Hyperbolic Geometry for Visualization

Oregon State University

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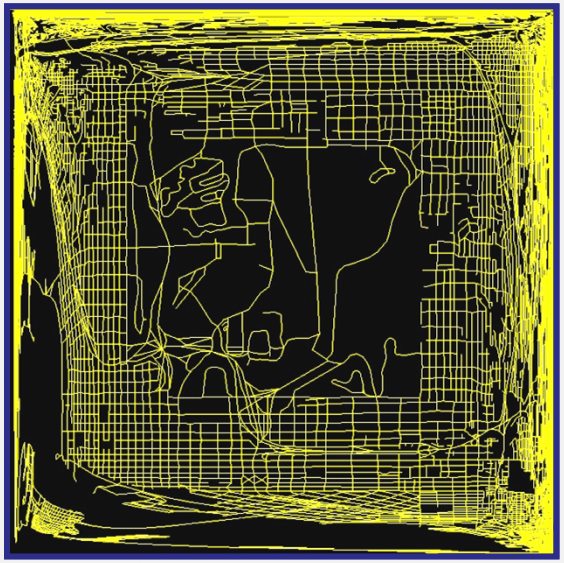

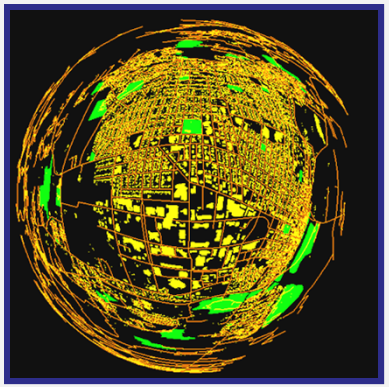

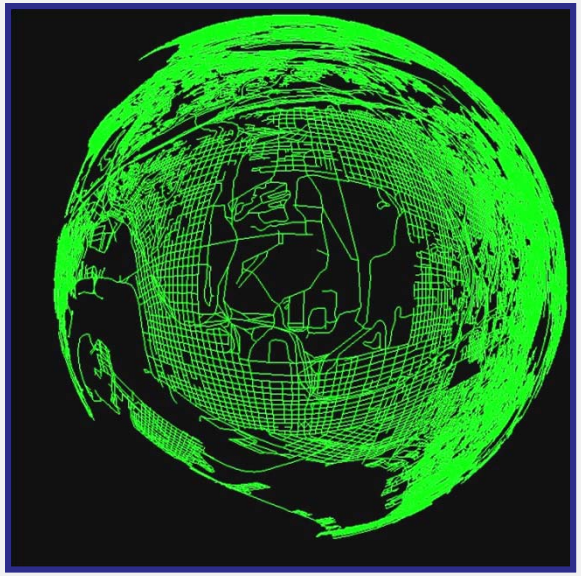

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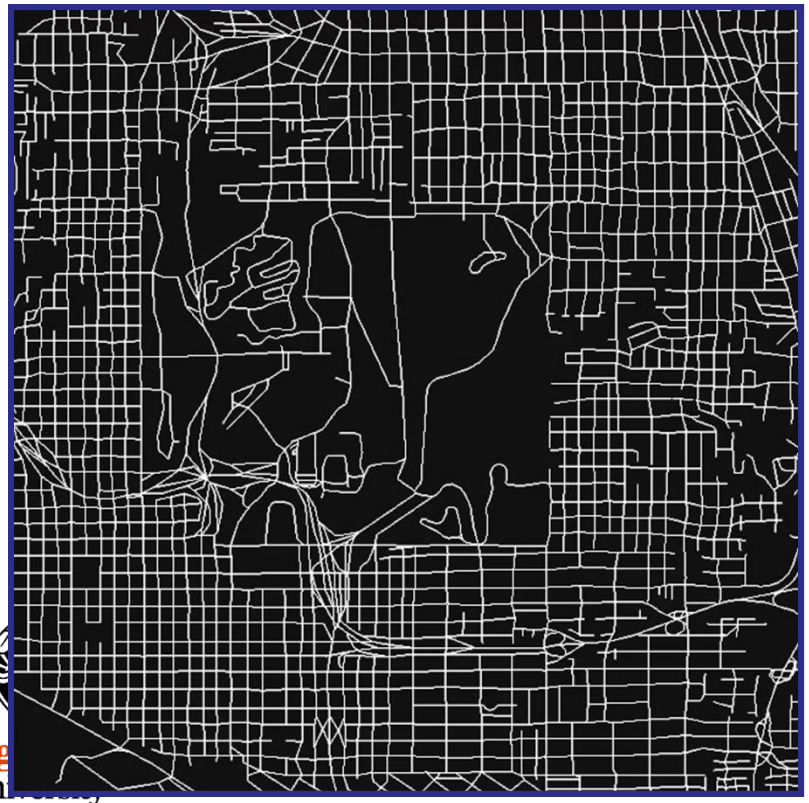
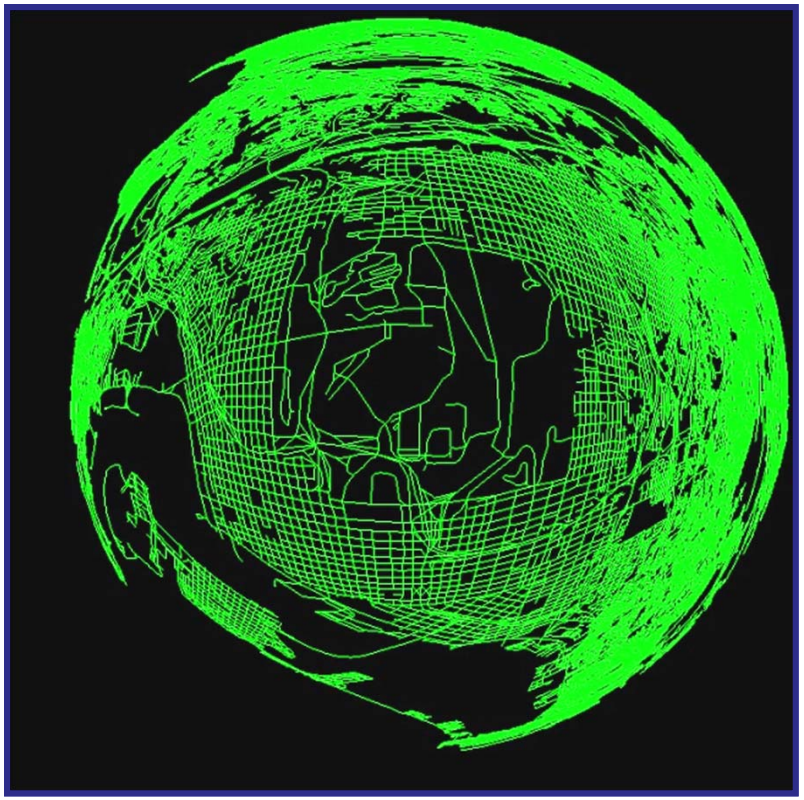
Zooming and Panning Around a Complex 2D Display

