

Fundamentals of Warping and Morphing

Luiz Velho

IMPA - Instituto de Matemática Pura e Aplicada

Outline

- **Metamorphosis in Nature**
- **Conceptual Framework**
- **Overview of Warping and Morphing**
- **Applications in Computer Graphics**
- **Paradigm of the Universes**
- **Structure of the Course**

Metamorphosis

*"transformation of a shape
and its visual attributes"*

- **Intrinsic in our Environment**
 - **Deformations in Nature**
 - **Man-made Deformations**
- **Powerful Concept**
 - **Comparison of Shapes**

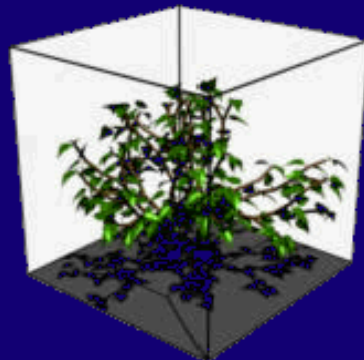
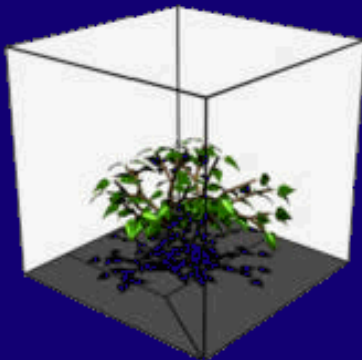
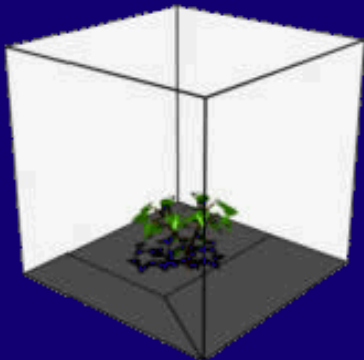
Shape Change In Nature

- Living Beings

internal forces

- Growth Processes
- Locomotion

Plant Growth



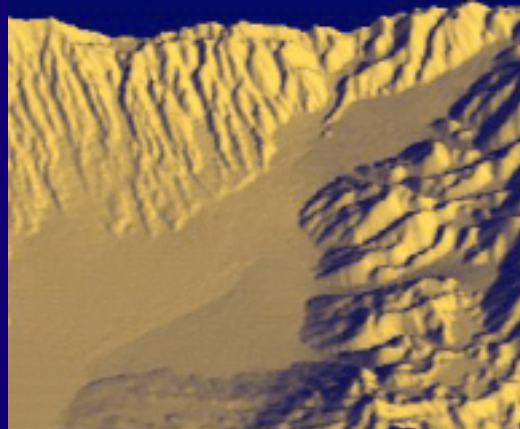
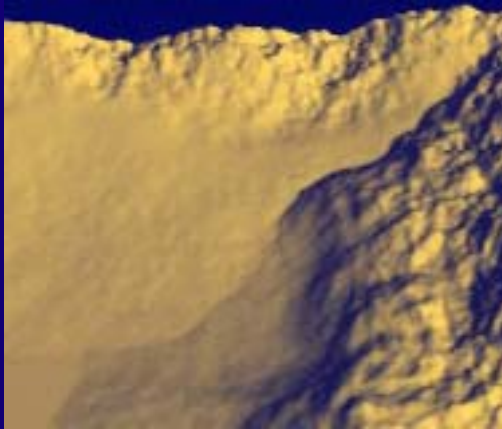
Shape Change In Nature

- Inanimate Things

external forces

- Environmental Phenomena
- Mechanical Processes

Erosion



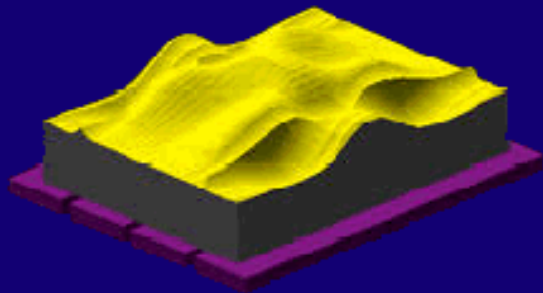
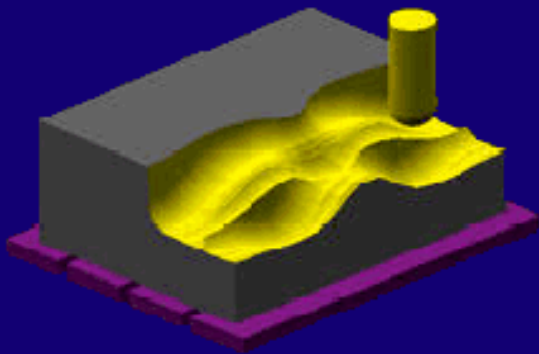
Man-Made Deformations

