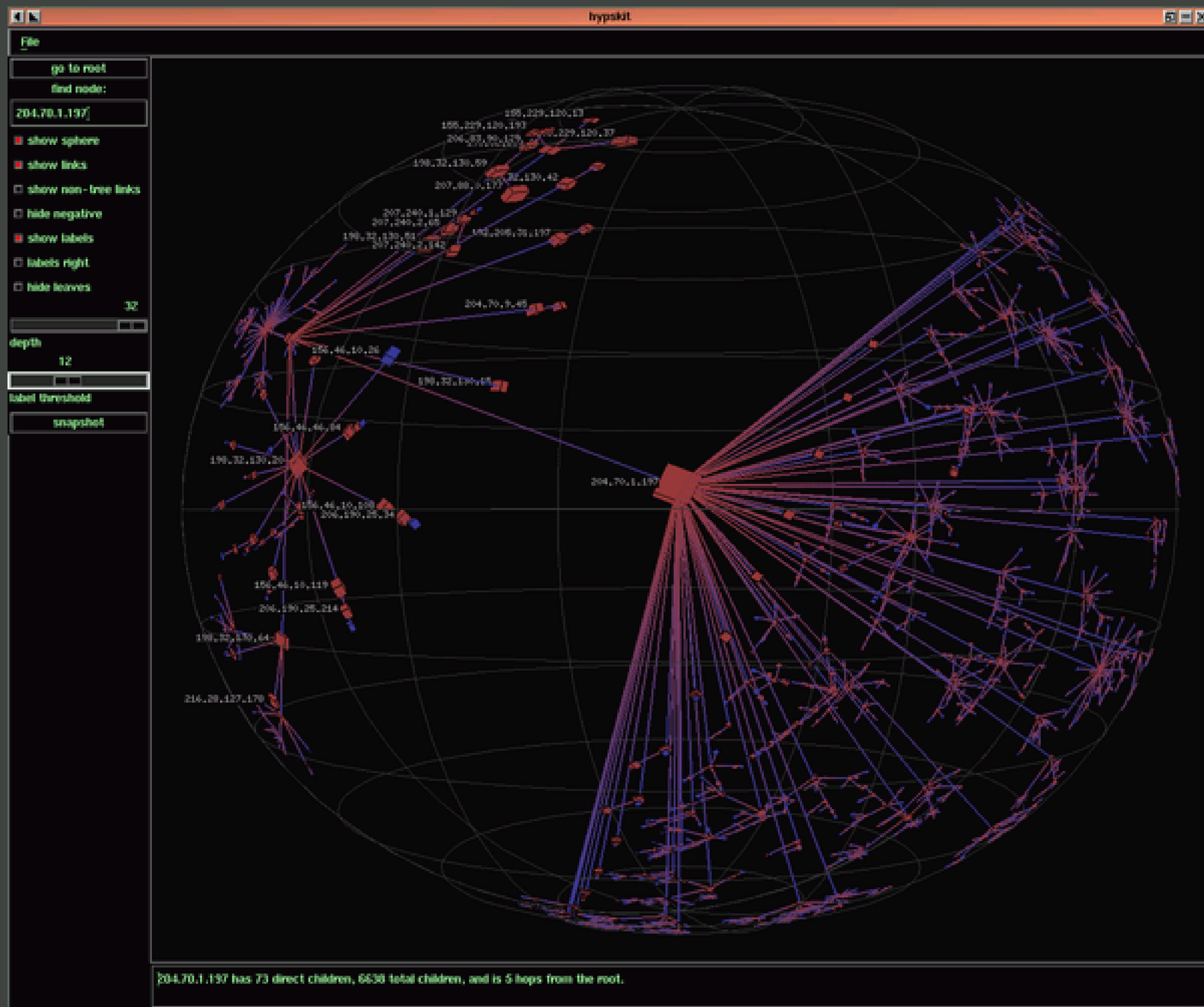


	center	fringe
3D	dozens	thousands
2D	dozens	hundreds

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

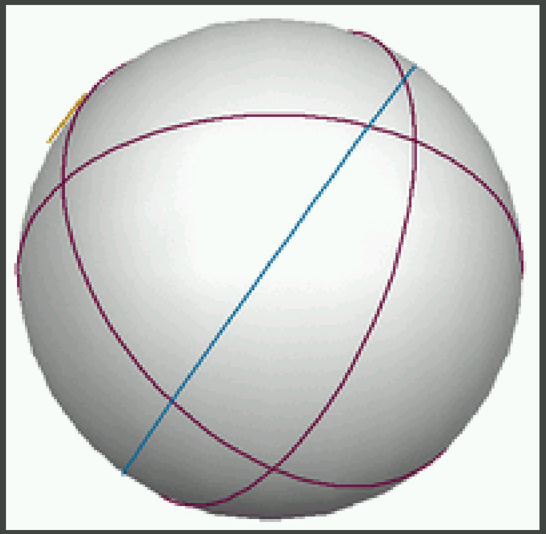
Noneuclidean geometry

Euclid's 5th Postulate

- exactly 1 parallel line

spherical

