

A system's architecture for Warping and Morphing of Graphical Objects

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Our Goal

***Develop a testbed system
for warping and morphing
of graphical objects.***

System Requirements

- **Use different graphical objects**
- **Use different shared techniques**
- **Plug in new objects**
- **Plug in different techniques**
- **Uniform and coherent interface**

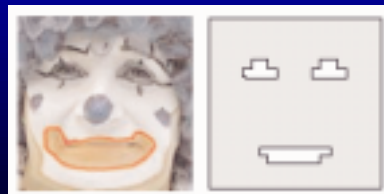
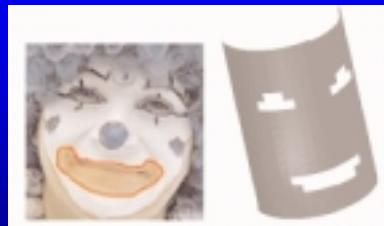
Importance of the Goal

- **Warping and morphing is a basic operation in graphics**
 - **Registration**
 - **Motion warping**
 - **Texture mapping**
 - **Correction of Optical distortion**
 - **Image stitching**
 - **Image based rendering and modeling**
- **Many applications**

Current Status

- Research has covered particular classes of graphical objects
- There has been no attempt to obtain an integrated framework
- There exists no flexible system architecture
 - Different graphical objects
 - Different techniques

Need for an integrated system



Key concepts

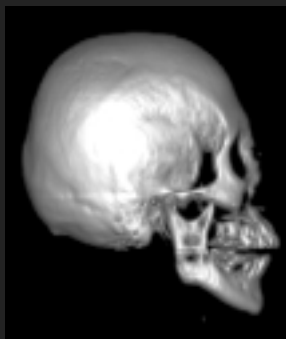
Physical	Mathematical	Representation	Implementation
Concrete	Abstract	Discrete	finite

- *Graphical object*
- *Warping and morphing*

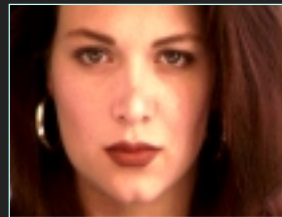
Graphical Objects



Drawings



Volume data



Images

Definition of a Graphical Object

- **Shape**

$$U \subset \mathbb{R}^n$$

- **Attributes**

$$f: U \subset \mathbb{R}^n \rightarrow \mathbb{R}^k$$

- **Dimension of the GO**

Image

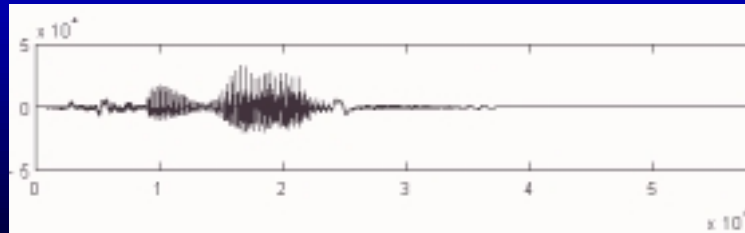


$$f: U \subset \mathbb{R}^2 \rightarrow \mathcal{C}$$

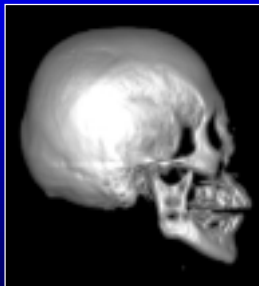
- **Shape is a rectangle**
- **Attribute is color**
- **Dimension = 2**

Audio

- Shape is an interval $f : U \subset \mathbb{R} \rightarrow \mathbb{R}$
- Attribute is air pressure
- Dimension = 1



Solid (volumetric object)

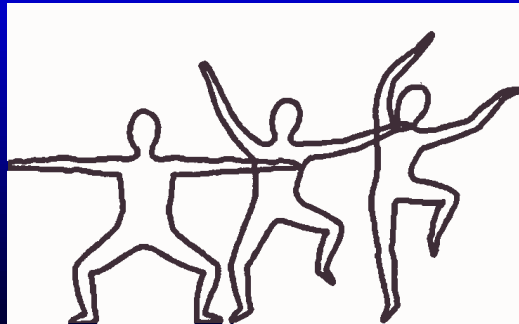


$$f : U \subset \mathbb{R}^n \rightarrow \mathbb{R}$$

- Shape is an spacial domain
- Attributes: density, ...
- Dimension = n

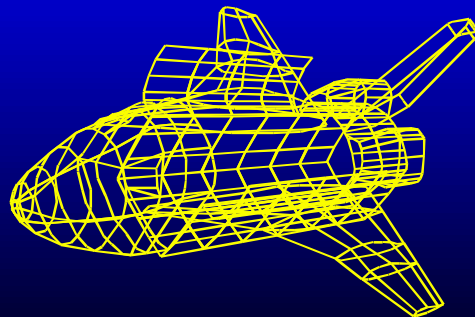
Curves (Drawings)