Reshape Matter

- **Arts & Crafts**
 - **Modeling**

- **Industry**
 - **Manufacturing**

Industrial Object



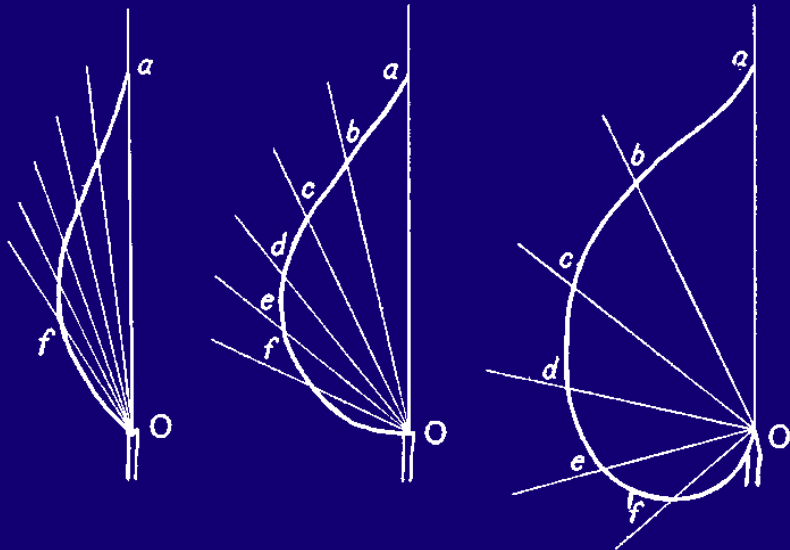
Comparison of Shapes

Classes of Shapes

**Transformation Group of n
Parameters**

- **Correlation**
 - **Related Shapes**

Classification of Plants



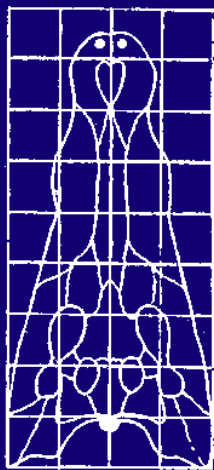
Comparison of Shapes

Classes of Shapes

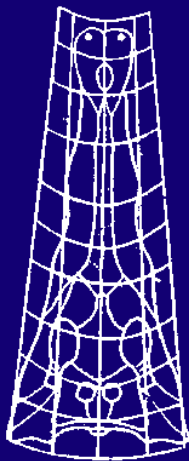
**Transformation Group of n
Parameters**

- **Evolution**
 - **Transitional Shapes**

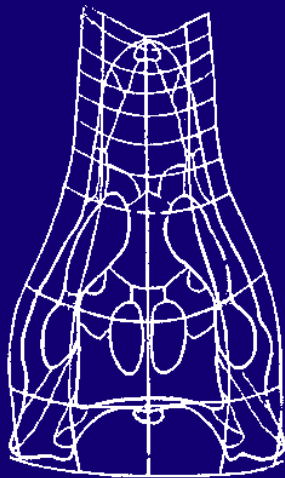
Crocodile Skull



a



b



c

Characteristics of Deformations

- **Action**
 - **Continuous**
 - **Discontinuous**
- **Effect**
 - **Non-Permanent (elastic)**
 - **Permanent (inelastic)**
- **Volume**
 - **Preserving**
 - **Non-Preserving**

Rules for a Good Morph

- **Most Natural**
- **Physically Plausible**
- **Perceptually Correct**

Images and Perception

- **Image:** *Representation of Objects*
- **Sequence of Images:** *Animation*

Image Blending -> Transitions

**Related Shapes x Unrelated
Shapes**

Cross Dissolve of Unrelated Images

Unrelated Shapes

·Time / Space Changes

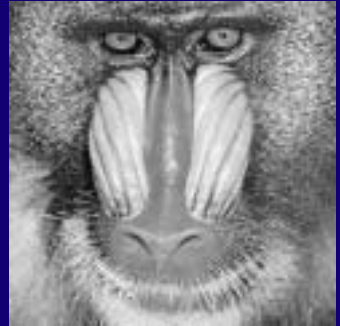


(passage of time/space
)