- geodesic = great circle
- no parallels



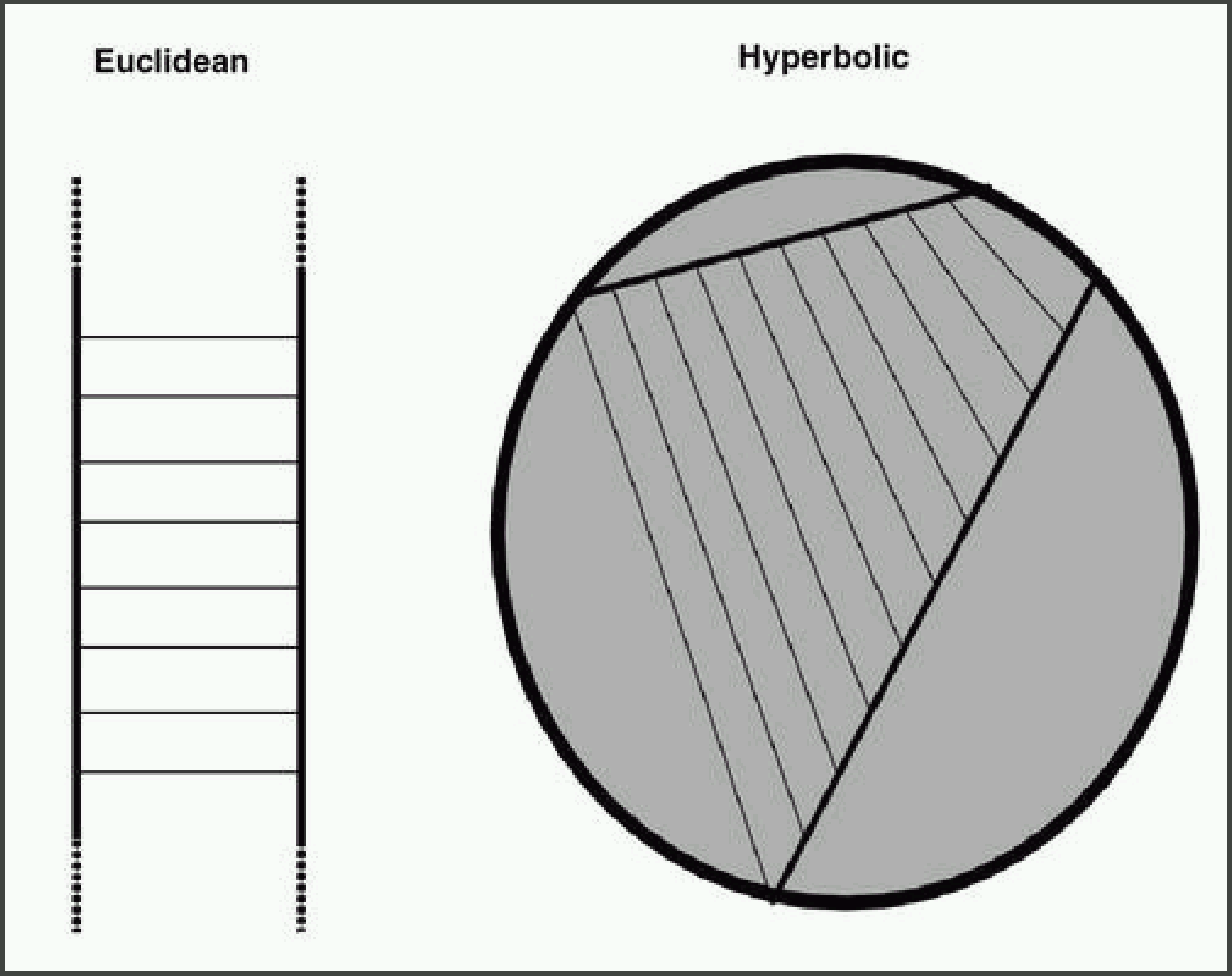
[torus.math.uiuc.edu/jms/java/dragsphere]

hyperbolic

- infinte parallels

Parallel vs. equidistant

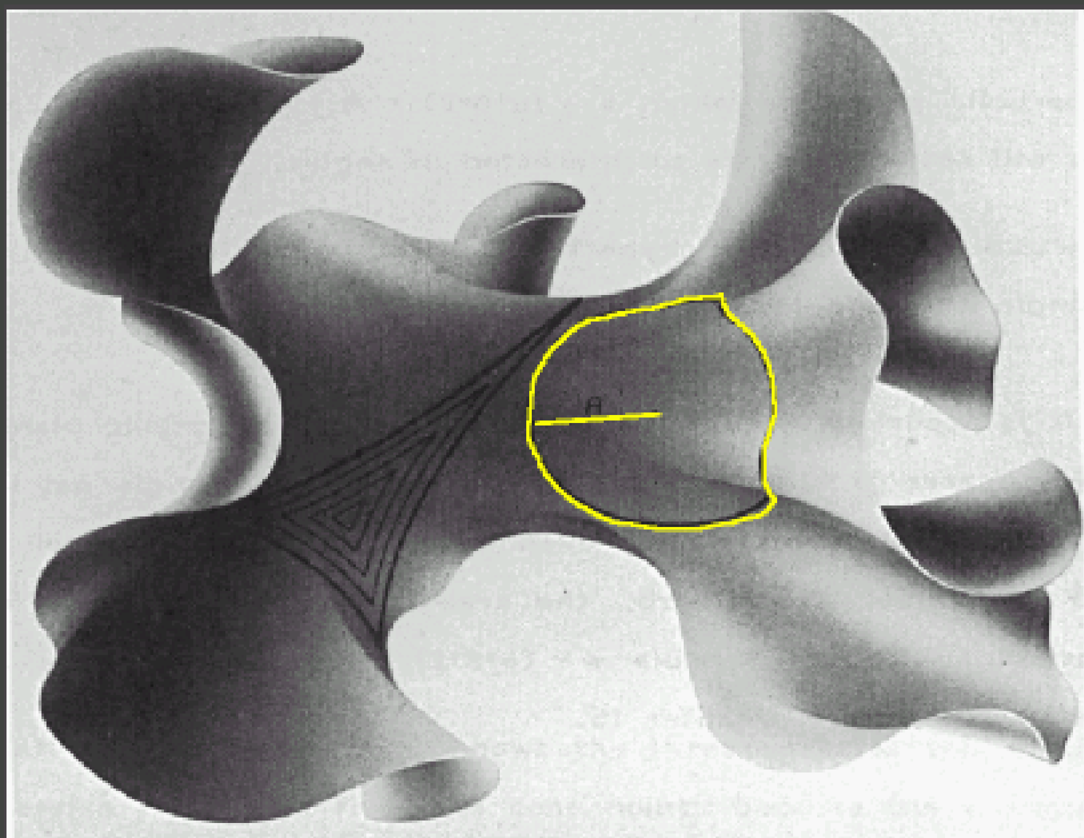
euclidean: inseparable
hyperbolic: different