- One-dimensional graphical objects of the plane



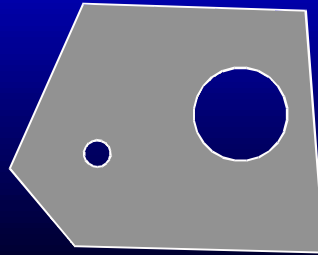
Surfaces

- Two-dimensional graphical objects of the space



Two-Dimensional Solids

- 2D graphical objects of the plane
- Binary image
 - Shape is the focus



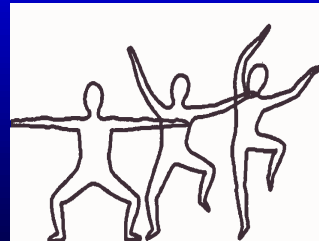
Animation

- Variation of a graphical object along the time

$$\mathcal{O} = (U, f), U \subset \mathbb{R}^n$$

$$\varphi: [a, b] \times \mathcal{O} \rightarrow \mathbb{R}^n$$

$$t \mapsto \varphi(t, \mathcal{O}) = \mathcal{O}_t$$

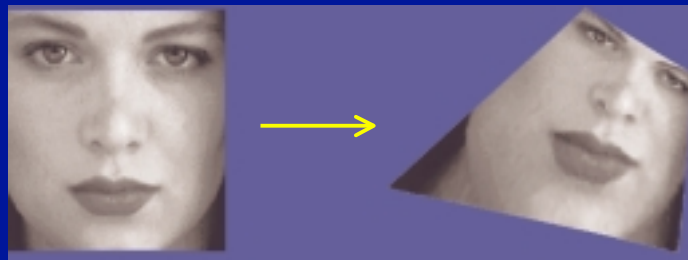


time

Warping and Morphing

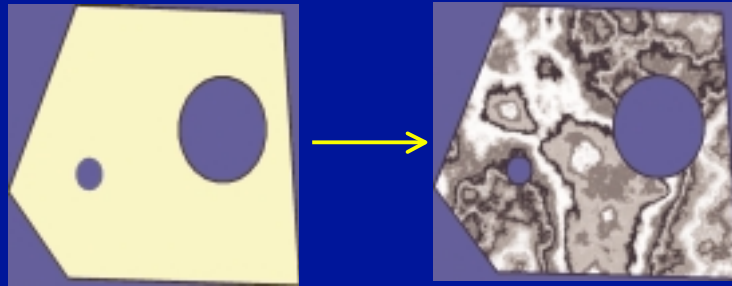
- Transformation of GO
 - Transforming shape
 - Transforming attributes

Transforming Shape



- transformation of the image shape

Transforming Attributes



- **Texture transformation**

Transforming Shape and Attributes

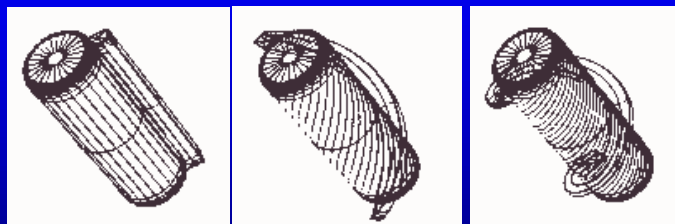
- **An example:**
 - **Color, Geometry and topology**



Our goal: Continuous Deformation



Continuous Deformation



- ***Twist:*** Rotation angle increases with height

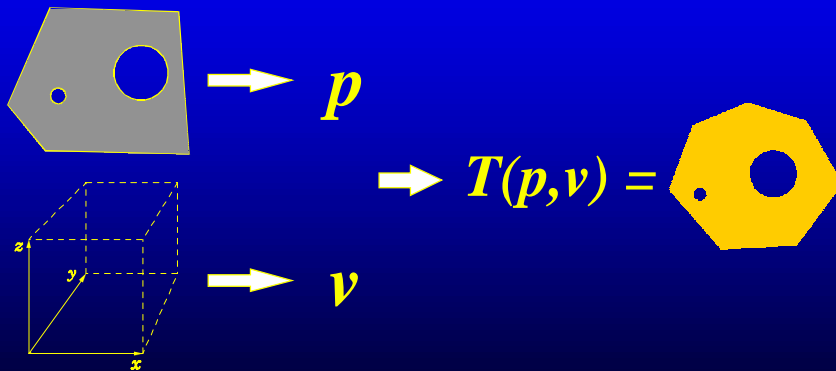
Continuous twist

$$R(x, y, z) = \begin{pmatrix} \cos f(z) & -\sin f(z) & 0 \\ \sin f(z) & \cos f(z) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