Metamorphosis of Similar Shapes

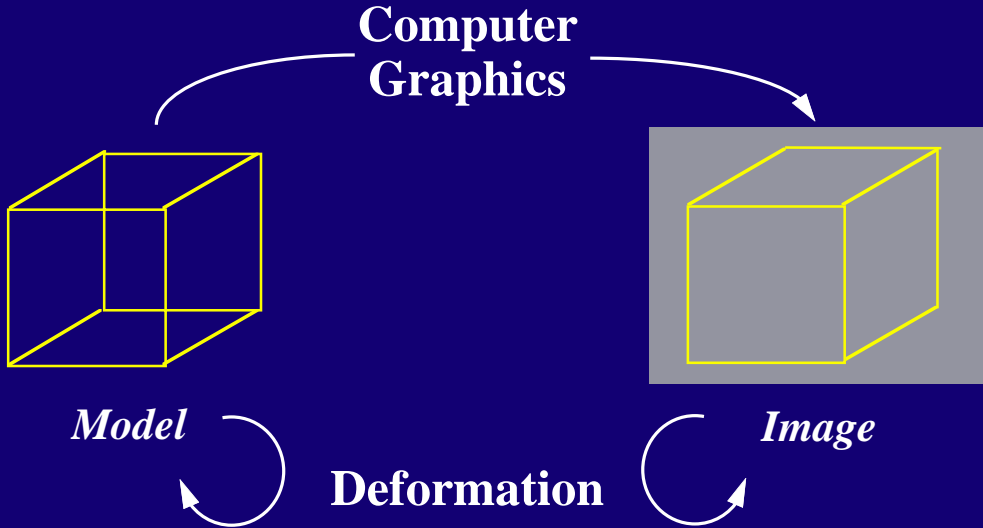
Related Shapes

·Metamorphosis

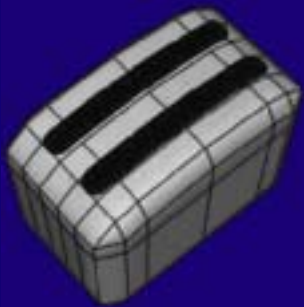


(interpolation of attributes)

Metamorphosis and Graphics



Model Deformation

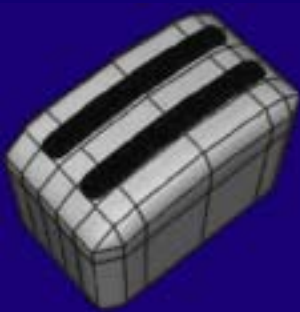


Deform the Model



Render

Image Deformation



Render



Deform Image

Conceptual Framework

Goals

Integrated View

Common Theory

- Unifying Concepts
 - Graphical Objects
 - Shape Transformations

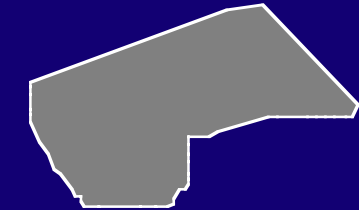
Graphical Objects

- **Components**
 - **Shape**
(geometric support)
 - **Attributes**
(visual properties)

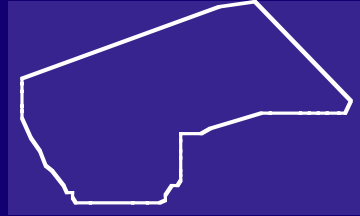
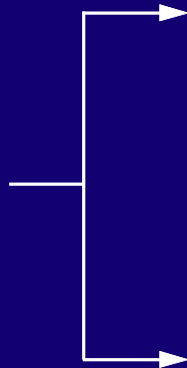
Examples

**Particle Systems, 2D Drawings,
Images, Surfaces, Volumes**

Example: 2D Drawing



Graphical Object



Shape



color



texture

Attributes

Shape Transformations

- **Operations**

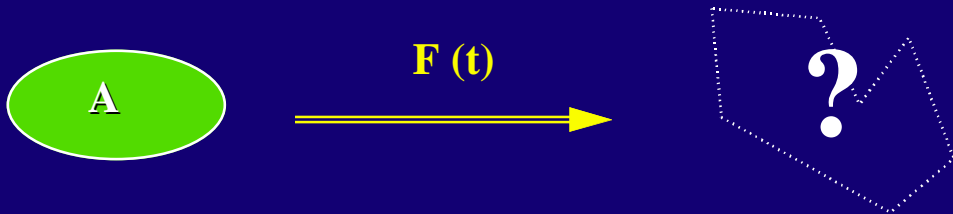
- **Warping:** Unary Op
- **Morphing:** Binary Op

“Two Related Problems, Same Framework”

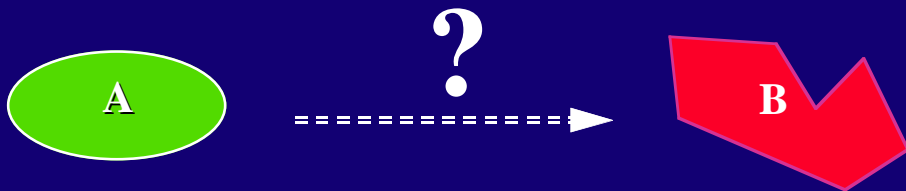
1 - Given Object A and Xform, find Object B