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

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

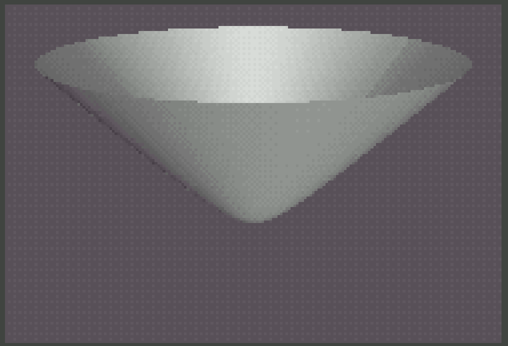
euclidean: polynomial

$$2\pi r^2$$

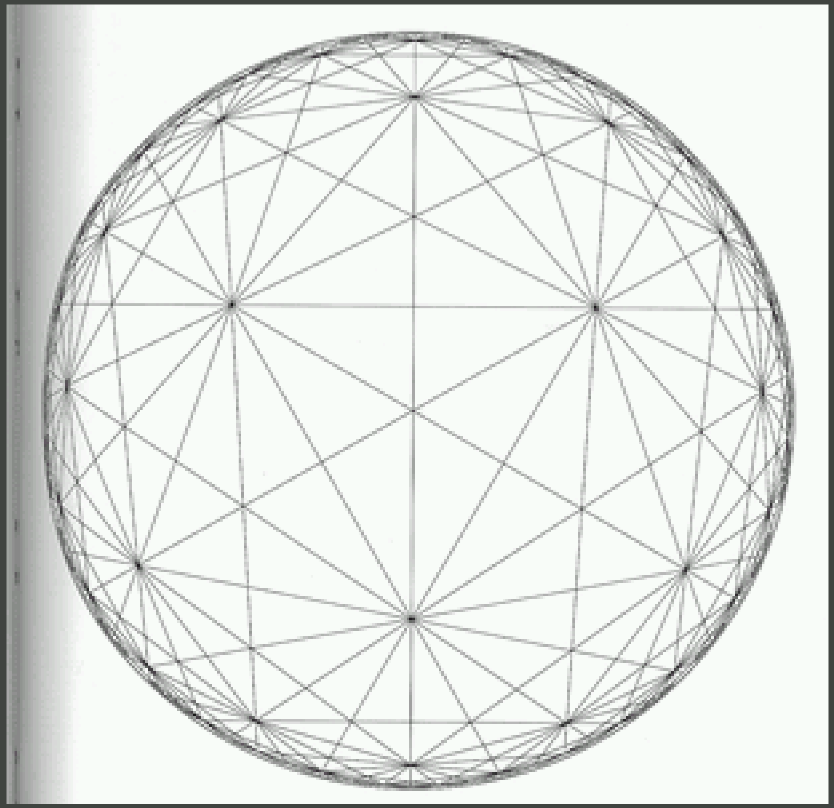
Models, 2D

not just round!

