

Computer Animation

9-Deformations

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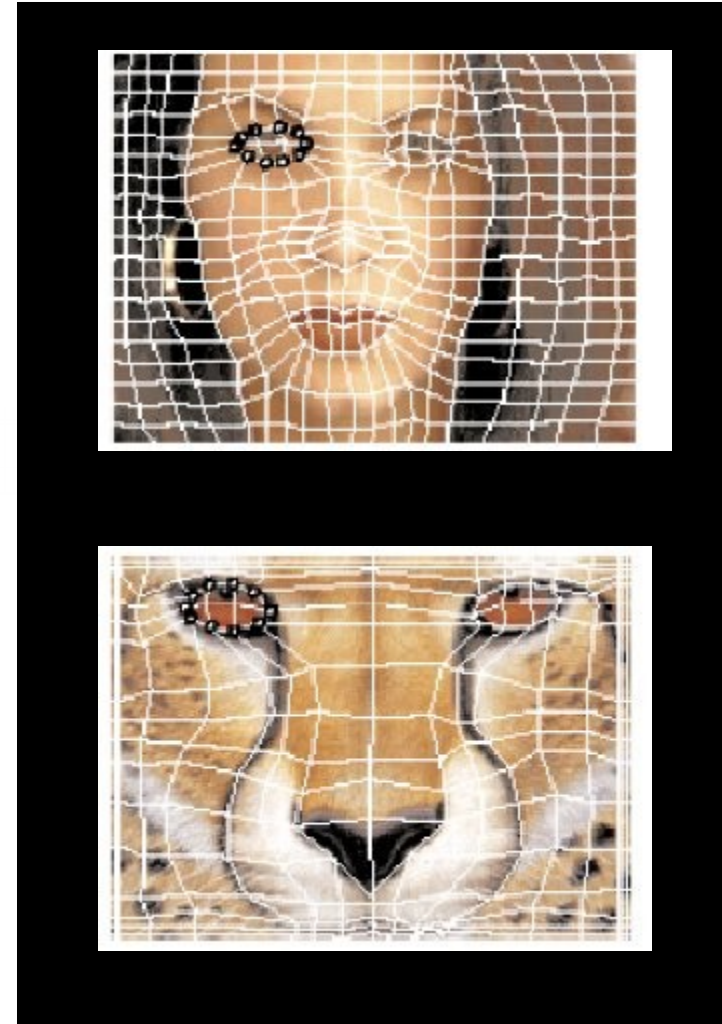
Morphing (2D)

- Morphing stands for two-dimensional image metamorphosis
- Typically, the user wants to transform one image (source image) into another image (destination image)