- Standard (Euclidean) geometry zooming forces much of the information off the screen
- This eliminates the context from the zoomed-in display
- This problem can be solved with *hyperbolic methods* if we are willing to give up Euclidean geometry





Usual Zooming in Euclidean Space

123,101 line strips
446,585 points

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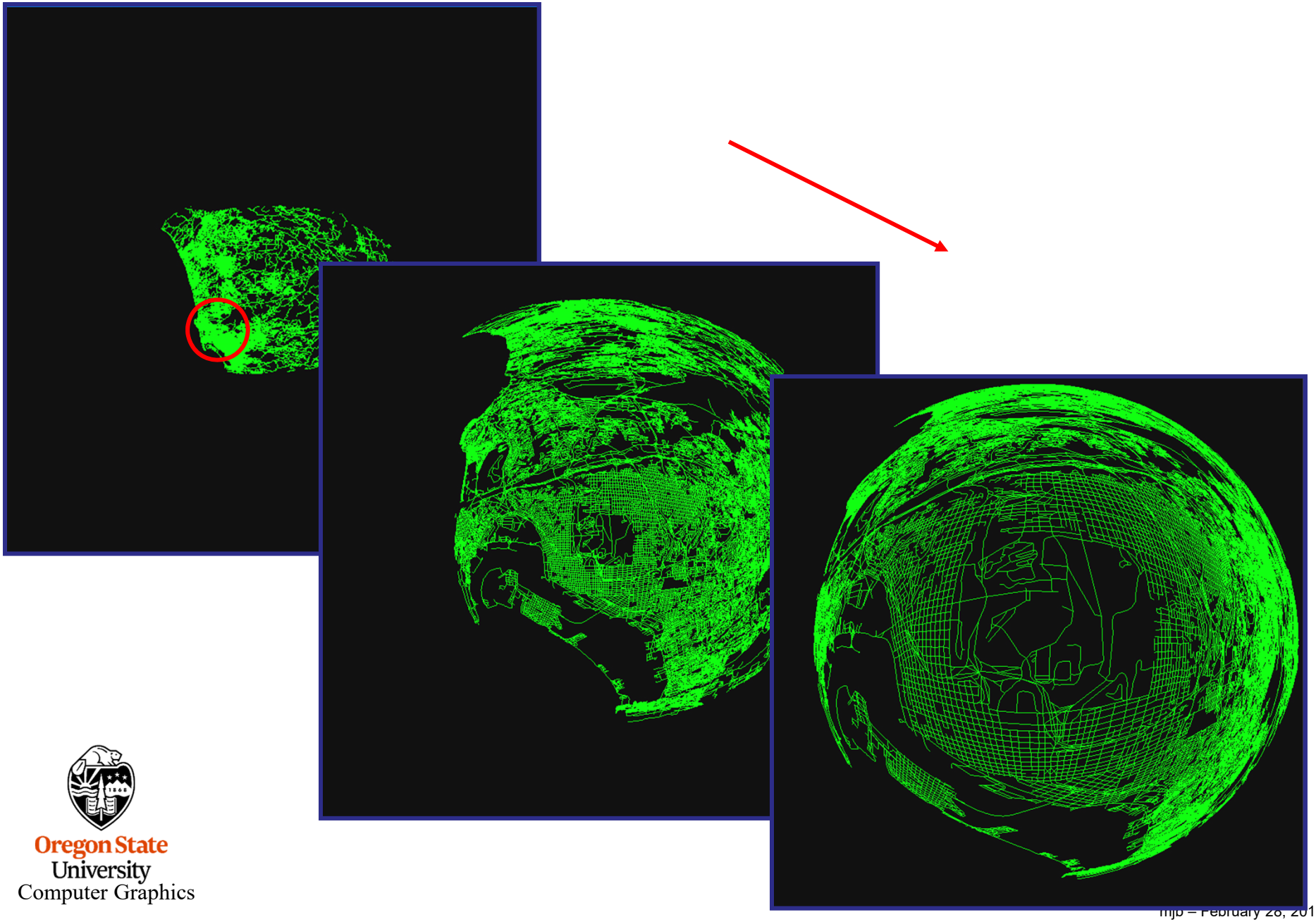
Zooming in Polar Hyperbolic Space



