

# *Visualisation, Rendering and Animation*

*2 VO / 1 KU (2001-2004)*

---

*Heinz Mayer, Franz Leberl & Andrej Ferko*

[ferko@icg.tu-graz.ac.at](mailto:ferko@icg.tu-graz.ac.at)

Short podcast version 2020



# *Unit 5 - Content*

## *7. Scientific Visualization*

*“The purpose of computing  
is insight not numbers“*

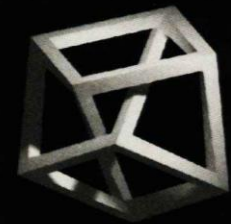
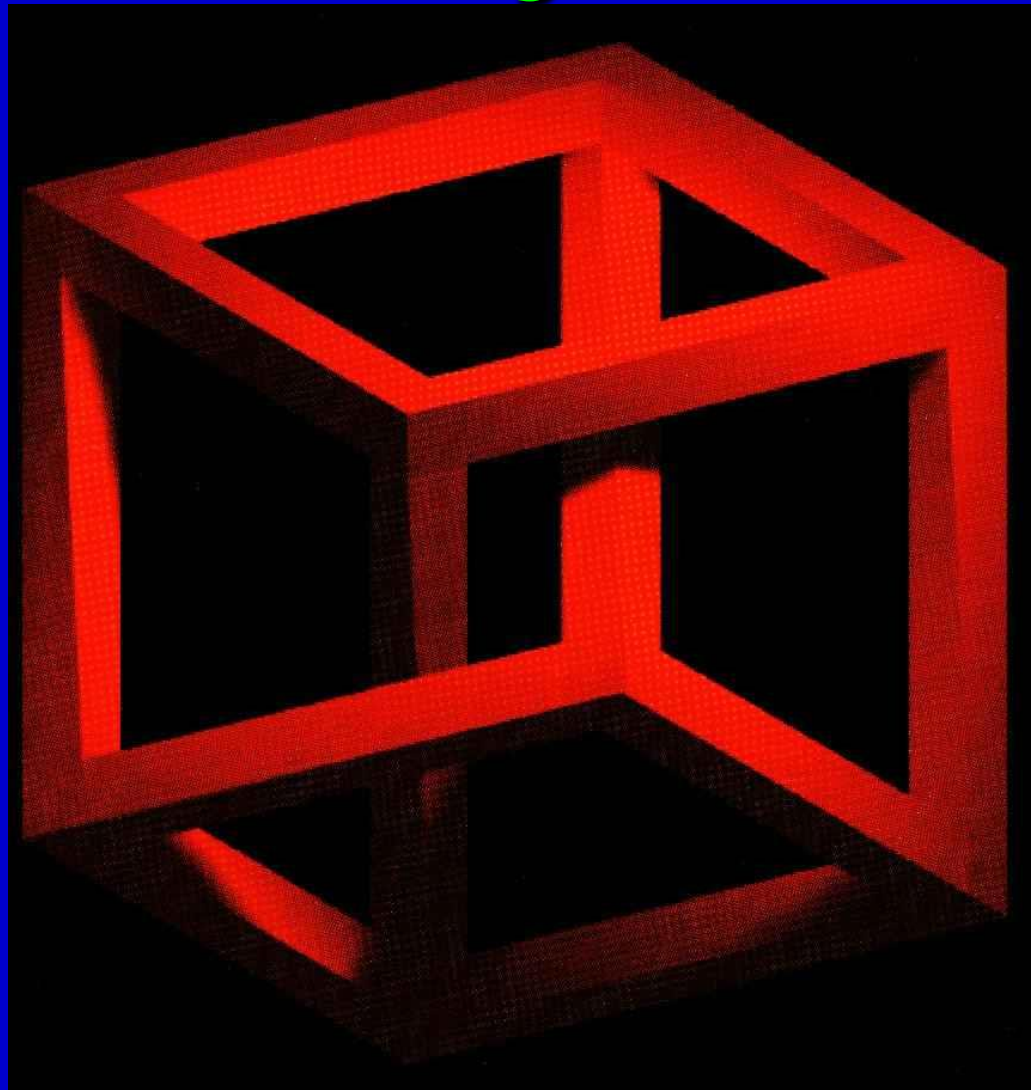
*Richard Hamming*