2 - Given Object A and Object B, find Xform

1 - Warping



2 - Morphing



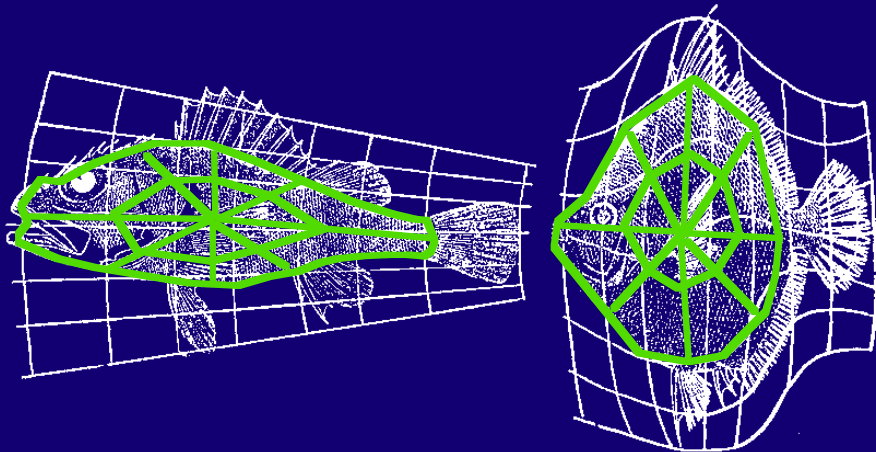
Warping and Morphing of Graphical Objects

Processing Pipeline

- **Geometry Deformation**
- **Attribute Generation**
- **Object Combination**

Geometry Deformation

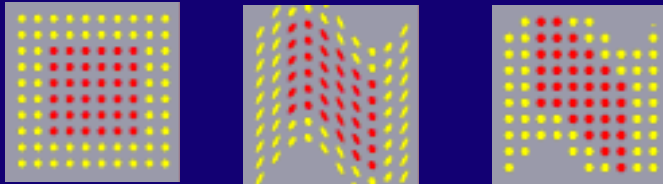
- Change of Coordinate Systems
 - Intrinsic
 - Extrinsic



Attribute Generation

- **Domain Uniformization**

- **Resampling** (adjust to new geometry)



- **Range Compatibilization**

(*morphing*)

- **Homogenization** (attribute equivalence)

ex: Color Spaces CIE-xyz / RGB

Object Combination

- **Correspondence between Objects**

- **Domain (shape)**
- **Range (attributes)**

- **Steps**

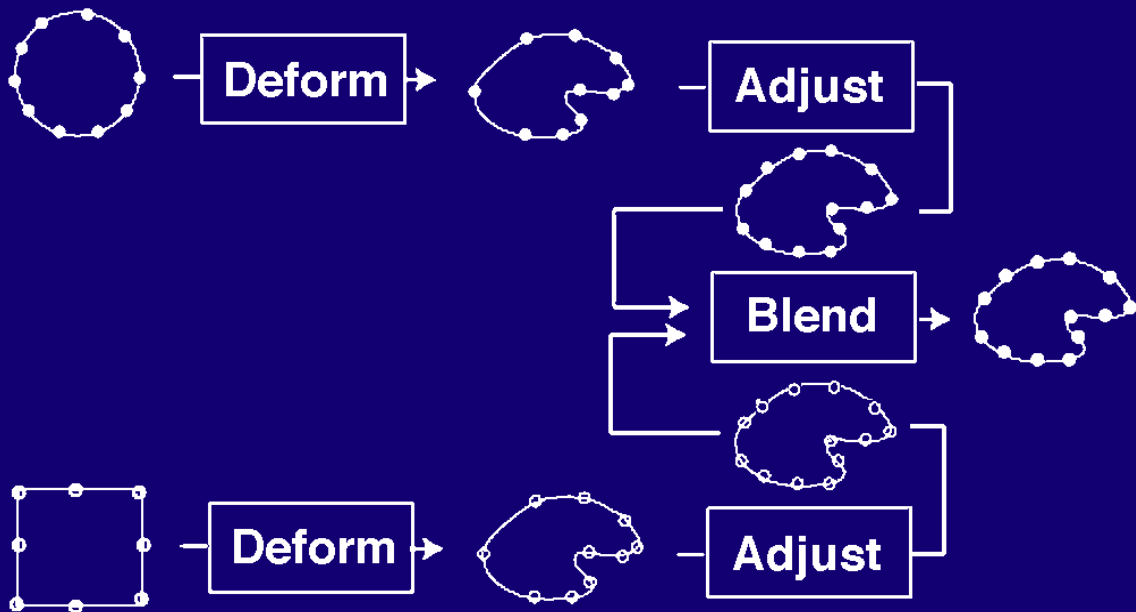
- **Geometry Alignment**
- **Attribute Blending**