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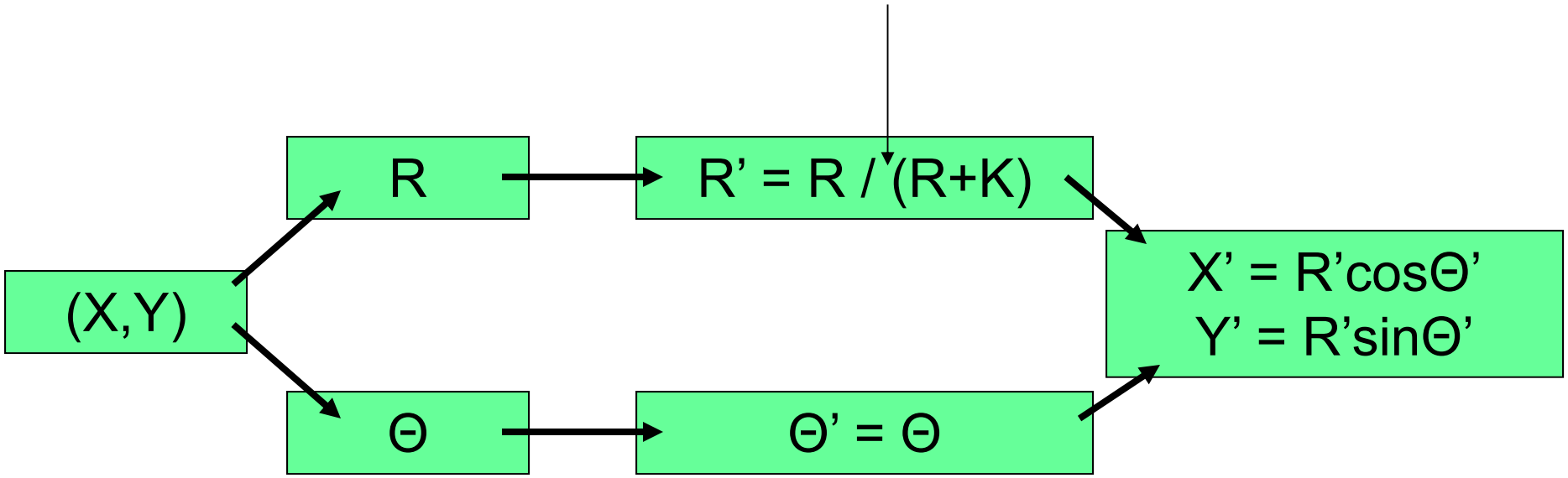
Polar Hyperbolic Equations

Overall theme: something divided by something else a little bigger



Because $R' = \dfrac{R}{R+K}$ **then:** $\boxed{\lim_{K \to 0} R' = 1}$ $\boxed{\lim_{K \to \infty} R' = 0}$