## *□ 8. Animation*

*□ “There is no particular  
mystery in animation... it's really very simple,  
and like anything that is simple, it is about the  
hardest thing in the world to do.”*

*□ Bill Tytla at the Walt Disney Studio, June 28, 1937.*

# *KUBOID by P. Eliáš*



# ***8. Animation***

---

***Making Alive using Motion***





# *Defining Animation*

- *ISO: Animation: image sequence ordered in time for video display. This covers all changes which cause visual effect (position, shape, color, transparency, object structure and texture, lighting, camera parameters, even the rendering technique).*
- *Anima - spirit, soul, life...*

# ***Animation*** ([www.siggraph.org](http://www.siggraph.org))

- ***Introduction***
- ***Types of Animation Control Systems***
- ***Low level Motion Control***
- ***Camera Animation***
- ***Character Animation***
- ***Particle Systems***
- ***Artificial Life***
- ***Post - Production in Computer Animation***

# ***Animation***

- ***Origins in film production***
- ***Advantages against cel animation***
  - *Virtual models*
  - *No limits for camera (even multiperspective)*
  - *Costs*
- ***Applications***
  - *Film Industry*
  - *Flight- / Military / NASA Simulation*
  - *Crash-Tests*
  - *...*

# *Categories Watt&Watt*

- *Procedural Animation*
- *Representation Animation*
  - *Animated articulated structures*
  - *Soft object animation*
- *Stochastic Animation*
- *Behavioural Animation*
- *Low-Level Motion Control*

# Authoring Tools

## VRML case:

- 1) Modeling (3DS Max, Rhino 3D, Maya, Spazz Cosmo Worlds, trueSpace etc.)
- 2) Manual VRML editing, recommended "VrmlPad" (ParallelGraphics), by J. Zara
- 3) Animate

## General case:

- 1) WWW, WWD, RenderMan, AutoCAD, HyperFun, Organica, VolVis, FractInt, ... freeware, dedicated software...
- 2) Combine/Animate



# ***Animation Control Systems***

- ***Scripting Systems***
- ***Procedural Animation***
- ***Representational Animation***
- ***Stochastic Animation***
- ***Behavioral Animation***

# *Scripting Systems*

- *earliest type of motion control systems*
- *animator writes a script in the animation language*
- *must learn animation language*
- *not interactive*
- *actors ~ OOP objects*
- *MAYA - MEL*



# *Procedural Animation*

- *Procedures define movement over time:*
  - 1. laws of physics (Physically - based modeling)*
  - 2. animator generated methods:*
- *a motion that is the result of some other action (this is called a "secondary action"), for example throwing a ball which hits another object and causes the second object to move.*

# Representational Animation

- *Allows an object to change its shape during the animation:*
  - **1. animation of articulated objects**,
    - *i.e., complex objects composed of connected rigid segments*
  - **2. soft object animation**
    - *deforming and animating the deformation of objects, e. g. skin over a body or facial muscles*
  - **3. morphing 2D, 3D (5D? – Homotopic Fun)**

# *Stochastic Animation*

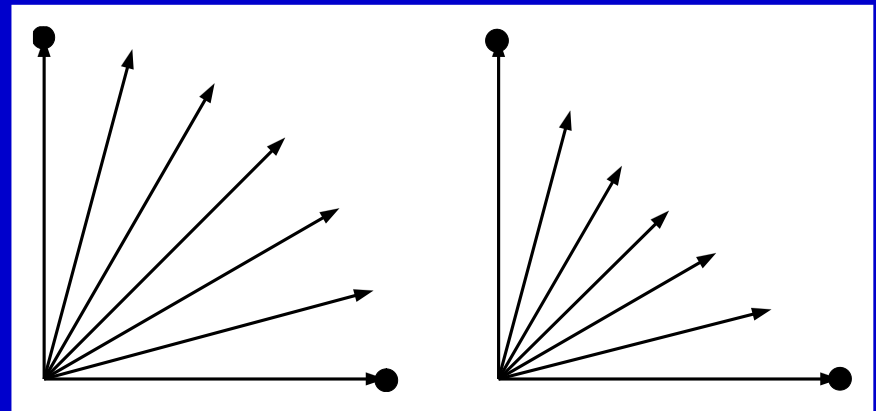
- *Using stochastic processes to control groups of objects, such as in particle systems.*
- *Examples are fireworks, fire, water falls, etc. – cloth simulation by M. Teschner*
- *Dragon Fireball in Shrek*