(morphing)

Warping Pipeline



Morphing Pipeline



(note: warping as morphing)

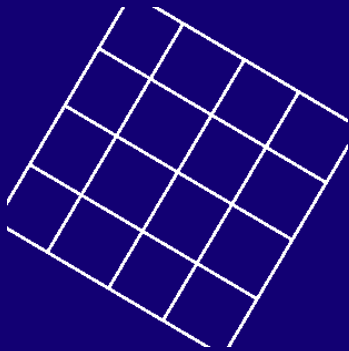
Implementation Issues

- **Specification**
 - **Type of Transformation**
 - **Rate of Change**
- **Computation**
- **User Interface**

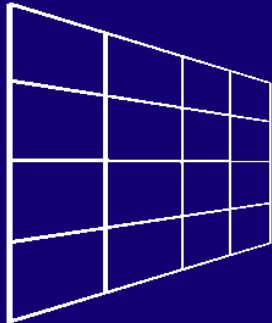
Specification of Transformations

- Global Transformations
 - Affine Maps
 - Projective Maps
 - Non-Linear Maps

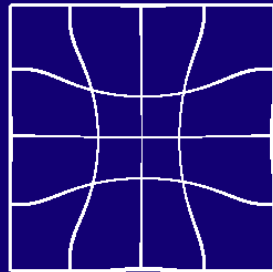
Examples of Global Transformations



Rotation



Perspective

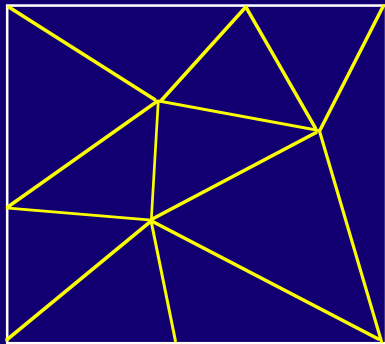


Pinch

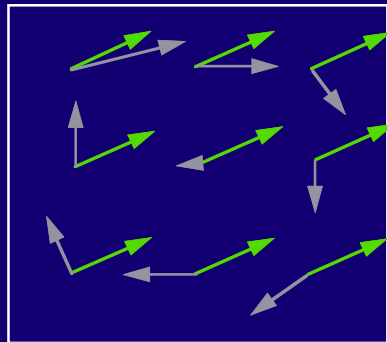
Specification of Transformations

- Piecewise: (*parts + continuity*)
 - Domain Decomposition
 - Vector Fields

Examples of Piecewise Transformations



Triangulation



Displacement Fields

Computation of Transformations

- **Direct**
 - **Moving Points of the Object**

$$p \in U$$

$$p \rightarrow f(p)$$

- **Suitable for:**
 - **Parametric Representations**

Computation of Transformations

- **Indirect**
 - **Transform the Ambient Space**

$$F: R^n \supset U \rightarrow R^n$$

- **Suitable for:**
 - **Implicit Representation**

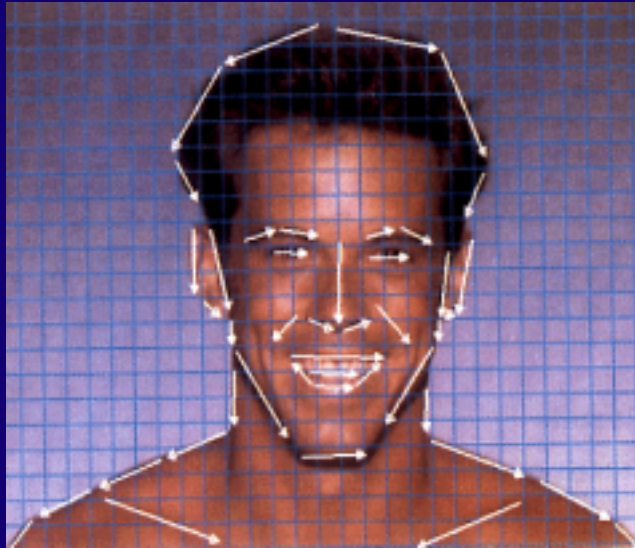
*Can be used also for Parametric
Representation*

