MIT Class 6.S080 (AUS)
Mechanical Invention through Computation
3-dimensional Expanding Structures
Mechanism – relation to base geometry

Linkages orthogonal to 3D surface

Linkages tangential to 3D surface
Transformable Typology: Expanding Shapes
Kinematic mode
Icosahedron
Radial expansion

Points on expanding shape move radially outwards.
Turning surfaces into mechanisms
Surface terminology

- Positive curvature
- Zero curvature
- Negative curvature

Surface normals

Planes of principal curvatures

Normal vector

Tangent plane

Negative curvature
Zero curvature
Positive curvature
Original patent: angulated scissor
Original patent: expanding polygon
Hubs create out of plane connections between linkages
Original patent: 3d loop linkage (4-sided)
Original patent: 3d loop linkage (6-sided)
Original patent: expanding sphere
Original patent: expanding icosahedron
Mini Sphere

Mini sphere works with double scissor between hubs
Angulated scissor construction - review

Call this surface-line (this line will lie on the surface of the shape to be built.)

Call this normal line (orthogonal to the surface)

180 - G

Note that surface-line in each position is the same shape – only the scale has changed (size is a function of angle $\phi$)

two links are identical

The location of their three respective pivots forms a similar triangle to the surface-line

Projection of scissor (angulated line) scales as scissor folds
As additional scissors are added, ratio of folded to unfolded size decreases.
Hub and link assemblies (4-sided)

To maintain symmetry, distance from hub to center scissor connection must be equal for all links going into a single hub.
Hub and link assembly (3-sided)

Hub pair

Hub pair
Base geometry

For structures with single scissors between adjacent hubs, circle tangency is required.

Hubs are located at center of circles.

Dual figure gives location of scissors.
Surface made up of tangential circles
Link construction from base geometry

Construct links as shown
Wireframe

Centerline geometry of scissors
Scissors shown without hubs

Need to allow space for hubs to avoid interferences
Method to set hub geometry

Scaling method
1. Scale original link length (A%)
2. Add line extension (B%)

where
A% + B% = 100%
(end points of construction line are same as original)

3. Insert scaled version back into base geometry

Red lines give wireframe hub geometry
Mini Sphere – single scissor version

Hub construction
Hub construction (alternate method)

Core polyhedron

Dual of core polyhedron

Lines represent scissors (these expand/contract in physical mechanism)

Polygons represent hubs (these do not expand/contract in physical mechanism)

decompose $\Rightarrow$ scale $\Rightarrow$ recompose
Double scissor construction

Construct a line whose end-points lie on original angulated line

Segments (composed as shown) provide wireframe geometry of links

Mid-point of constructed line
Mini sphere construction with double scissor

Original base geometry (single scissor)

Modified base geometry (double scissor)

Mid-point of constructed line

Construct links from line segments as shown
Establish hub geometry

For structures with 2 or more scissors between adjacent hubs, circle tangency is not required.
Wireframe
Product
Surface geometry => structural mechanism

- Surface Shape
Surface geometry => structural mechanism

- Surface Shape
- Tessellation
Surface geometry => structural mechanism

- Surface Shape
- Tessellation
- **Normal Vectors**
Surface geometry => structural mechanism

- Surface Shape
- Tessellation
- Normal Vectors
- **Intersections**
Surface geometry => structura
Surface geometry => structural mechanism
Korean Aerospace Institute
Korean Aerospace Institute
Expanding Sphere, CBIT Conference, Hanover, 2010
Expanding
Expanding Helicoid
Museo Interactivo Mirador, Chile
Smith Haut Lafitte
Bordeaux, France
Hyperbolic parabolid
Hyperbolic paraboloid