# *Behavioral Animation*

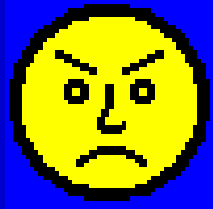
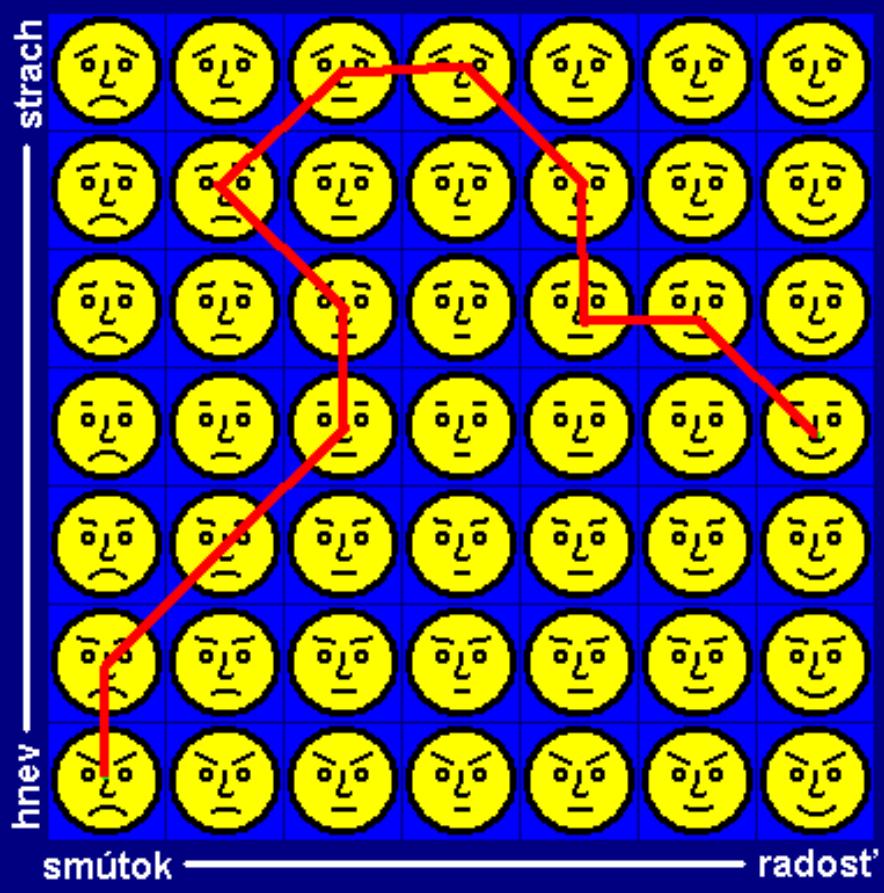
- *Objects or "actors" are given rules about how they react to their environment.*
- *Examples: schools of fish or flocks of birds where each individual behaves according to a set of rules defined by the animator*
- *Mass scenes: hair, vegetables in soup, crowds of people (Titanic, Star Wars, Gladiator... **Shrek 2**)*

# Key Framing

- **Named after hierarchic production system by Disney**
- **Artist creates key frame sequence (3D!)**
- **Interpolation of inbetweens (MPEG)**
- **In computer animation:**
  - **What ( $xyz, k_d, k_s, \dots$ )**
  - **How ( $t, s, v, \dots$ ) to interpolate ?**