User Interface

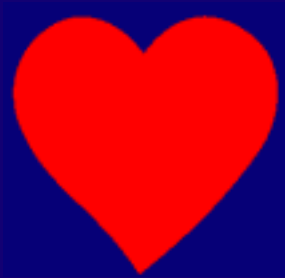
Features

- **Object Properties**
 - **Functional**
 - **Perceptual**
- **Uses**
 - **Handle for Transformations**
 - **Object Correspondence**

User Interface: Features



Features and Perception



Features and Perception



obs: sound / motion

Transformation of Graphical Objects

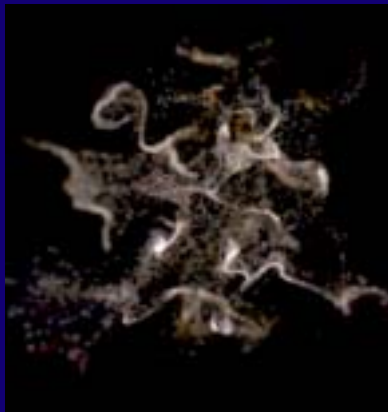
- **Particle Systems**
- **Curves and Surfaces**
- **Images and Volumes**

Transformation of Points

Discrete Enumeration

- **Specification**
 - **Force Fields**
- **Computation**
 - **Direct**

Particle Systems



Transformation of Curves and Surfaces

Parametric Description

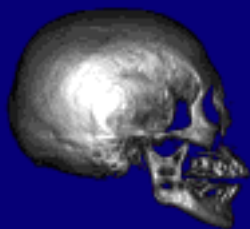
- **Specification**
 - **Control Points**
- **Computation**
 - **Direct**



Transformation of Images and Volumes

Volumetric/Implicit Description

- **Specifiacion**
 - **Change of Coordinate System**
- **Computation**
 - **Indirect**



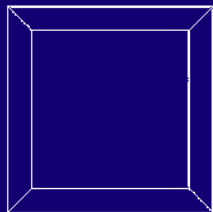
Applications in Graphics

- **Modeling**
- **Animation**
- **Special Effects**
- **Shape Analysis**

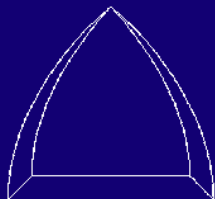
Modeling I

- **Shape Operators**
 - **Deformations**
 - ex: taper, twist, bend**
- **Usage**
 - **Simulation of Manufacturing Processes**