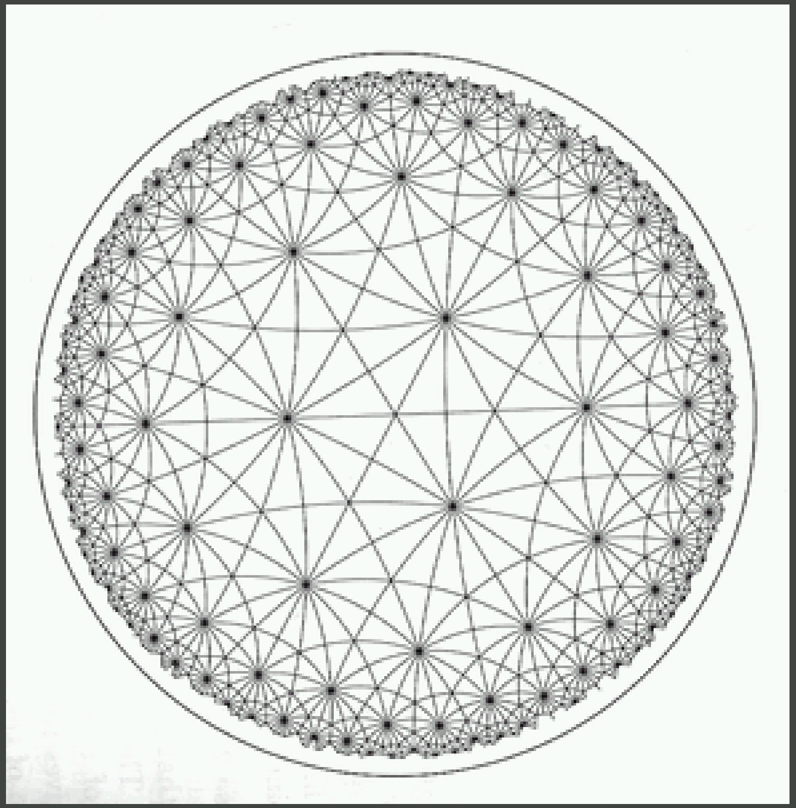
Minkowski



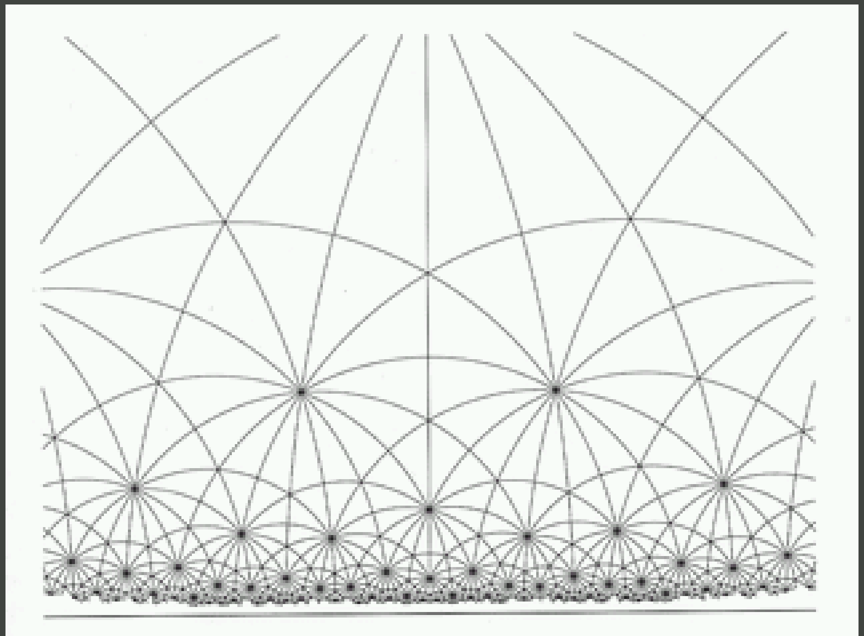
Klein/projective



Poincare/conformal



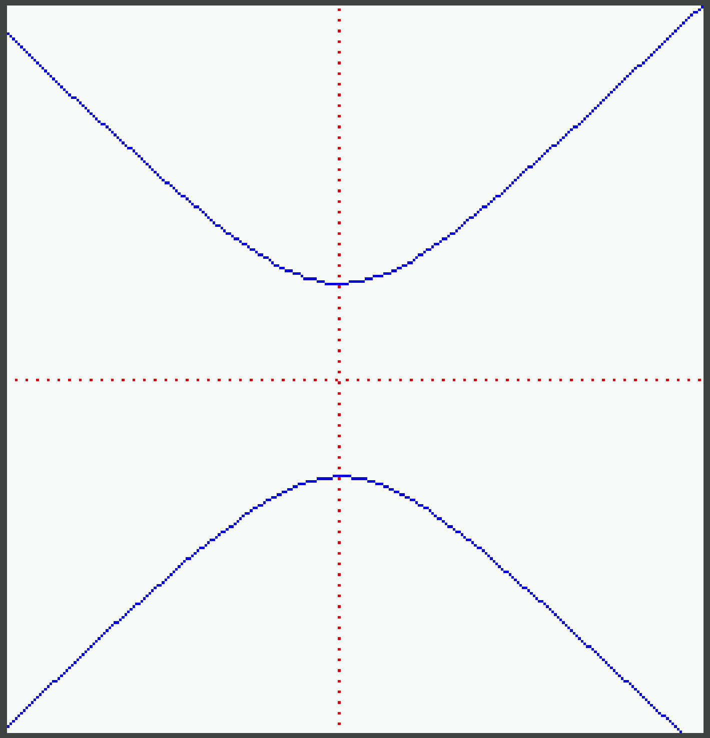
Upper Half Space



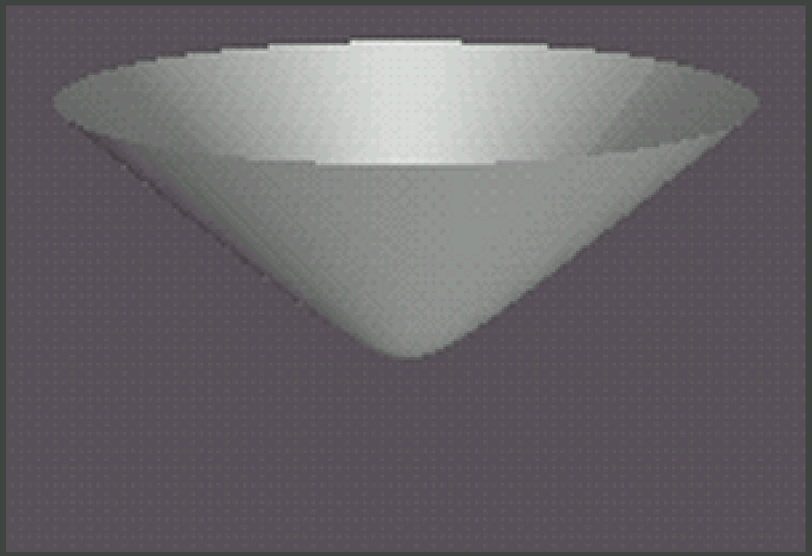
[Three Dimensional Geometry and Topology, William Thurston, Princeton University Press]