- Parameter space (z axis)

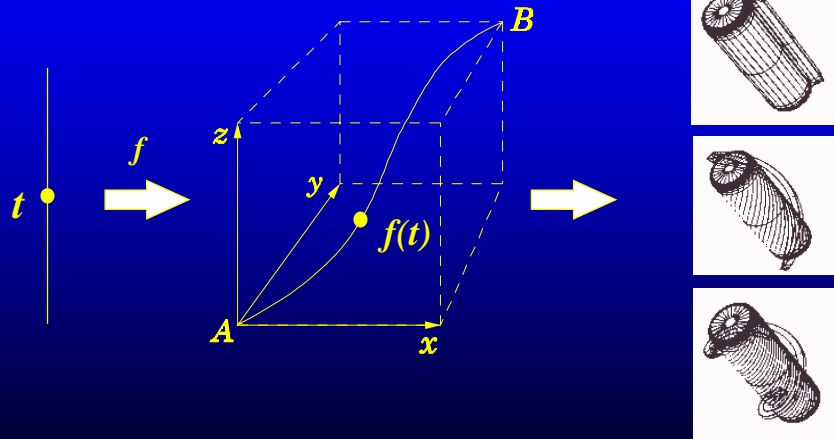
Families of Transformations

Graphical Object



Parameter Space

From families to animation



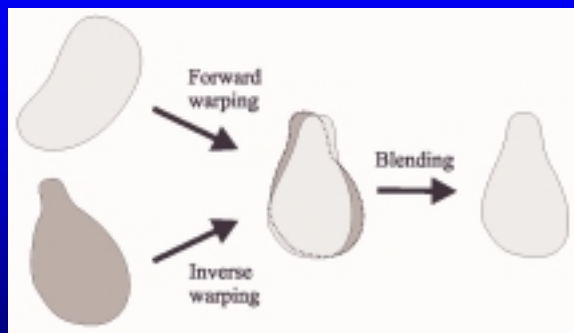
Warping and Morphing

- **Warping**
 - Continuous family of transformations of a graphical object
- **Morphing (metamorphosis)**
 - Warping between two graphical objects

Warping and Morphing

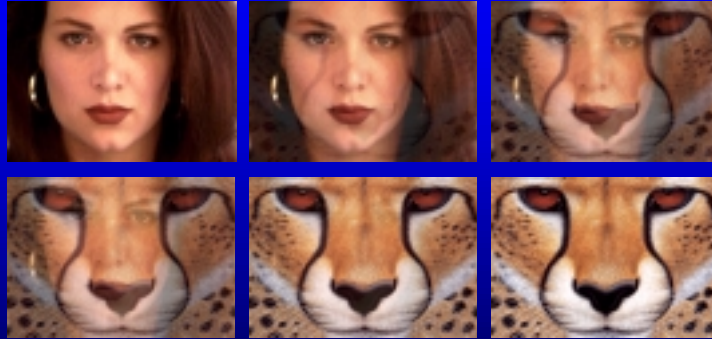
- **Warping**
 - Source object
 - No target object
- **Morphing**
 - Source object
 - Target object