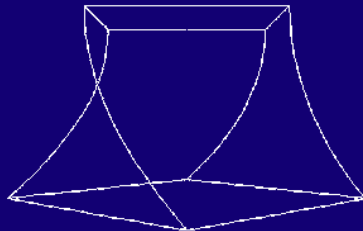
Examples of Deformation Operators



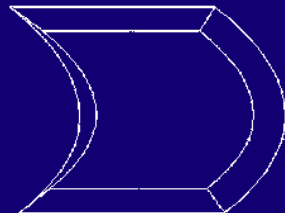
Cube



Taper



Twist



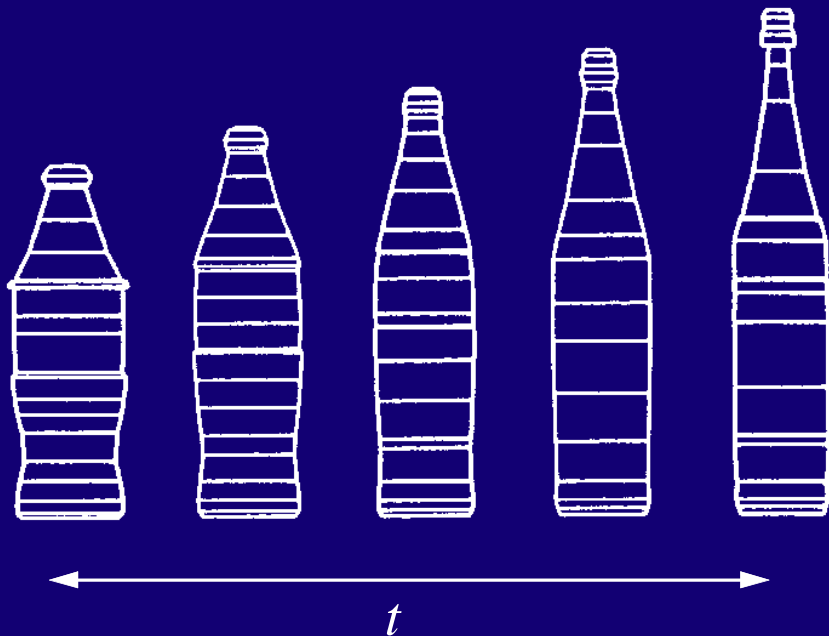
Bend

Modeling II

- **Shape Families**
 - **Interpolation**
 - **n-parameters**

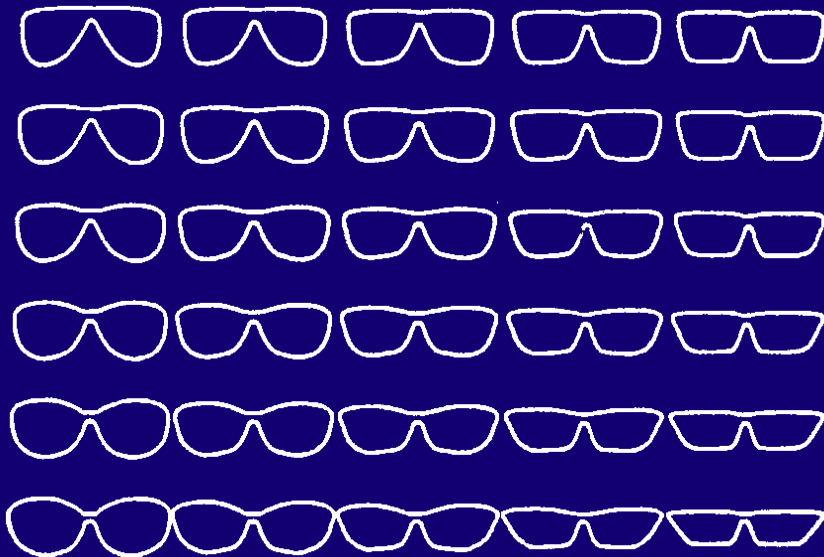
- **Usage**
 - **Style Evolution**
 - **Features**

Bottle (1-parameter)



Sun Glasses (2-parameters)