Minkowski

1D



2D

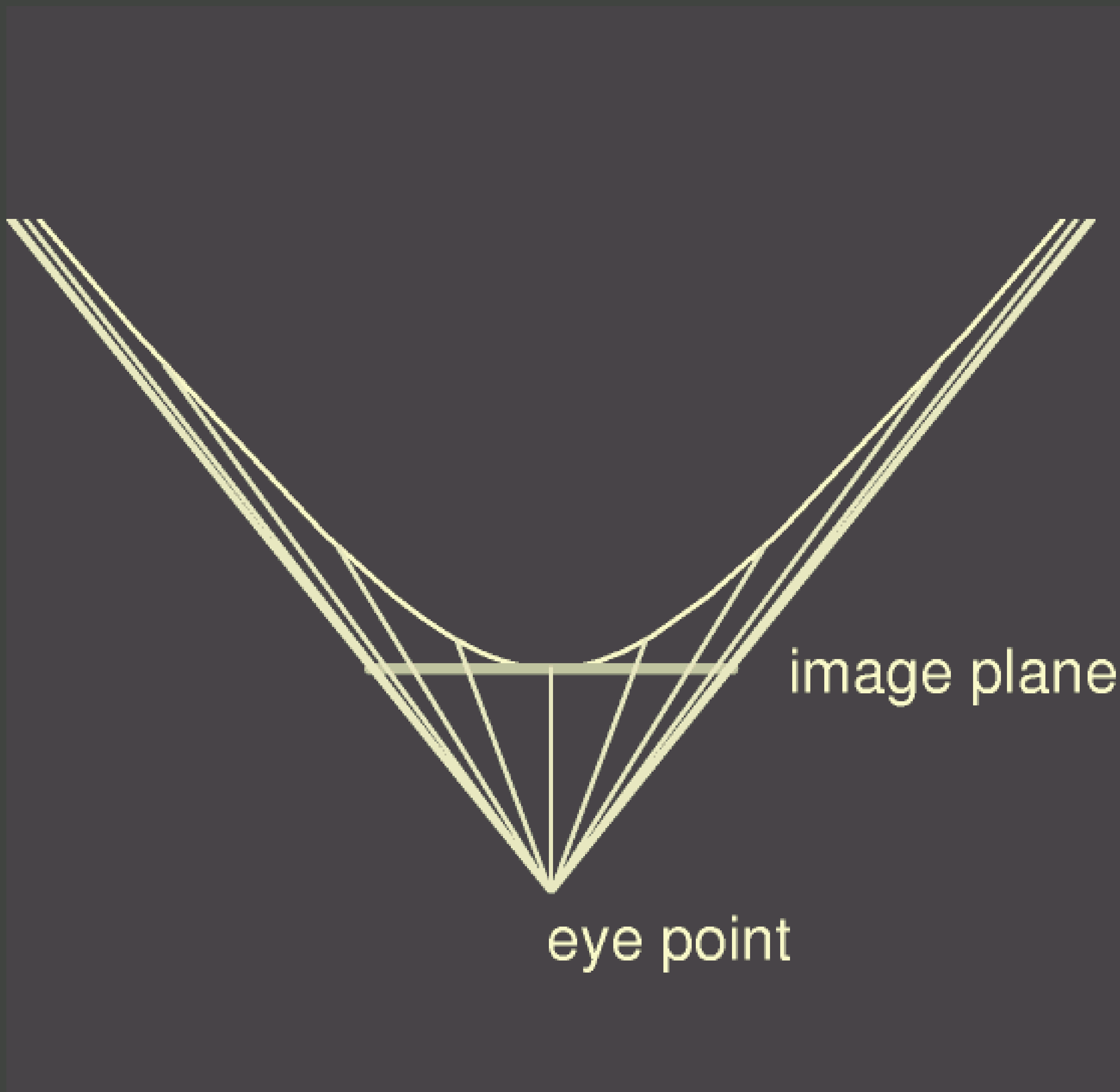


[www-gap.dcs.st-and.ac.uk/~history/Curves/Hyperbola.html]
[www.geom.umn.edu/~crobles/hyperbolic/hypr/modl/mnkw/]