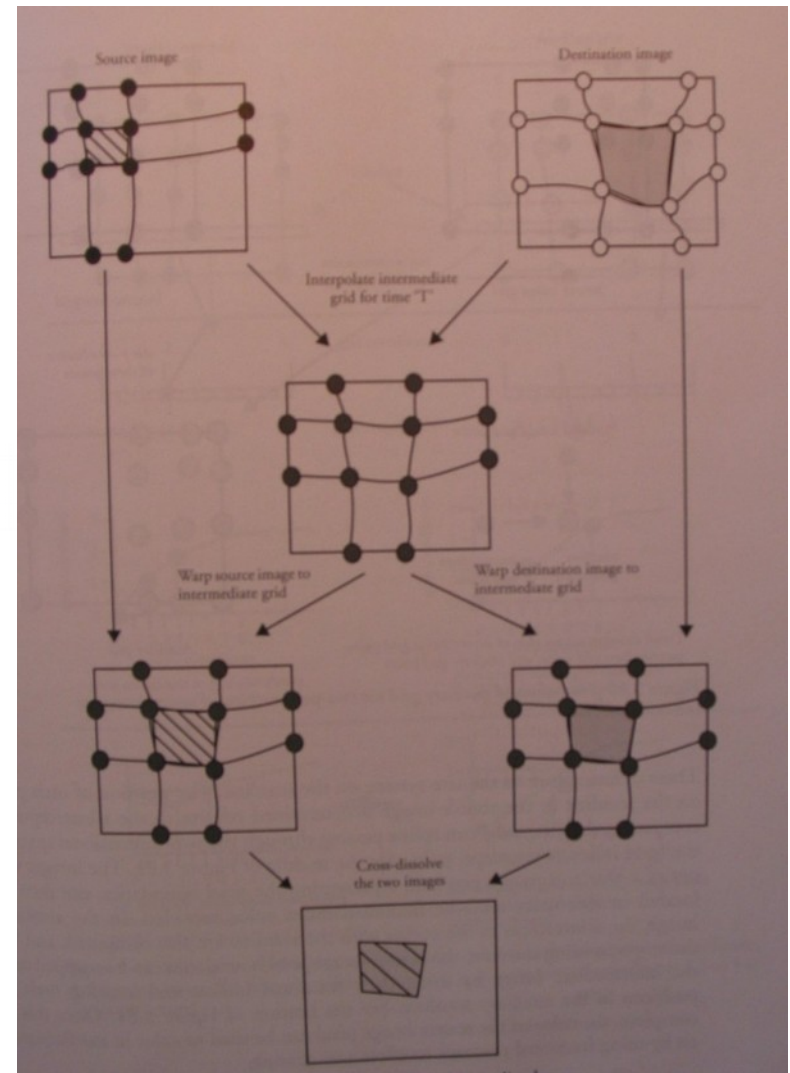
Morphing

- The user defines a curvilinear grid over each of the two images
- Corresponding elements in the pictures must lie in corresponding cells on the grids
- The number of the cells must also be the same
- To calculate k intermediate images, the vertices (= points of intersection of the curves) are either linearly interpolated or higher order interpolation is used



Morphing

- Pixels from source and destination are stretched so that the warped versions of both the source and the destination coincide
- On a pixel by pixel basis a cross dissolve is then performed to obtain the desired effect
- This is done pixel wise on a scanline basis



Feature based morphing

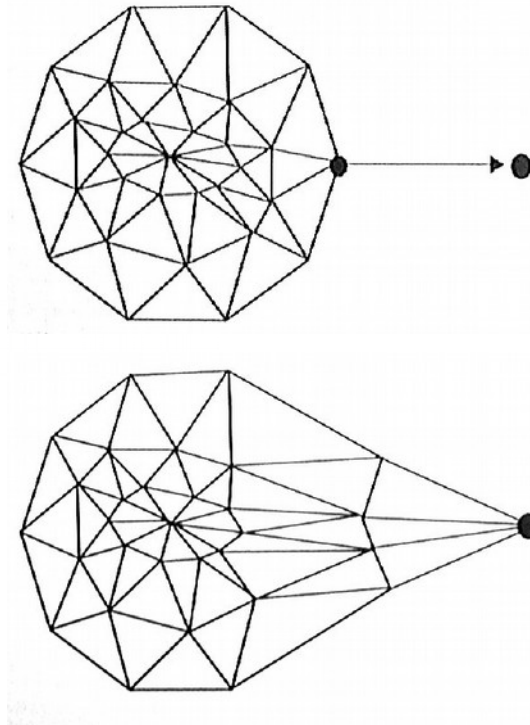
- Instead of using a grid, the user can establish the correspondence between images by using feature lines
- These feature lines are interpolated to form an intermediate feature line set
- The interpolation can be based
 - either on interpolating endpoints
 - Or on interpolating center points and orientation
- In any case, a map is made for each pixel to each interpolated feature line, and a weight is computed saying how much influence that feature line should have on that pixel
- Such mapping is used in the source image to locate the source image pixel corresponding to that intermediate image pixel
- The weight is used to average the source image locations generated by multiple feature lines into the final source image location
- This location is used to compute the color of the intermediate image pixel
- Same procedure is applied to destination image
- The resulting intermediate images are then cross dissolved