rayban



square

s

round

t

cat

Animation

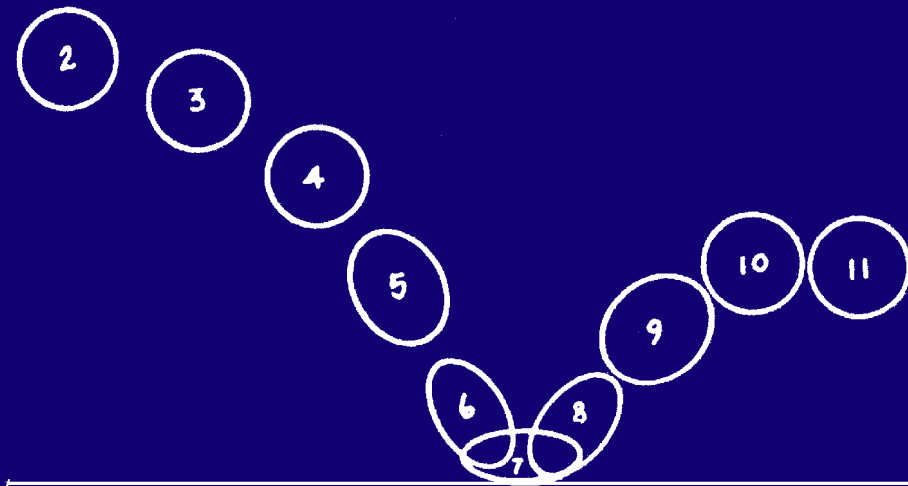
- Emphasis

- Stretch

- Squash

- * Distortion × Motion

Stretch and Squash



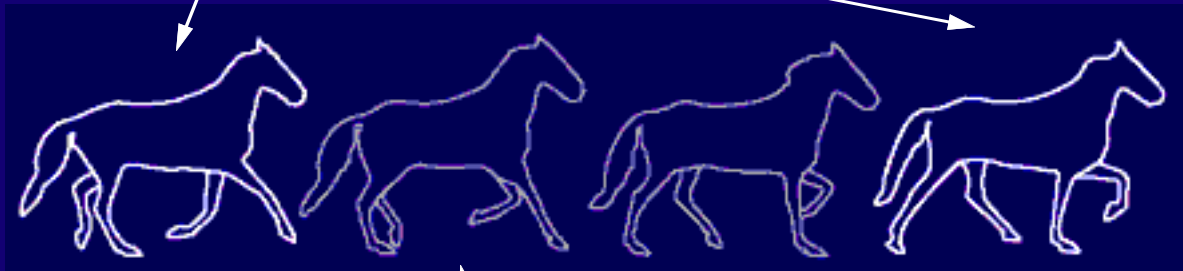
Animation

- Control
 - Keyframing
 - Inbetweening

* *Distortion* × *Motion*

Animation

Keyframes

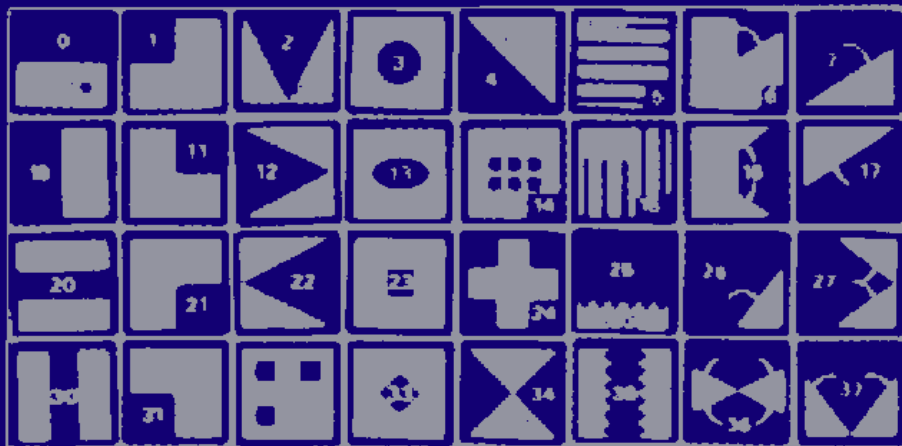


Inbetweens

Special Effects

- Transitions
 - Dissolve
 - Wipe

Example: Wipe Patterns



Special Effects

- Transformations
 - Image
 - Surface

ADO



Mirage

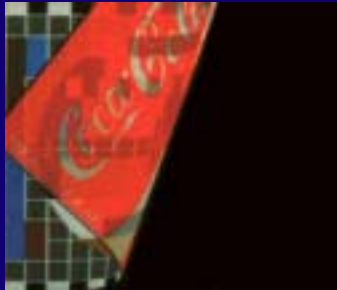
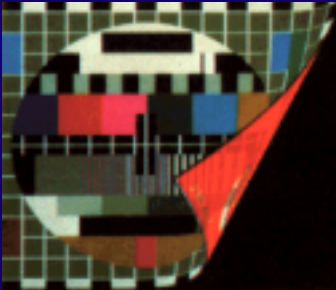


Image Analysis

- Fitting
 - Registration

Texture Registration

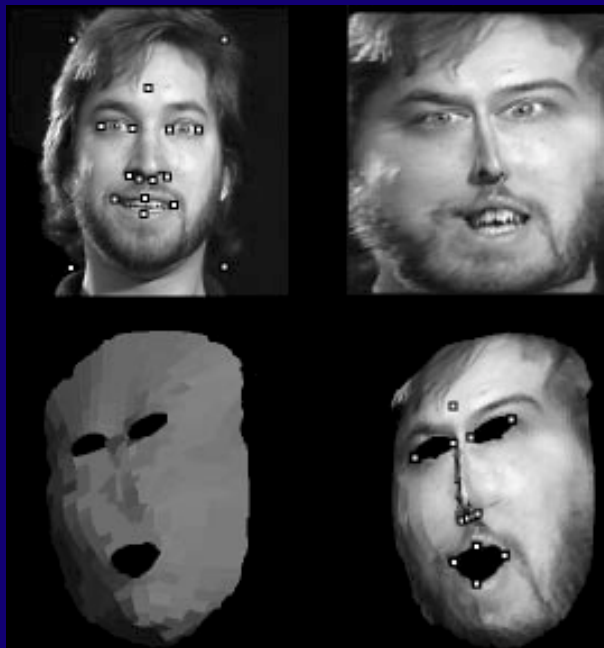
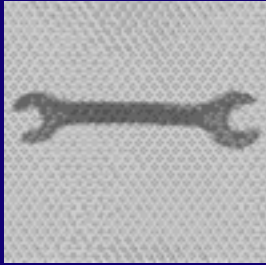


Image Analysis

- Matching
 - Recognition

Modal Analysis



template



5.1



object



24.4

match

*strain
energy*

Paradigm of the Universes

- **Understanding an Area**
- **Levels of Abstraction**
- **Conceptual Issues**

Levels of Abstraction

Physical Universe



Mathematical Universe



Representation Universe



Implementation Universe

Conceptual Issues

1 - Define the Elements of Math Universe

graphical objects

2 - Specify Operators on Math Universe

shape transformations

3 - Construct Representation Schemes

specification

4 - Develop Instructional Materials

Structure of the Course

- **Luiz Velho** - **Overview**
- **Jonas Gomes** - **Graphical Objects**
- **Transformations**
- **Bruno Costa** - **Computation**

- **Lucia Darsa** - **Specification**
- **Thad Beier** - **Applications**