the hyperboloid itself
embedded one dimension higher

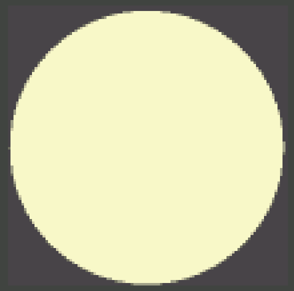
1D Klein

hyperbola projects to line

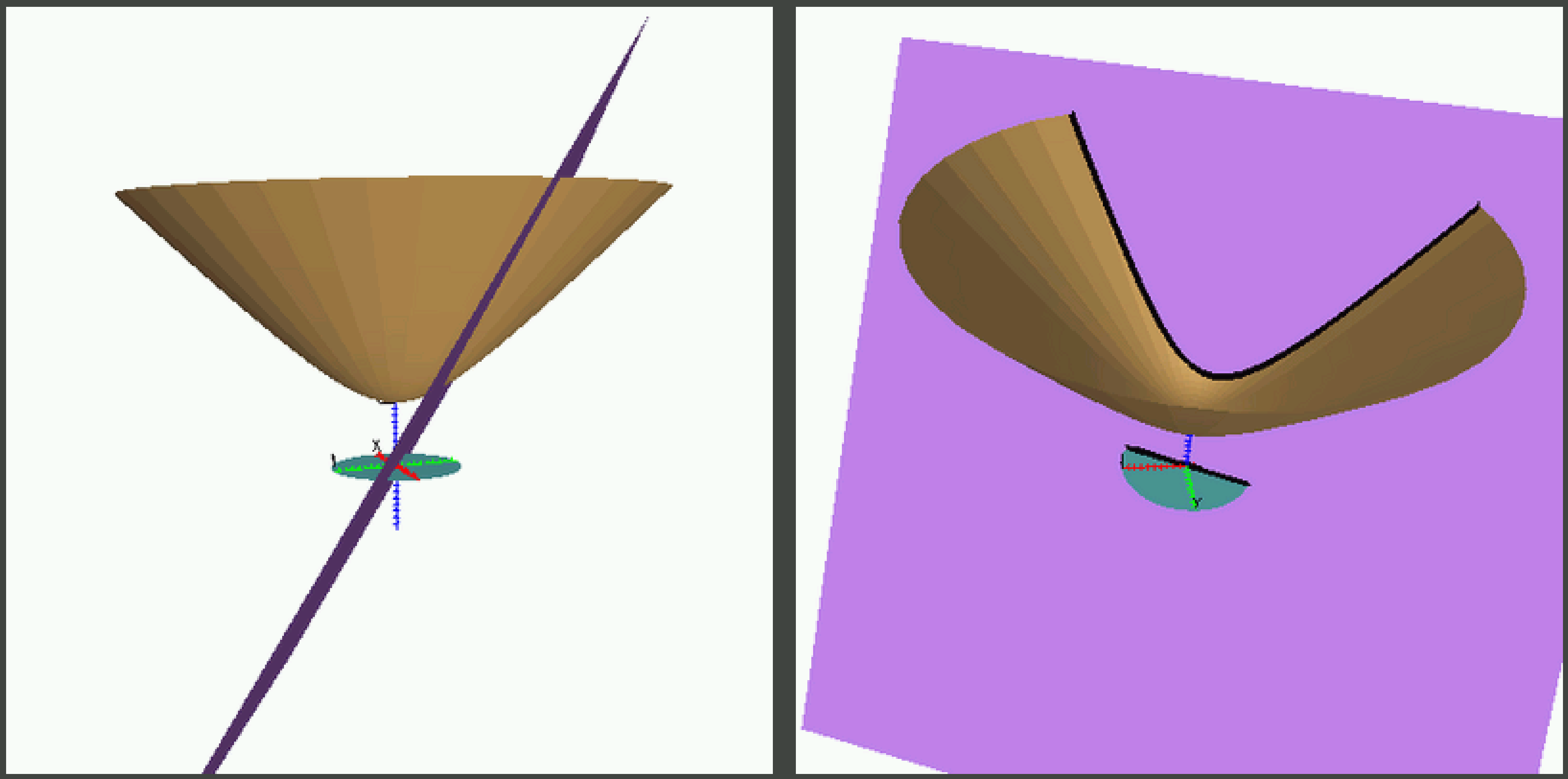


2D Klein

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]

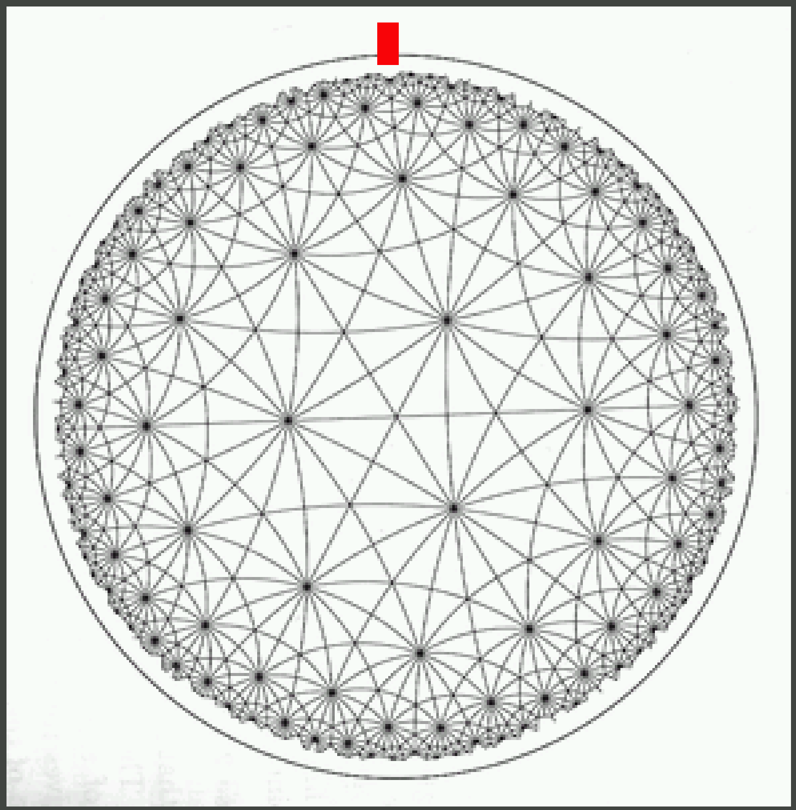
graphics

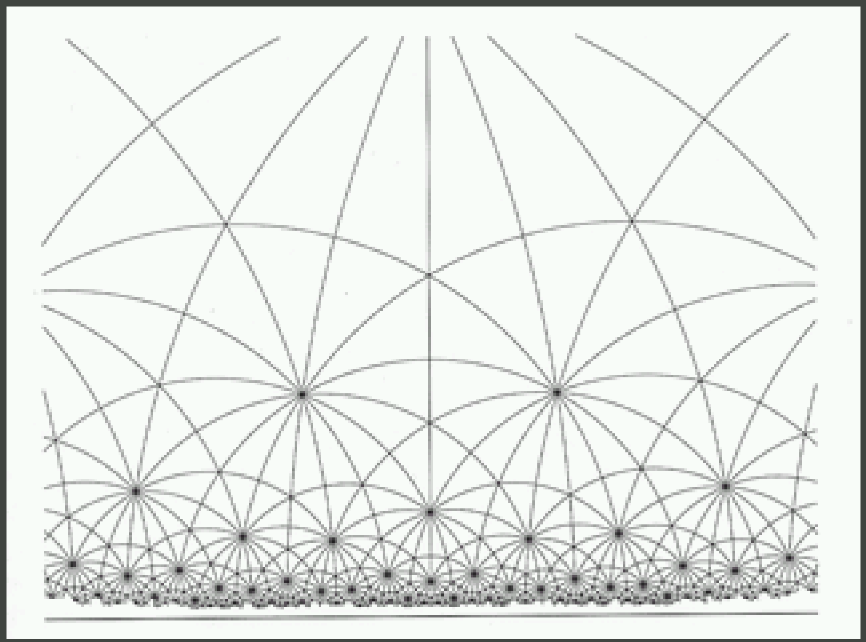
- Klein: 4x4 real matrix
- Poincare: 2x2 complex matrix