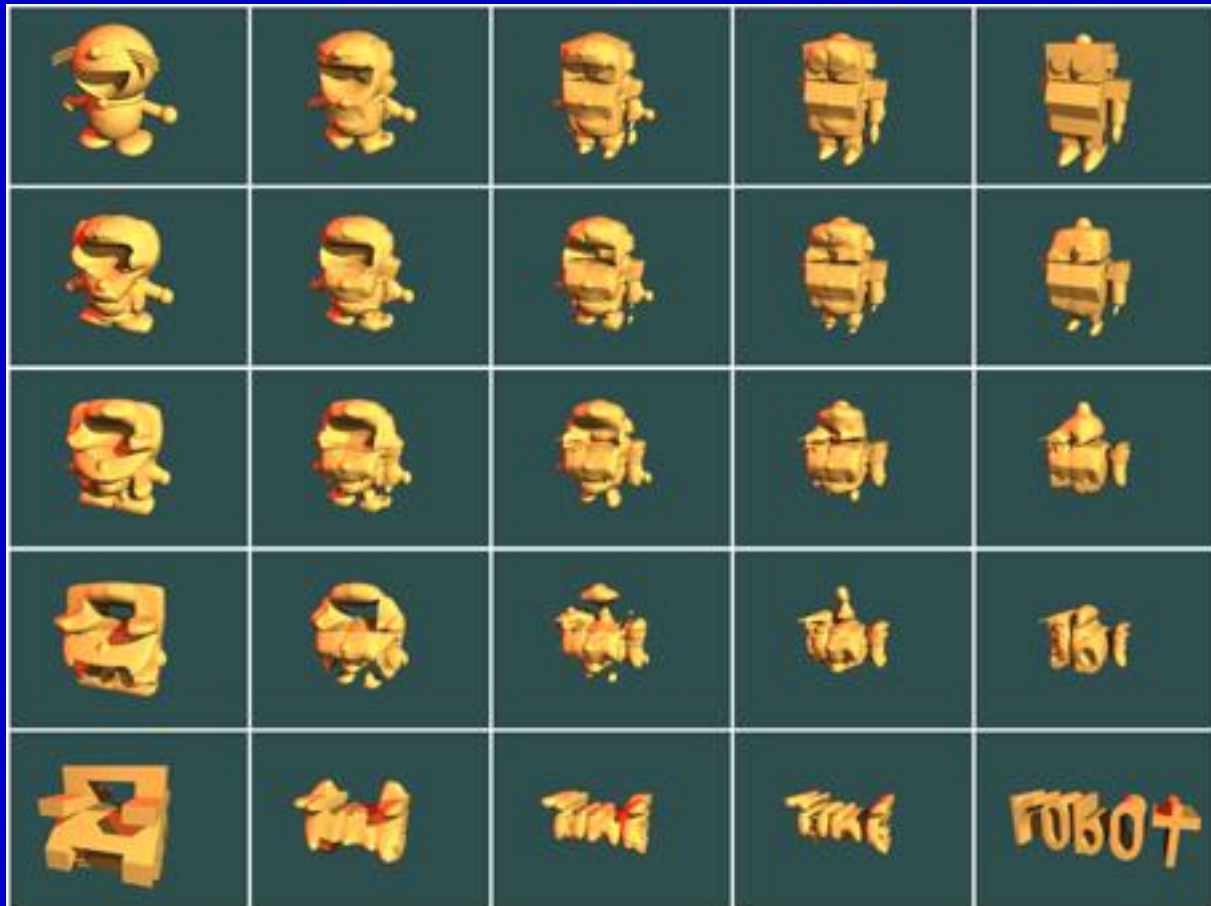


# Matrix of Animations (Simulations)



# Spreadsheet Rendering

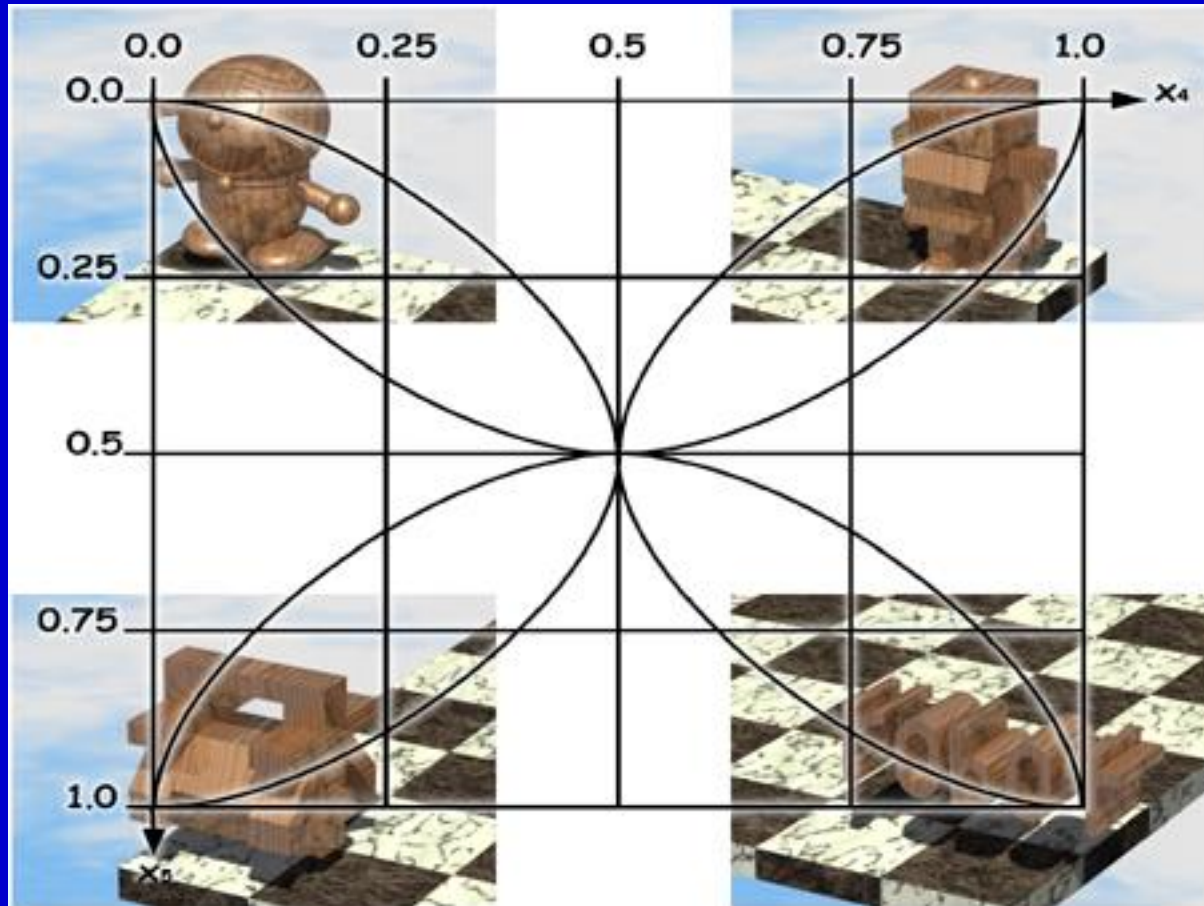