Warping and Morphing

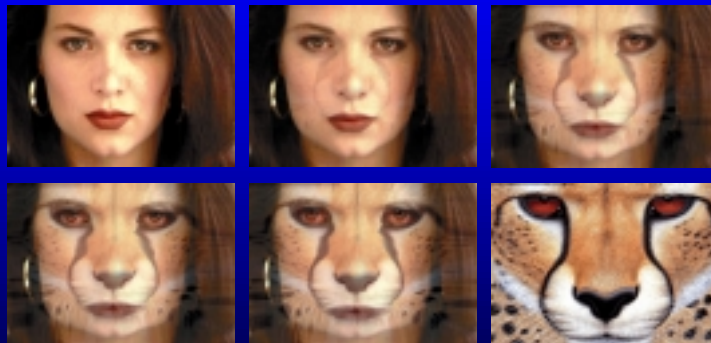


$\text{morphing} = (\text{warping})^2 + \text{blending}.$

Attribute Blending

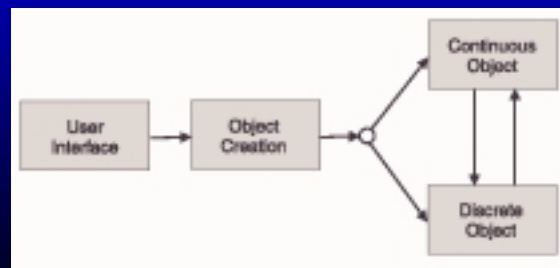


Shape Warp + Attribute Blending



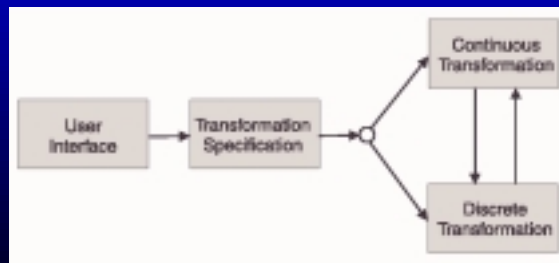
Computing Graphical Objects

- Description
- Representation
- Reconstruction

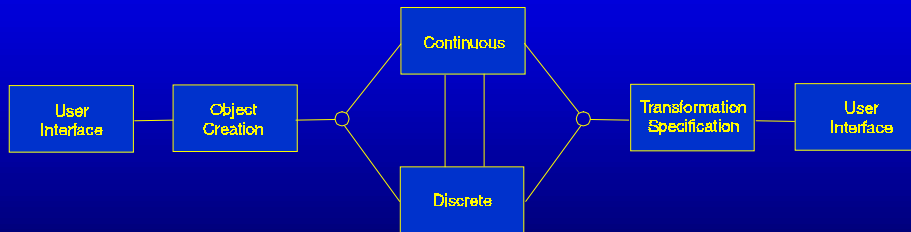


Computing transformations

- Specify transformations
- Represent transformations
- Reconstruct transformations

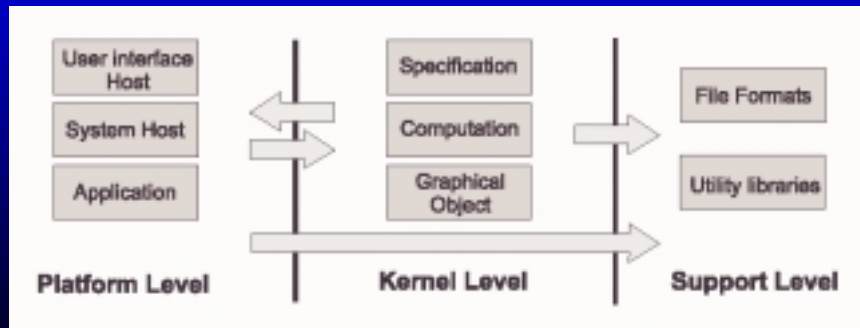


Computational Pipeline



A Warping and Morphing System

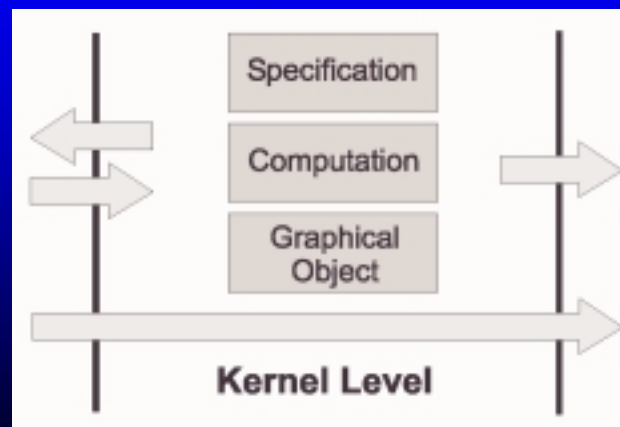
- System components



System components

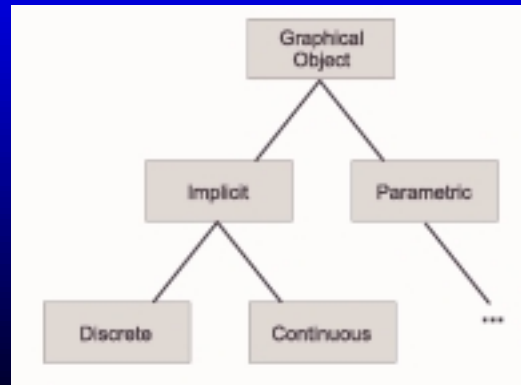
- **Support level**
 - input and output of graphical objects
 - file formats
 - commonly used classes
 - vectors, lists, matrices
- **Platform Level**
 - User interface
 - Platform-dependent resources
- **Kernel level**