Upper Half Space

"cut and unroll" Poincare

- one point on circle goes to infinity

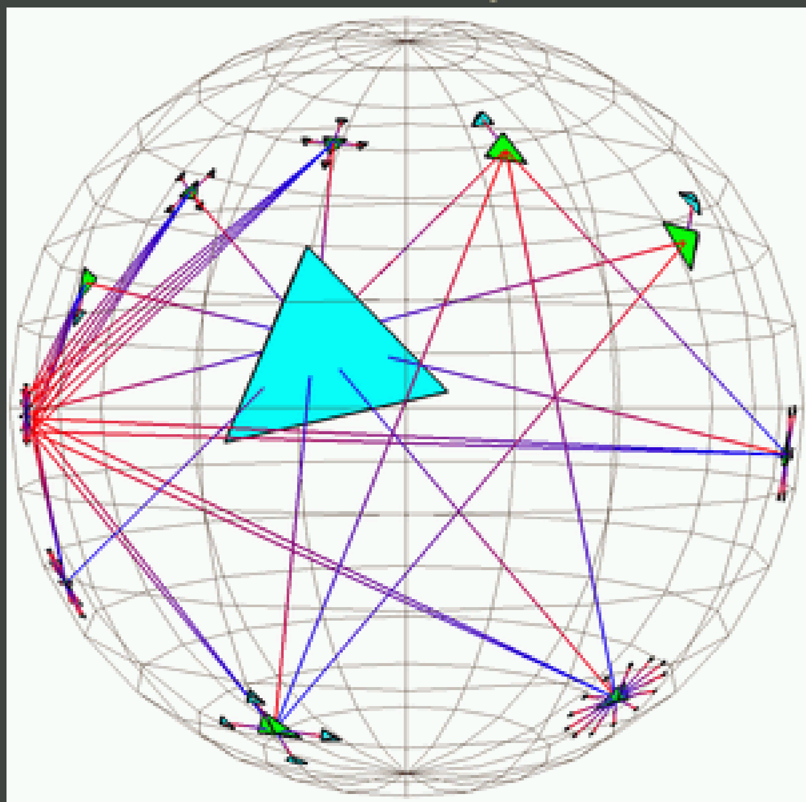




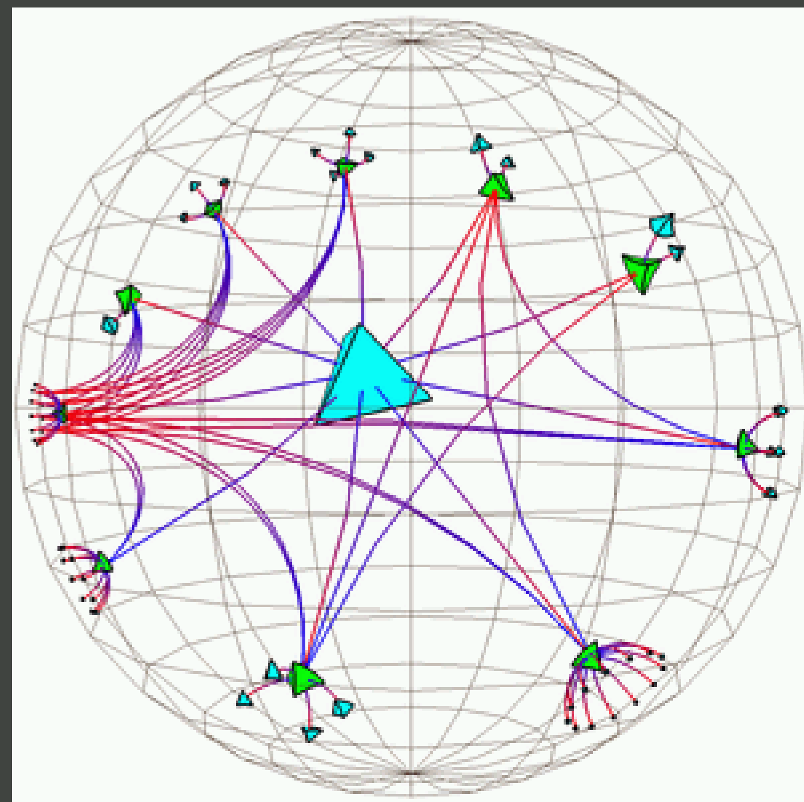
[demo: www.geom.umn.edu/~crobles/hyperbolic/hypr/modl/uhp/uhpjava.html

Models, 3D

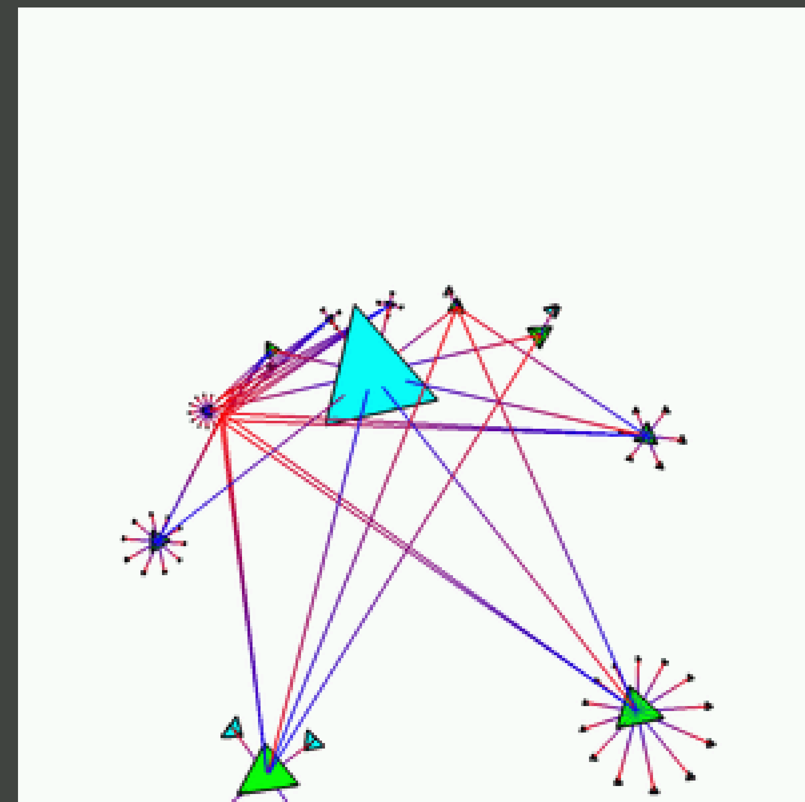
Klein/projective



Poincare/conformal



"insider"