by Alexander PASKO, [www.hyperfun.org](http://www.hyperfun.org)



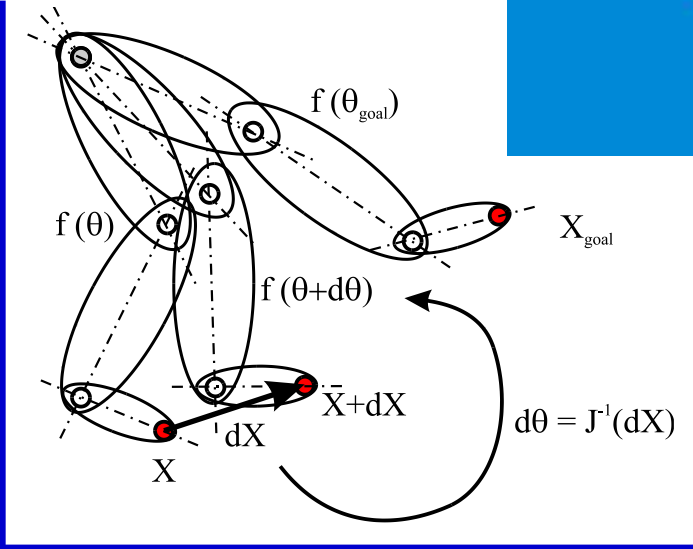
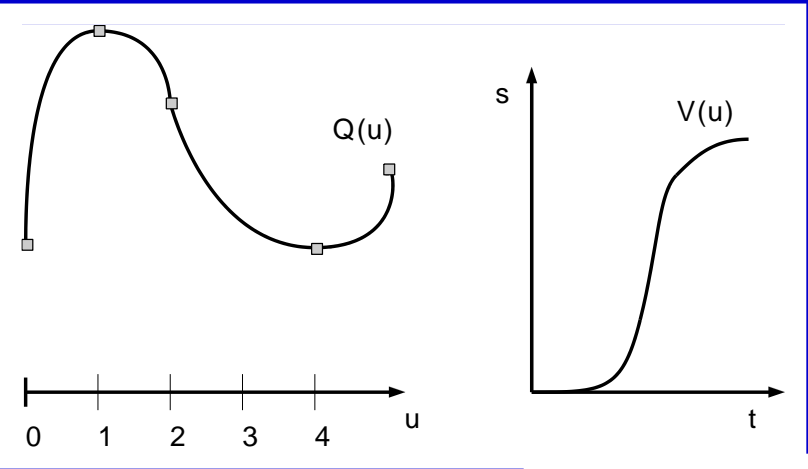