Deforming 3D objects

- Deforming objects is a powerful animation technique
- The simplest transformation that can be applied to an object is an affine transformation
 - Affine transformations preserve straight lines
 - In general, an affine transformation is a composition of rotations, translations, dilations and shears.
 - They are represented by 3x3 matrices plus a translation:
 $\underline{x}' = \underline{x}A + \underline{k}$ with A non singular (i.e. $\text{Det } A \neq 0$)
- They can be used for the squashing and stretching of an object and the shearing of a sudden stop of an object

Warping objects

- A simple way to modify the shape of an object is to
 - pull one or more vertices and
 - propagate displacement to neighbouring points
- Such displacement can be attenuated by attenuating relative displacement of first node and transfer it to neighbours



Warping objects

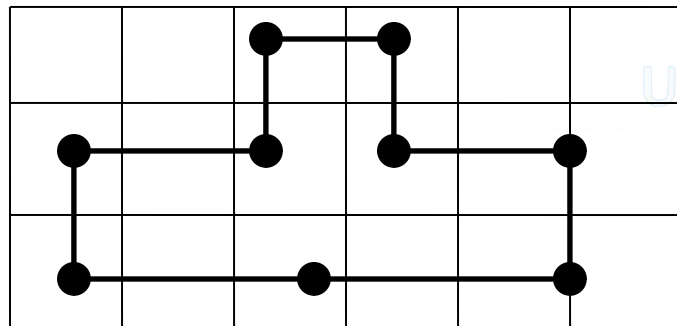
- For this, a distance function may be used, e.g.
 - Min # of edges to be displaced
 - Min distance travelled on object surface between seed vertex and vertex to be displaced
 - Attenuation is chosen as function of distance metric
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- One way to do it is to allow the user to select a function from a set of power functions
 - For a vertex which is at distance i from seeded vertex, a scale factor is applied to the displacement
$$S(i) = 1 - (i/n + 1)^{k+1} \quad k \geq 0$$
$$(1 - (i/n + 1)^{-k+1}) \quad k < 0$$
 - When $k=0$ we have here linear attenuation
 - $k < 0$ have the effect of quite rigid displacement

Coordinate grid deformation

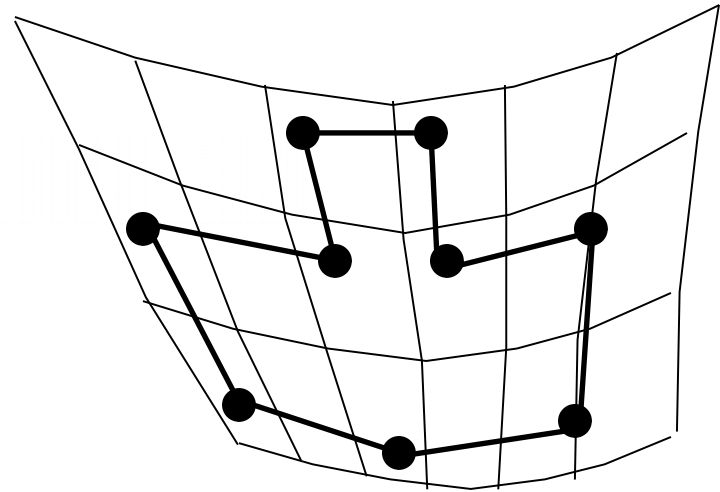
- Sederberg introduced *free form deformation* (FFD)
- The idea is to use a local coord system to encase the area of the object to be distorted
 - Typically, this would be initially an orthogonal grid
 - Object vertices are then expressed in this local coord system
 - The user is then allowed to distort local coordinates
- Notice that normally one would choose distortion so that the transformation is continuous
 - i.e. the space is not torn apart
- Transformations can be however non-linear
 - Thus, deformations done this way are more flexible
 - AND they are more natural and intuitive for the user