The Kernel Level

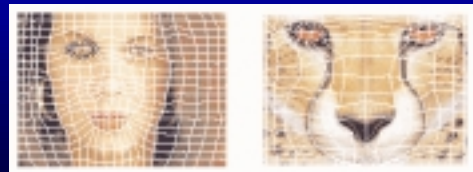
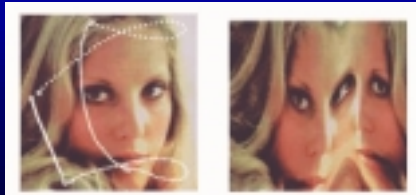
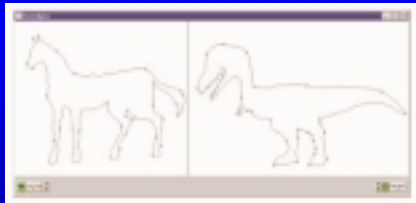


Graphical Objects

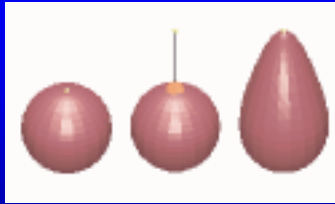
- Hierarchy of abstract data types



Specification

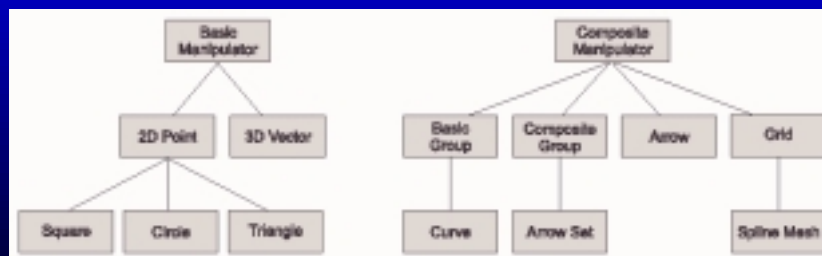


Specification



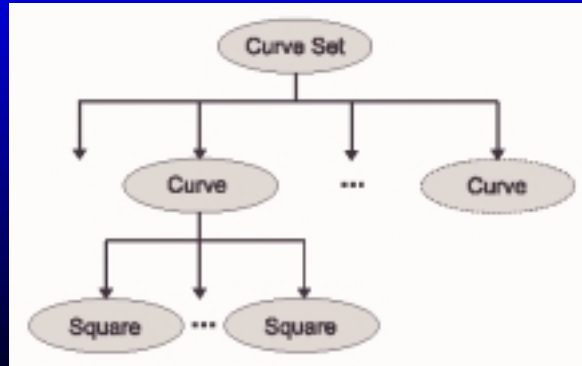
Specification

- Hierarchy of Manipulators
 - Basic
 - Composite

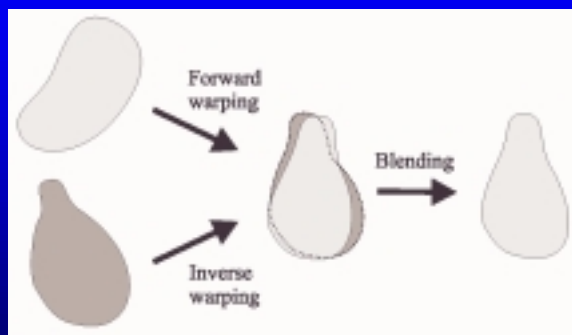


Composite manipulators

- Instantiation hierarchy



Computation



morphing = (warping)² + blending.

Computation

- **Warping and Morphing engine**

Object Traversal	Warping Reconstruction
Inverse mapping	Field-based
Direct mapping	Radial functions
...	...
Attribute Combination	Shape Combinations
Cross-dissolve	Exponential blend
z-buffering	Linear interpolation
...	...

Computation

- **Animation schedulers**
 - slow-in, slow-out



The *Morphos* System

- **Windows / C++ / OpenGL**
- **Side by side user interface**
- **Figure 13**
- **How to get it**
 - **Book & CD-ROM**
 - ***Warping and Morphing of Graphical Objects***
 - **Morgan kaufmann Publishers, 1998**
- **The morphing site**

Future additions to Morphos

- **Addition of volumetric objects**
- **Addition of surface warping**
- **Addition of surface morphing**
- **single window interface
(displacement vector)**
- **Automatic feature detection**
- **Temporal warping (video sequence)**
- **Port the system to UNIX**