# Animation Path in $t_1t_2$ Plane

by Alexander PASKO, [www.hyperfun.org](http://www.hyperfun.org)



# Mathematics for Computer Animation (Watt)



# *Key Framing Workflow*

## *Classic (cel) animation* *(handmade)*

### *Script* (*storyboard layout*)

- *action sketch and fabula description*

### *Object definition*

- *defining shape and properties of objects, synthetic actors*

### *Key-frame specifications*

- *discrete timing - draw significant frames*

### *Generation of in-between frames*

- *interpolating frames in time, between the keyframes*

# *Key Framing Steps*

*Chief animator (choreographer) designs and depicts objects.*

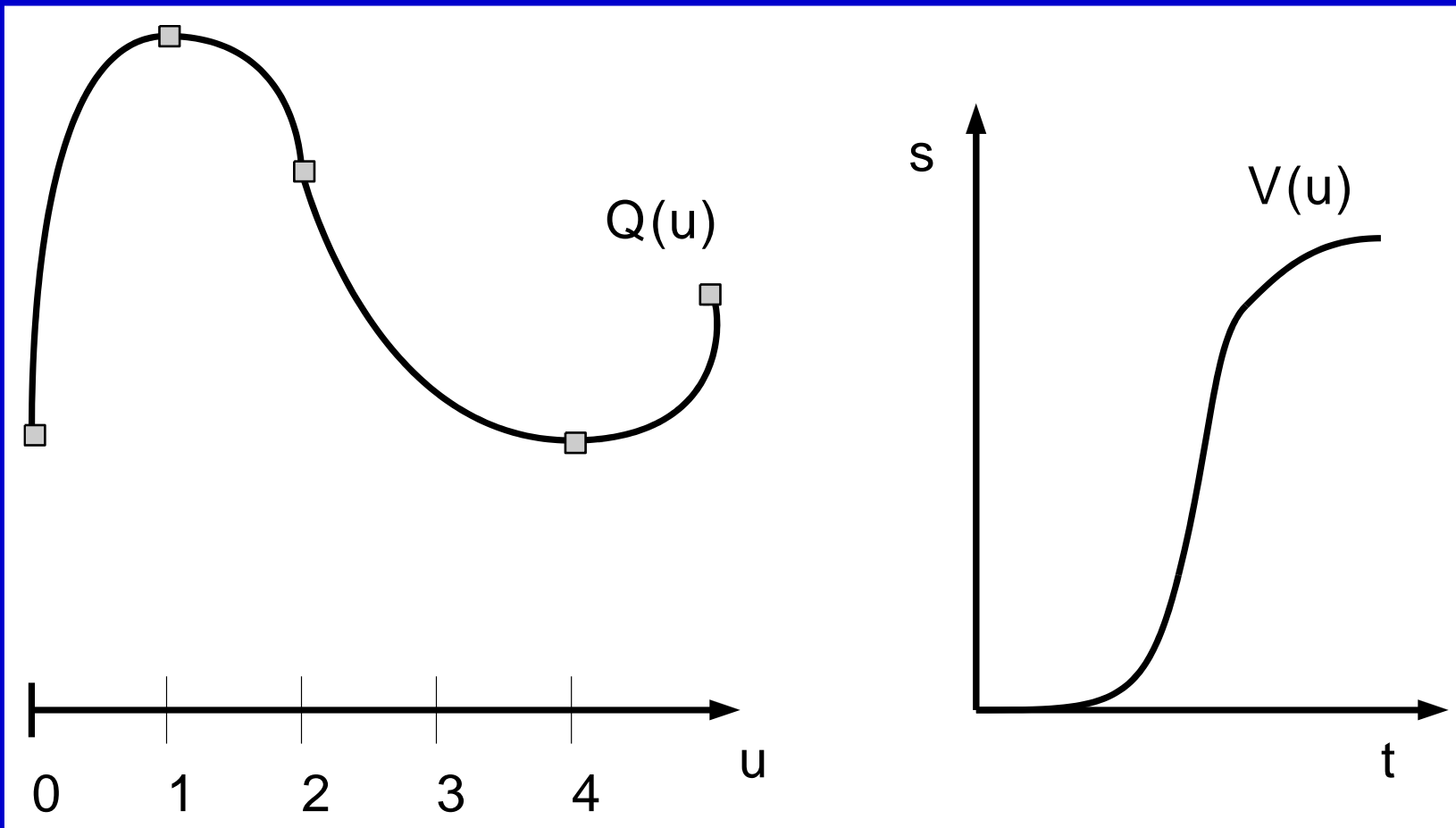
*Phasing of the complete animation is too complex, therefore she completes the key-framing.*