2D grid deformation

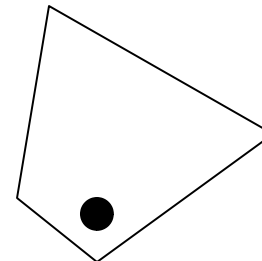
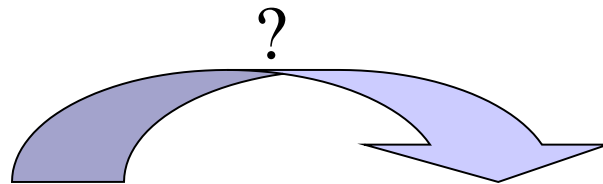
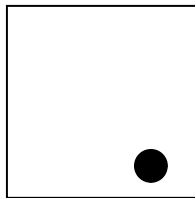
- The idea here is pretty simple:
 - Take your grid



- Map to warped space by using bilinear interpolation for the unknown points

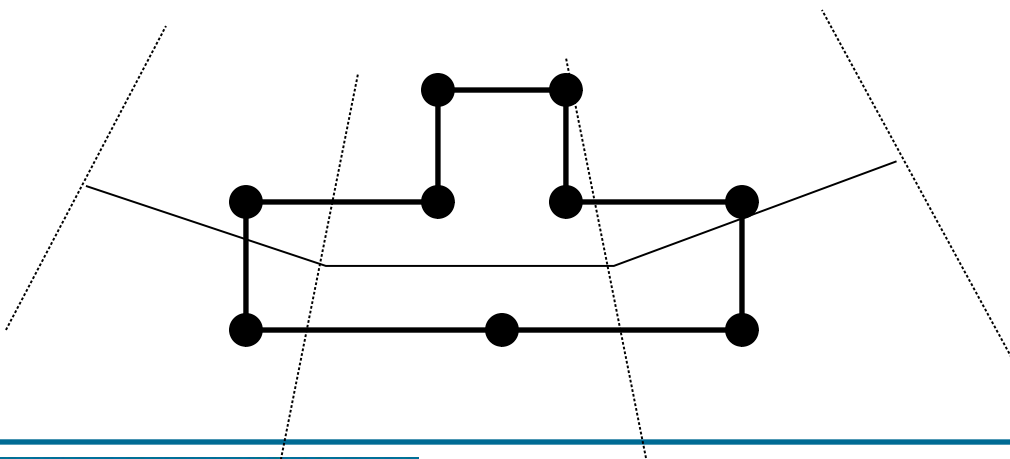


- Problem:



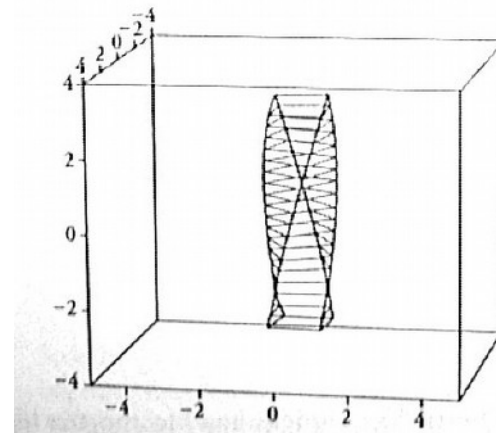
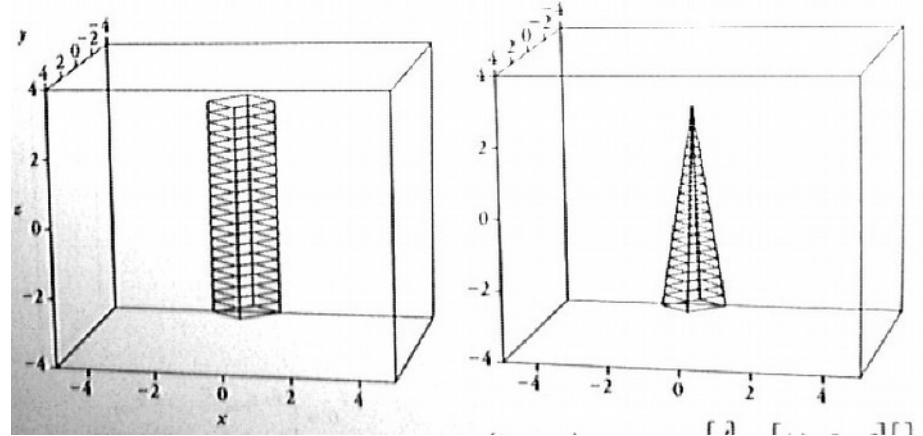
Polyline deformation