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Polar Hyperbolic Equations Don't Actually Need to use Trig

$$R = \sqrt{X^2 + Y^2}$$

$$\Theta = \tan^{-1}\left(\frac{Y}{X}\right)$$

$$R' = \frac{R}{R + K}$$

Coordinates moved to outer edge when K = 0

Coordinates moved to center when K = ∞

$$X' = R'\cos\Theta = \frac{R}{R+K} \times \frac{X}{R} = \frac{X}{R+K}$$

$$Y' = R'\sin\Theta = \frac{R}{R+K} \times \frac{Y}{R} = \frac{Y}{R+K}$$

Cartesian Hyperbolic Equations – Treat X and Y Independently

Polar

$$X' = \frac{X}{R+K}$$

$$Y' = \frac{Y}{R+K}$$

Cartesian

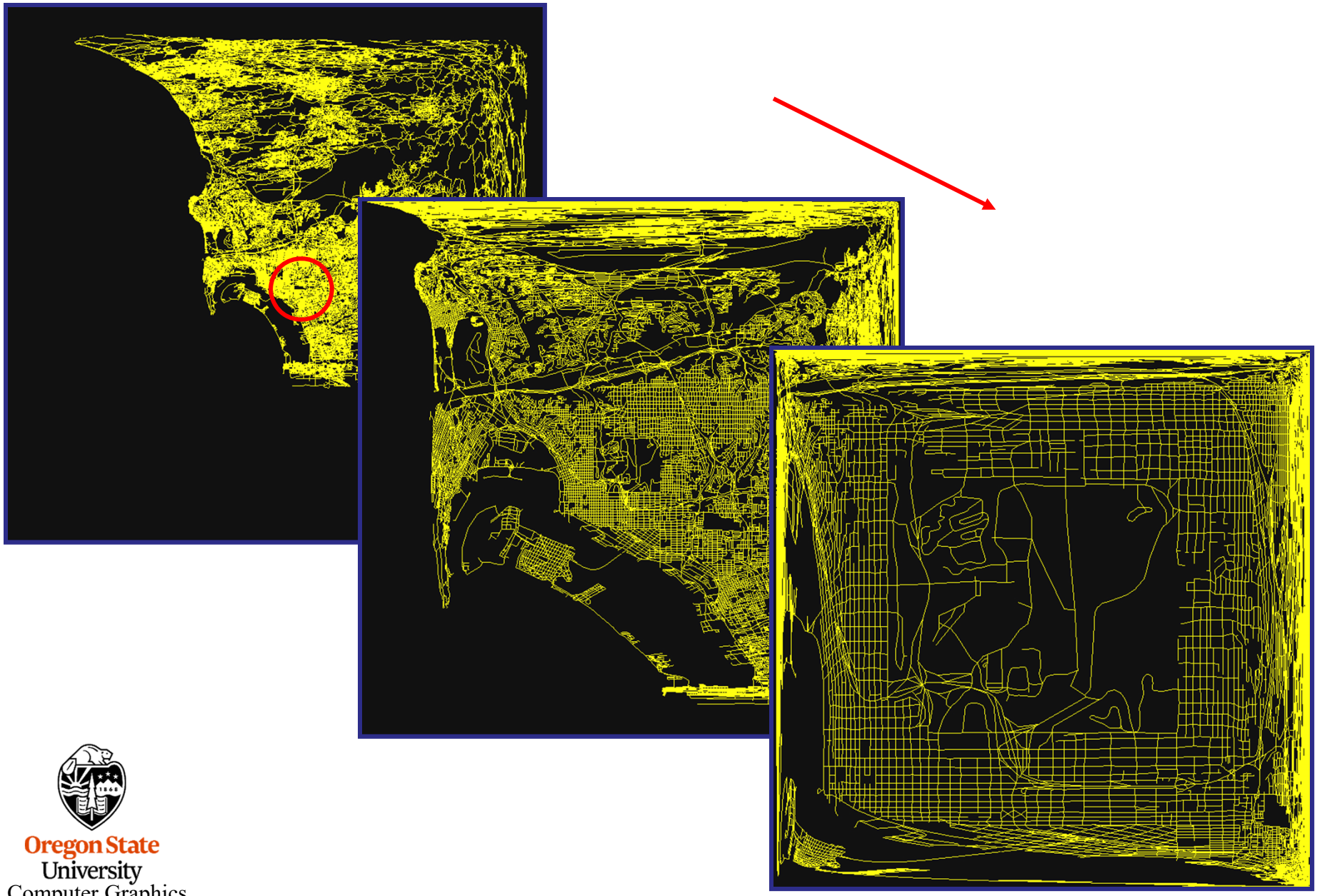
$$X' = \frac{X}{\sqrt{X^2 + K^2}}$$

$$Y' = \frac{Y}{\sqrt{Y^2 + K^2}}$$

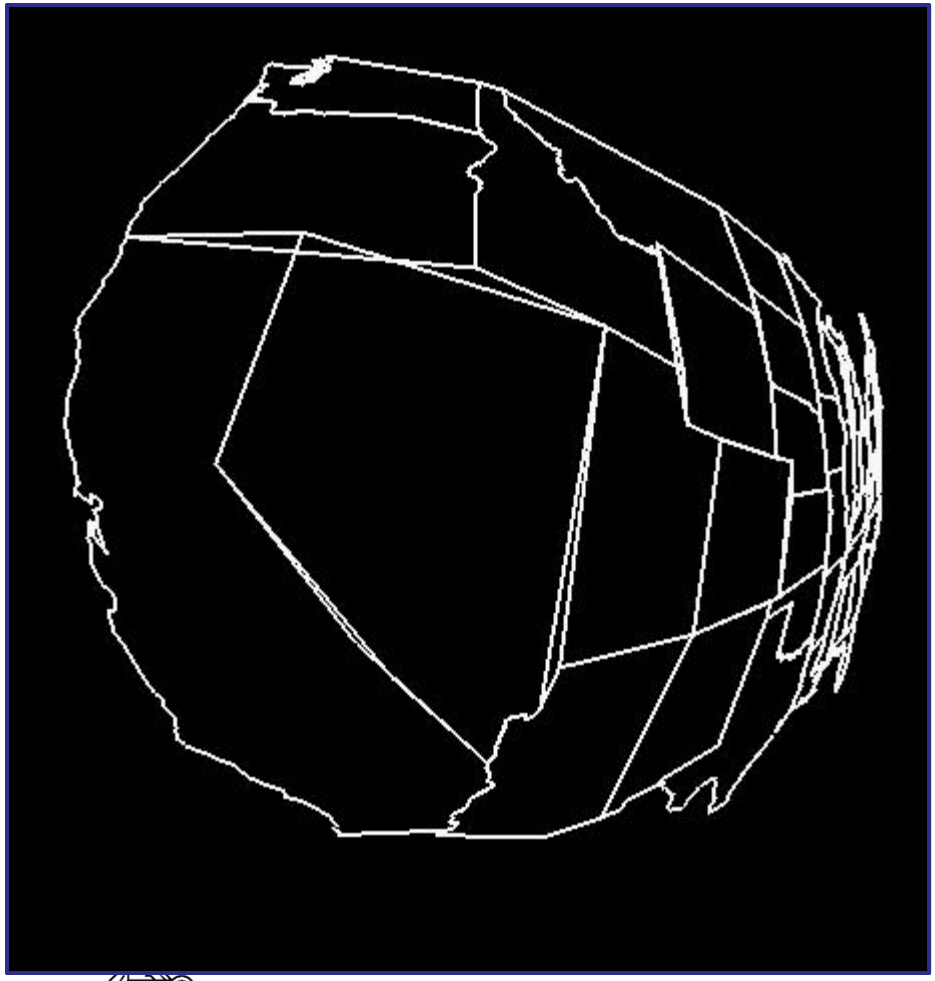
Coordinates moved to outer edge when K = 0