*Help animators do the phasing, coloring, etc. (in-between frames).*

*Time: 12 fps slow, 120 fps - super.*

# *Spline Parameterisation*

- *Arc length parameterisation*
  - *Parameter  $\neq$  arc length interpolation*
  - *Reparameterisation with  $u = A^{-1}(s)$*
- *Speed-up parameterisation*
  - *$V(u) = (t, s)$*
  - *Double reparameterisation*
- *Interpolating rotations*
  - *Problem with Euler angles  $R(\theta_x, \theta_y, \theta_z)$*
  - *Shortest arc lengths using quaternions*



# *Kinematics*

## □ *Notions:*

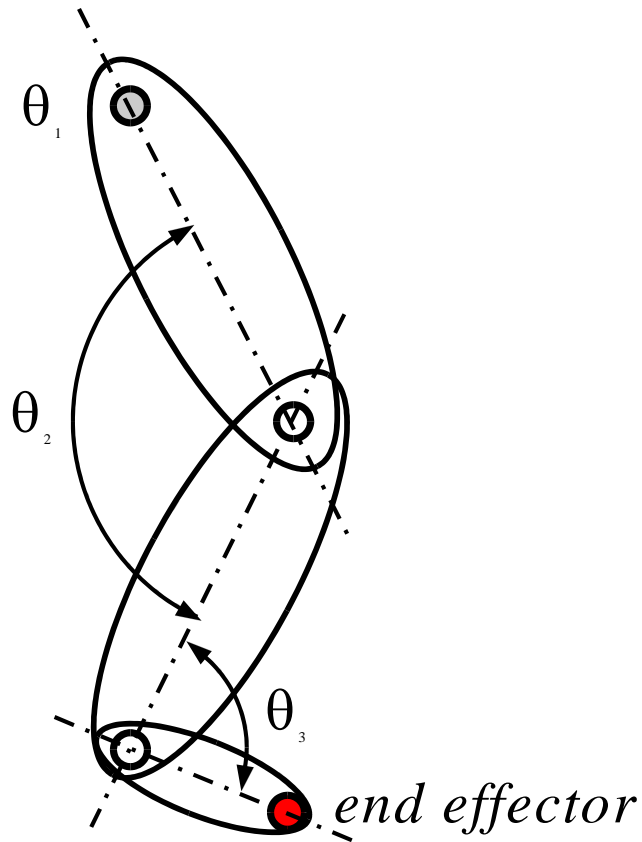
- *Articulated figures (Gliederstrukturen)*
- *Degrees of freedom (DOF)*
- *End effector  $X$  (freies Ende der Struktur)*
- *State vector  $\theta$  (Status der Zustandsvariablen)*

## □ *Techniques:*

- *Forward Kinematics:  $X = f(\theta)$*
- *Inverse Kinematics:  $\theta = f^{-1}(X)$*