- A similar method employs a polyline to do the deformation:
 - The user specifies a polyline to map the object
 - Each polyline segment boundary point partitions the space in two (boundary lines)
- Each vertex is mapped on the corresponding polyline segment:
 - Construct line between boundary lines // to the polyline segment
 - Store per vertex the following:
 1. Closest polyline segment
 2. Distance from polyline segment
 3. Ratio of length of polyline segment and distance
 - The polyline is then displaced for deformation and new point coordinates are retrieved



Global deformation

- Alan Barr proposed a method for globally deforming the space into which an object is embedded
- He applies a 3x3 transform matrix which is a function of the point to be transformed:
 $P' = M(P) \cdot P$
- The transformation function can in principle be any function



Free form deformation (FFD)

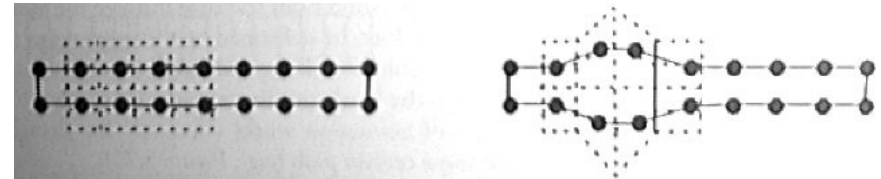
- Basically it is an extension of the 2D technique
- A local coordinate grid is laid around the object
- Transformations are applied to the local grid
- Positions of the new object points are computed through trilinear interpolation
 - Trilinear interpolation is the generalization of bilinear interpolation to 3D
- Alternatively Bezier, or any kind of interpolation can be used

Compositing FFDs

- FFDs can be composed sequentially or hierarchically
- This way detail can be added bit by bit to the model to achieve the desired level
- For example, if a bent tube is transformed, one can embed at the bend another finer grained FFD which is attached to the larger scale FFD
 - The finer FFD will control better the FFD of the bend

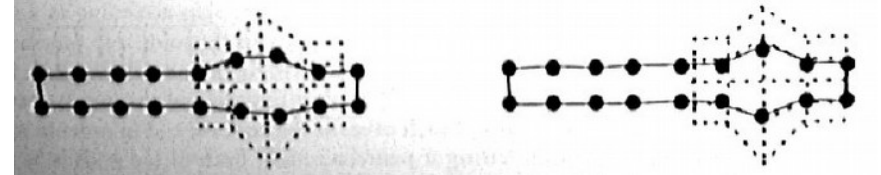
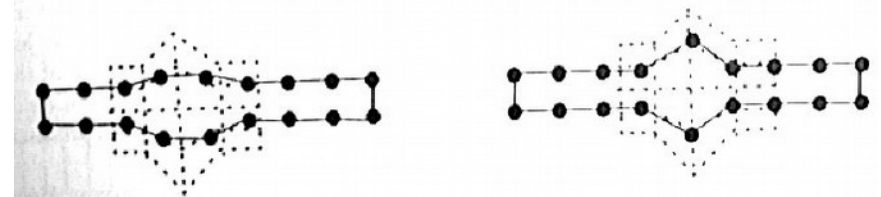
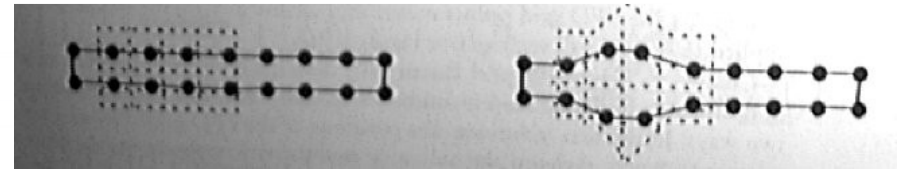
Deformation tools