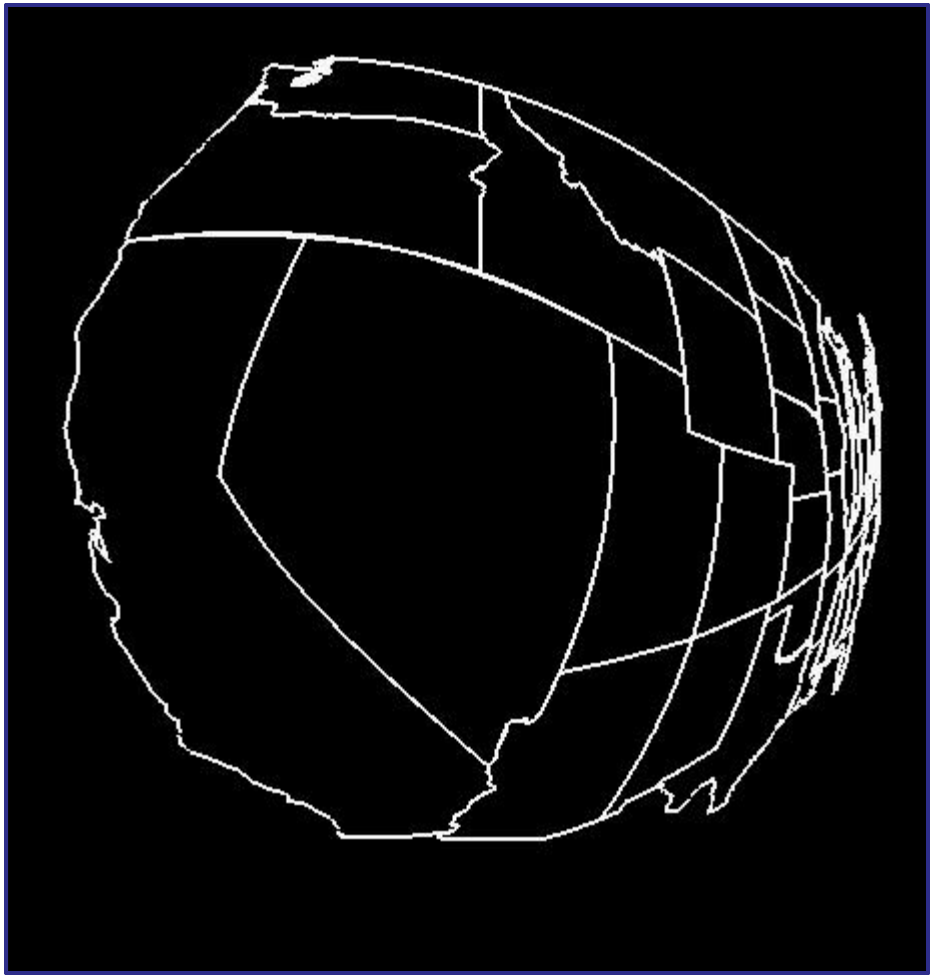
Coordinates moved to center when K = ∞

Zooming in Cartesian Hyperbolic Space



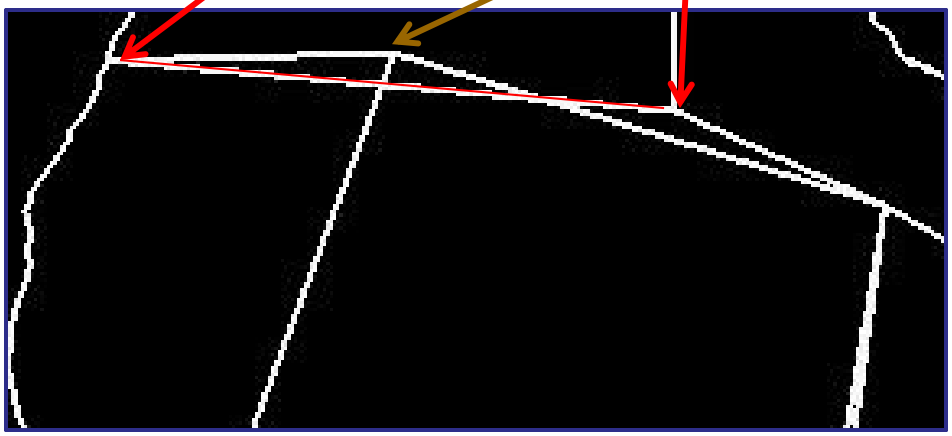
The Problem with T-Intersections





The Problem with T-Intersections

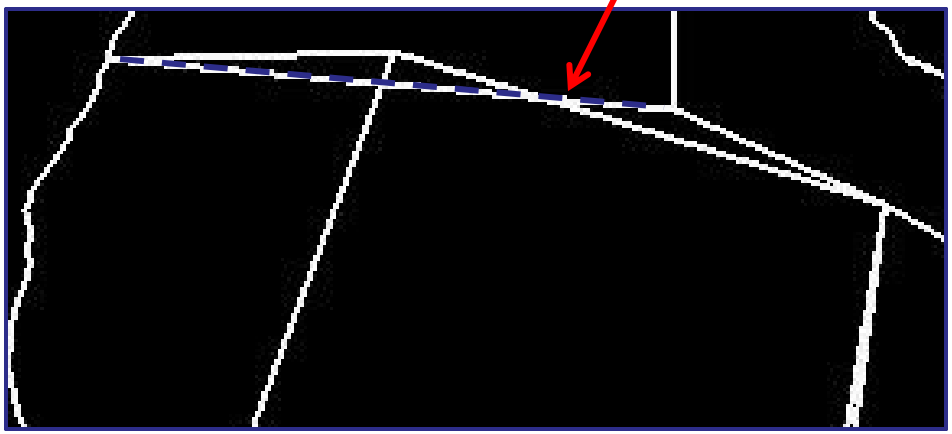
Your code computes the hyperbolic transformation here and here, and OpenGL draws a straight line between them. But, this point had its hyperbolic transformation computed separately, and doesn't match up with the straight line.



This kind of situation is called a T-intersection, and crops up all the time in computer graphics, even though we don't want it to. ☹