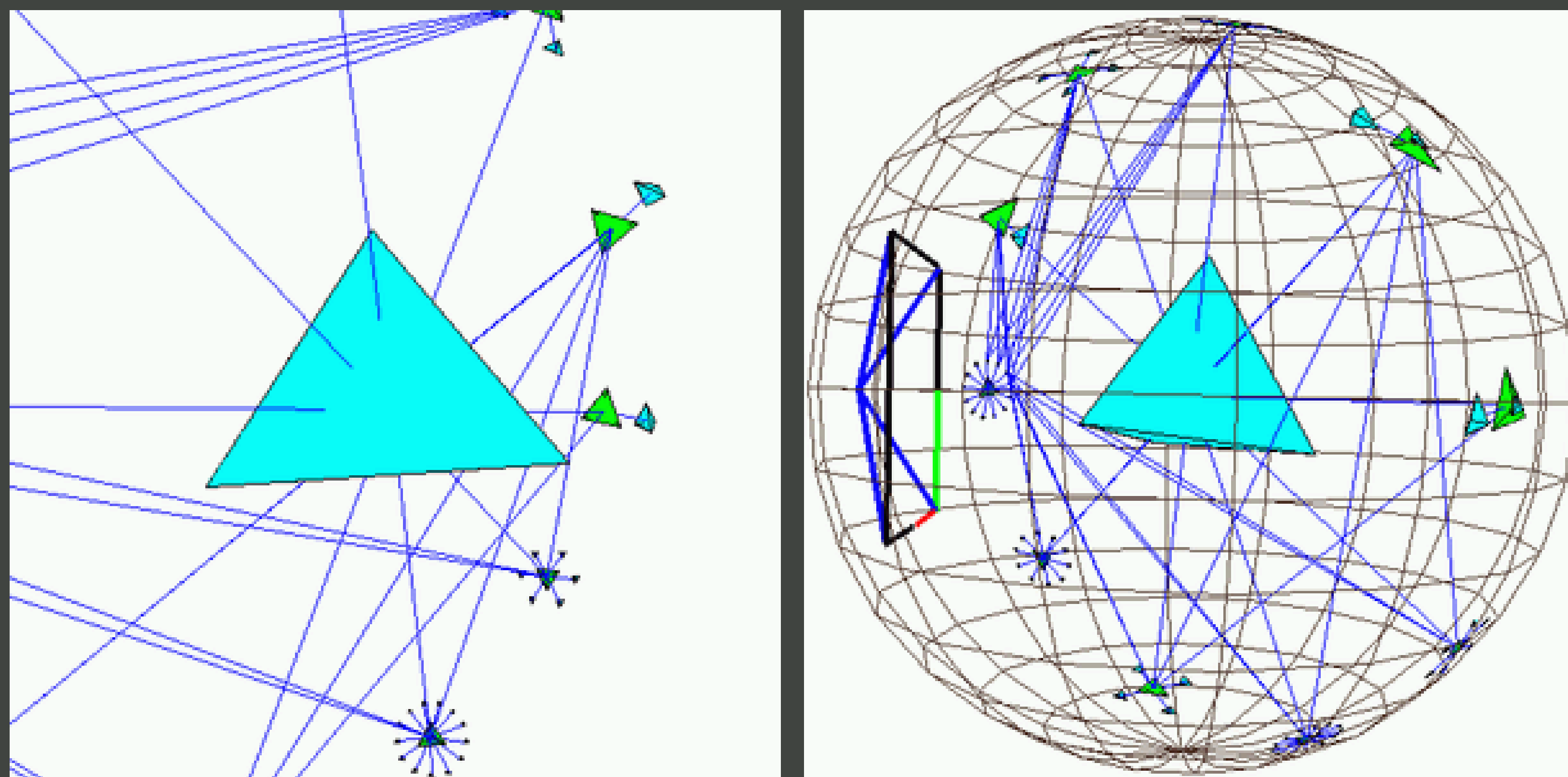
[http://graphics.stanford.edu/papers/webviz/]

- Upper Half Space
- Minkowski

3D Insider

insider: camera also moves by hyperbolic rules

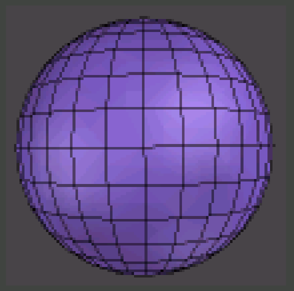
- cool, but limited visibility



[demo]

3D Klein

3-hyperboloid projects to solid ball



3D Minkowski

3-hyperboloid embedded in 4D space

light cone: special relativity

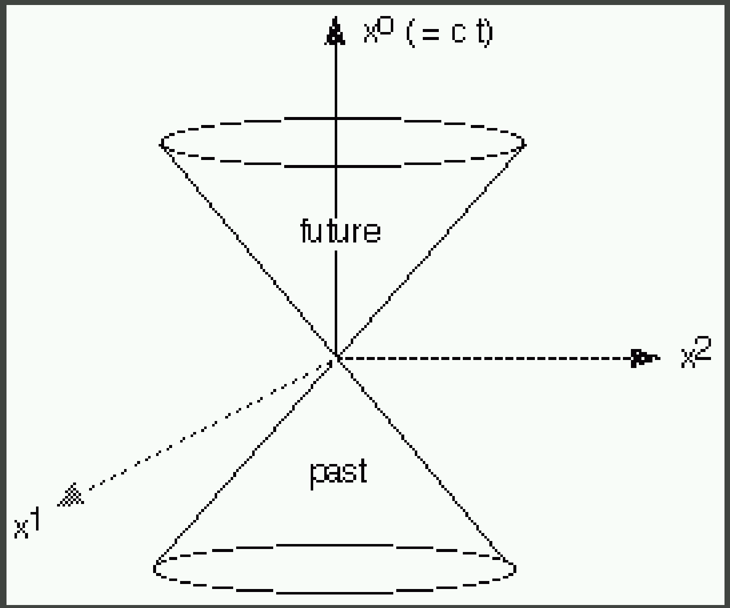
- diagrams in 2D for clarity

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]