- A deformation tool is the composition of an initial lattice and a final lattice (Cocquillart)
 - The initial lattice is user defined and is embedded in the region of the model to be modified (=animated)
 - The final lattice is the copy of the initial lattice that has been deformed by the user
- To the object a deformation tool is therefore defined which controls the deformation of my object
- One animates the object by specifying the movement of the deformation tool relative to the object



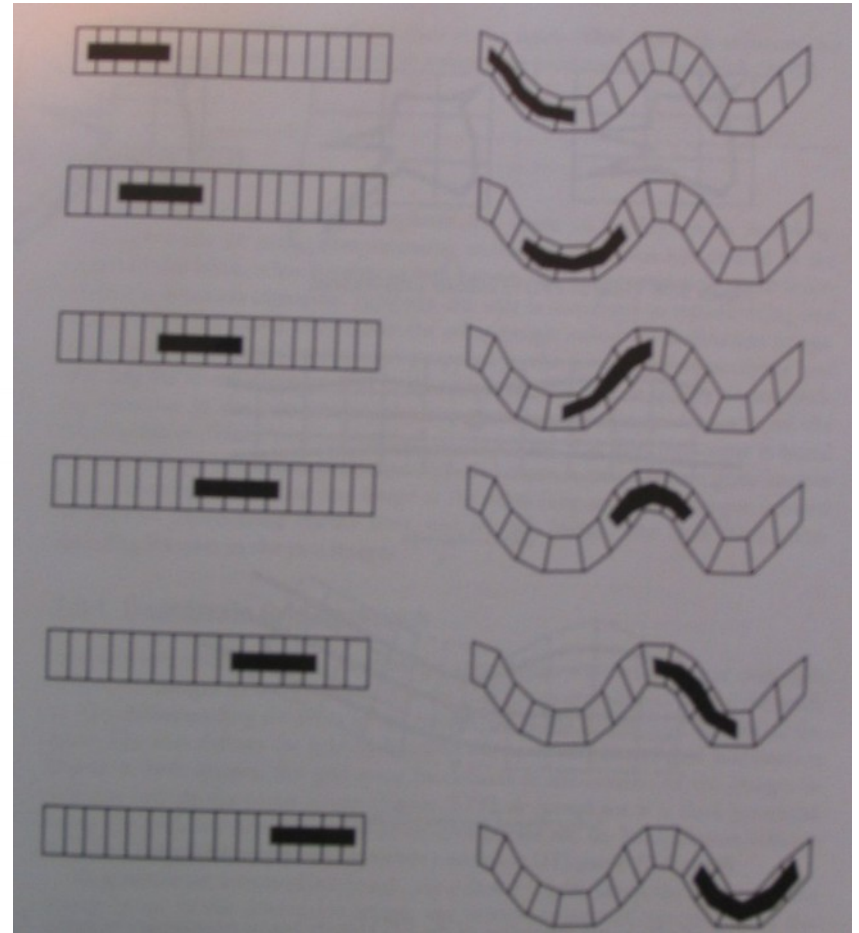
Deformation tool on an object

Moving the deformation tool



Animating the FFDs

- It is obvious that what we are doing is separating the logical space of the animation from the actual 3D space
- Look at the example: the logical animation is pretty simple
- Not so the real animation



3D shape interpolation

- Morphing 3D object is another pair of shoes
- Here, there is no general purpose solution available yet
- The real problem is the fact that this is a topologically complex problem, with deep roots in math
- Topology says that a continuous transformation from an object to another is only possible if the two objects are isomorphic
- Basically, there are two type of techniques:
 - Surface based
 - Volume based
- Surface based techniques modify the polygonal structure of the objects until there is a 1 to 1 map between the polygons
- The number of holes (genus) of the surfaces determine if they are transformable into each other or not