A Solution to the T-Intersection Problem

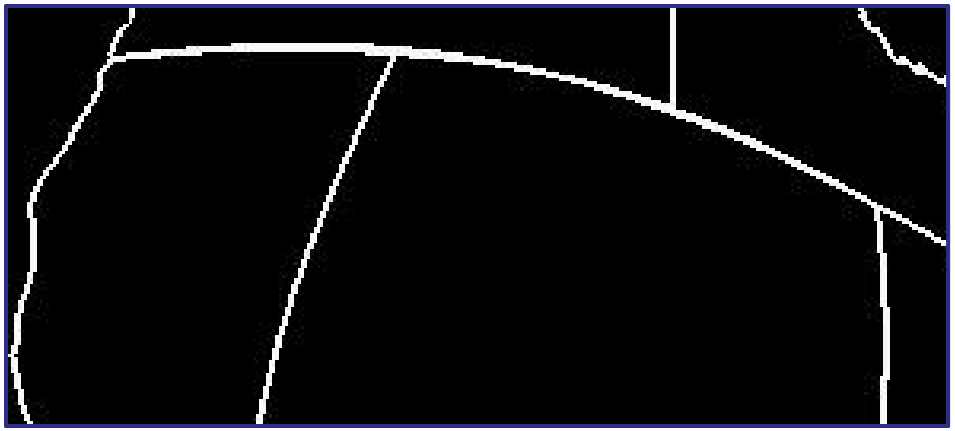
Break this line up into several (many?) sub-pieces, and perform the Hyperbolic Transformation on each intermediate point.



$$P(t) = (1-t)P_0 + tP_1$$

t = 0., .01, .02, .03, …

This makes that straight line into a curve, as it should be. But, how many line segments should we use?