3D shape interpolation

- For most cases, the shape transformation problem can be split in two subproblems:
 - The correspondence problem, i.e. Establishing a map between elements
 - The interpolation problem, i.e. creating the inbetween interpolations for the objects
- Moreover, a user must be given control about this, and might want to decide for himself which parts of an object are transformed into which parts of the other one

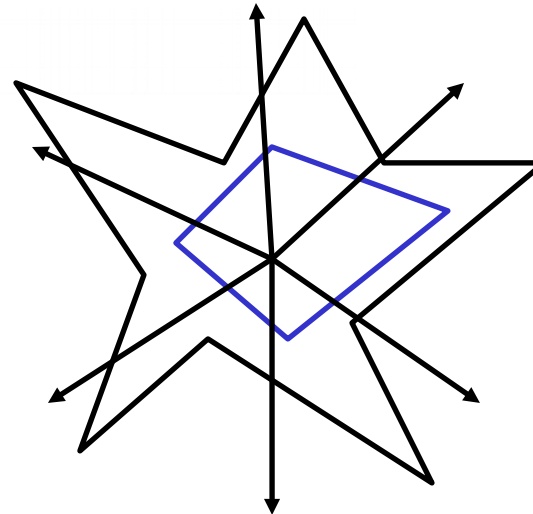
3D shape interpolation

- Simplest case: if one object has been derived from another one, then the polygonal structure is the same
- Thus they are easy to transform from one into another
- A simple interpolation between corresponding elements should be good enough

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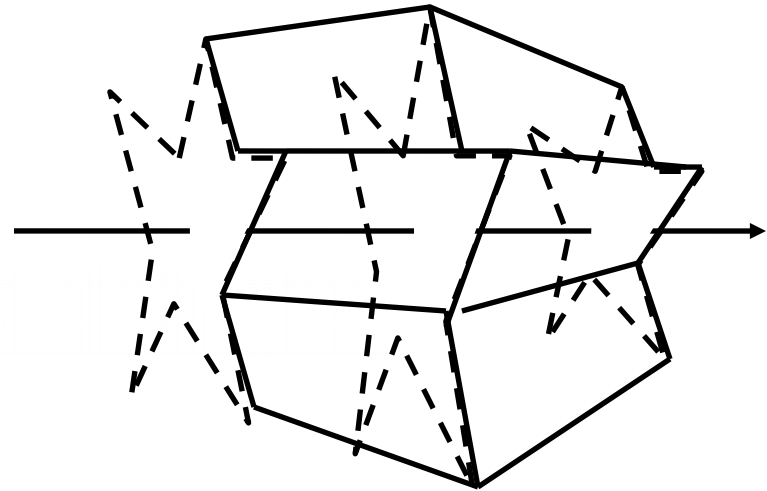
Other shapes

- Star shaped polyhedra can be transformed into each other by using polar coordinates (those are „2D“)
- Remember: a star shaped object is an object such that there is a point in the interior such that all points of the contour of the object are visible from this point
- Here one can simply sample along rays from the centre and interpolate corresponding points



Other shapes

- If the objects have an axis, and along this axis the intersection of the object with the slice is star shaped,
- then one can interpolate the slices as said before to transform one object into the other
- This approach can be extended to include the case when there is no axis, but there is a polyline which can function as an axis



Other shapes

- If the shapes are not such that the two former algorithms can be applied, there are also other possibilities
- If the objects are both of genus 0, one can try to map the objects to an intermediate common object such as a sphere
- Once both objects are mapped to a sphere, then the union of the corresponding mappings is constructed and used to map it inversely to the original objects
- All genus 0 objects can of course be mapped to a sphere, because they are homeomorphic to a sphere
- The problem is to find the homeomorphism, and there is no unique way to do so
- Even if one does so, this method is quite expensive, since the polygons of each object are subdivided in the second step.



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