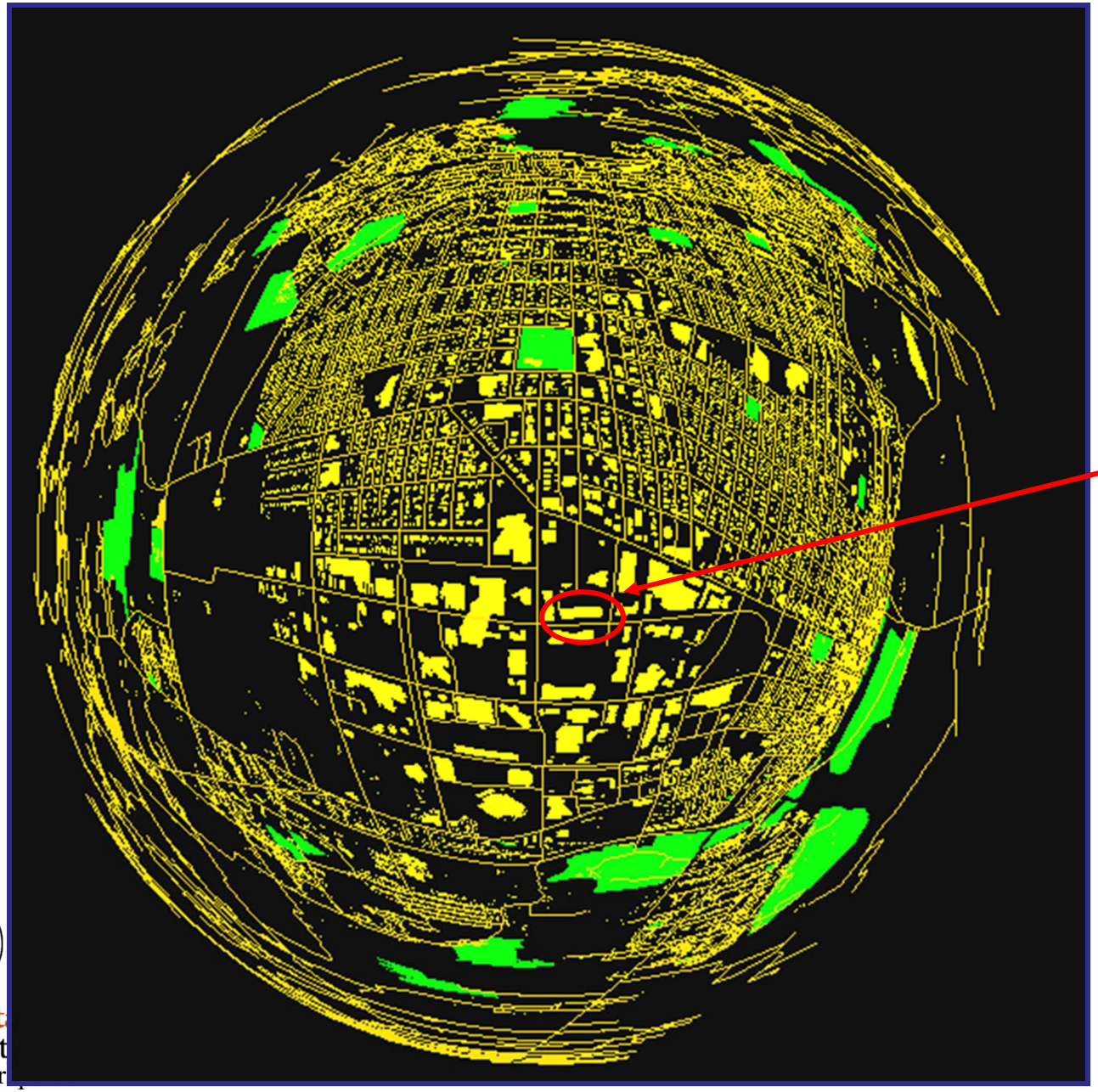


A More Elegant Approach is to Recursively Subdivide

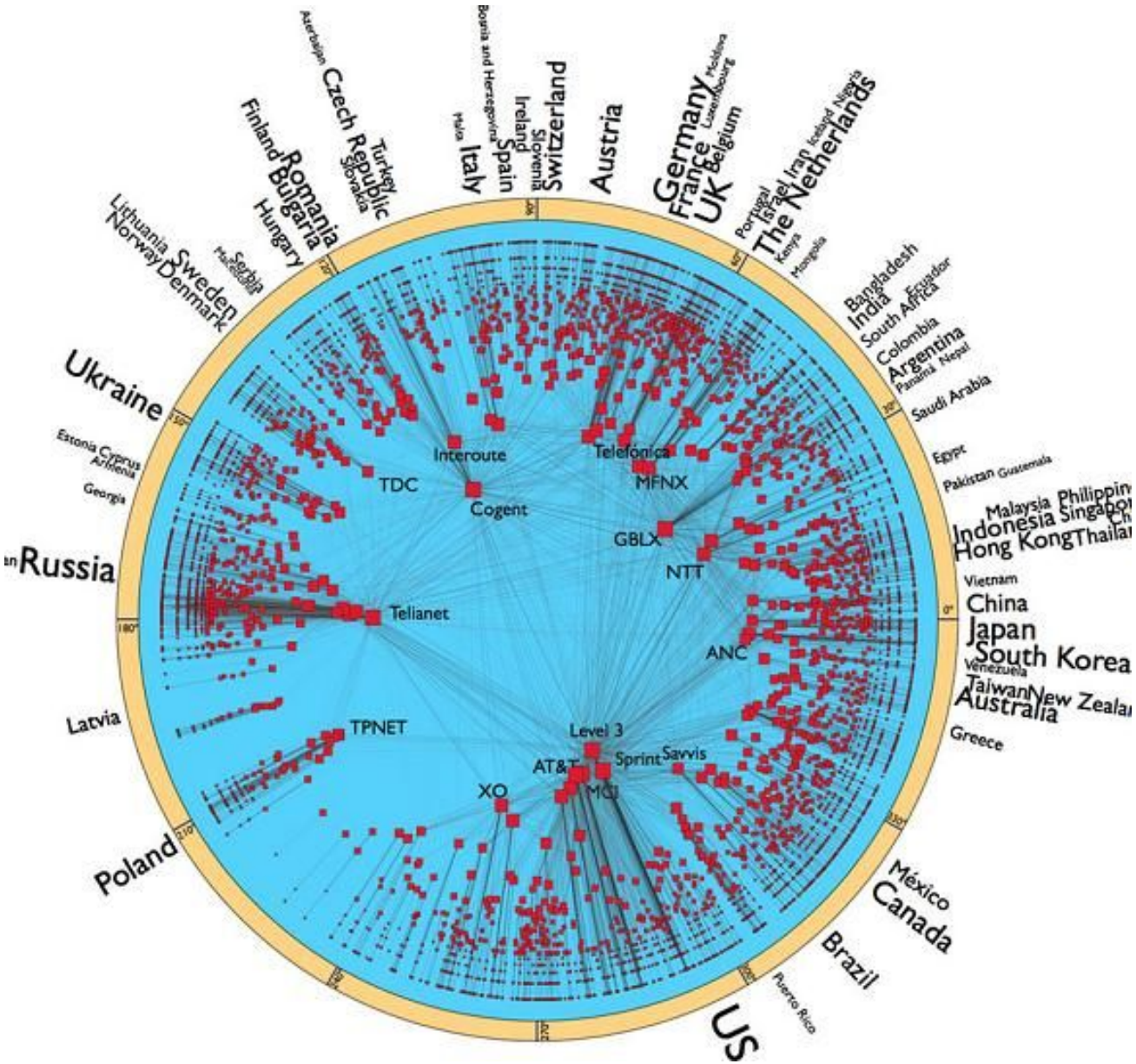
```
void
DrawHyperbolicLine( P0, P1 )
{
        Compute point  A = (P0 + P1) / 2.

        Convert point A to Hyperbolic Coordinates, calling it A'

        Convert P0 and P1 to Hyperbolic Coordinates P0', P1'

        Compute point  B' = (P0' + P1') / 2.

        Compare A' and B
        if( they are "close enough" )
        {
                Draw the line P0'-P1'
        }
        else
        {
                DrawHyperbolicLine( P0, A );
                DrawHyperbolicLine( A, P1 );
        }
}
```

Subdividing to render a curve or surface correctly is a recurring theme in computer graphics.

Hyperbolic Corvallis (Streets, Buildings, Parks)



Kelley Engineering Center



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