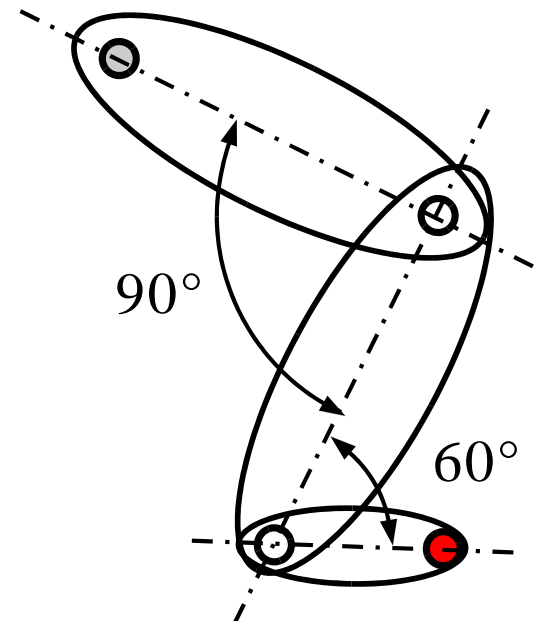


state vector  $\theta = (\theta_1, \theta_2, \theta_3)$



## Forward Kinematics

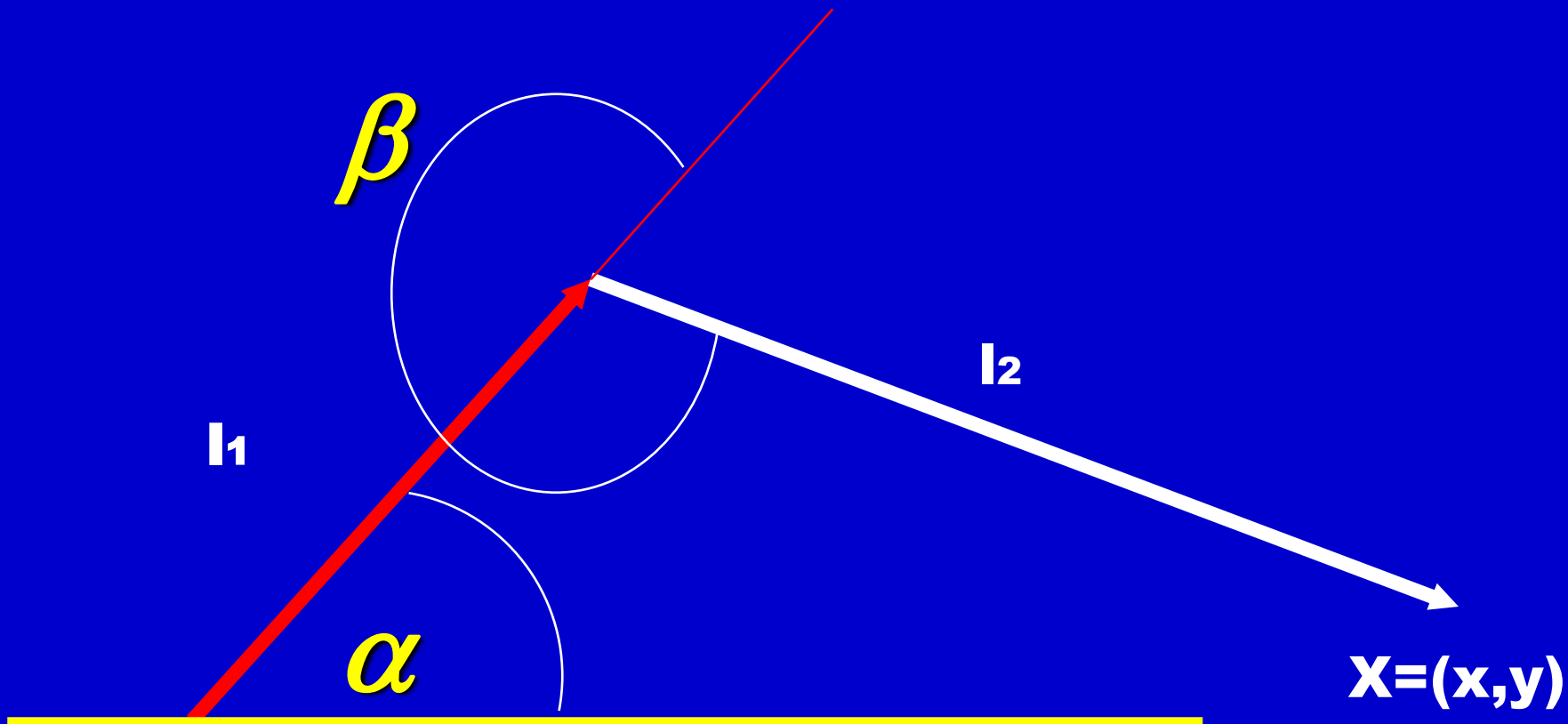
$\theta = ([x,y,z], 90^\circ, 60^\circ)$



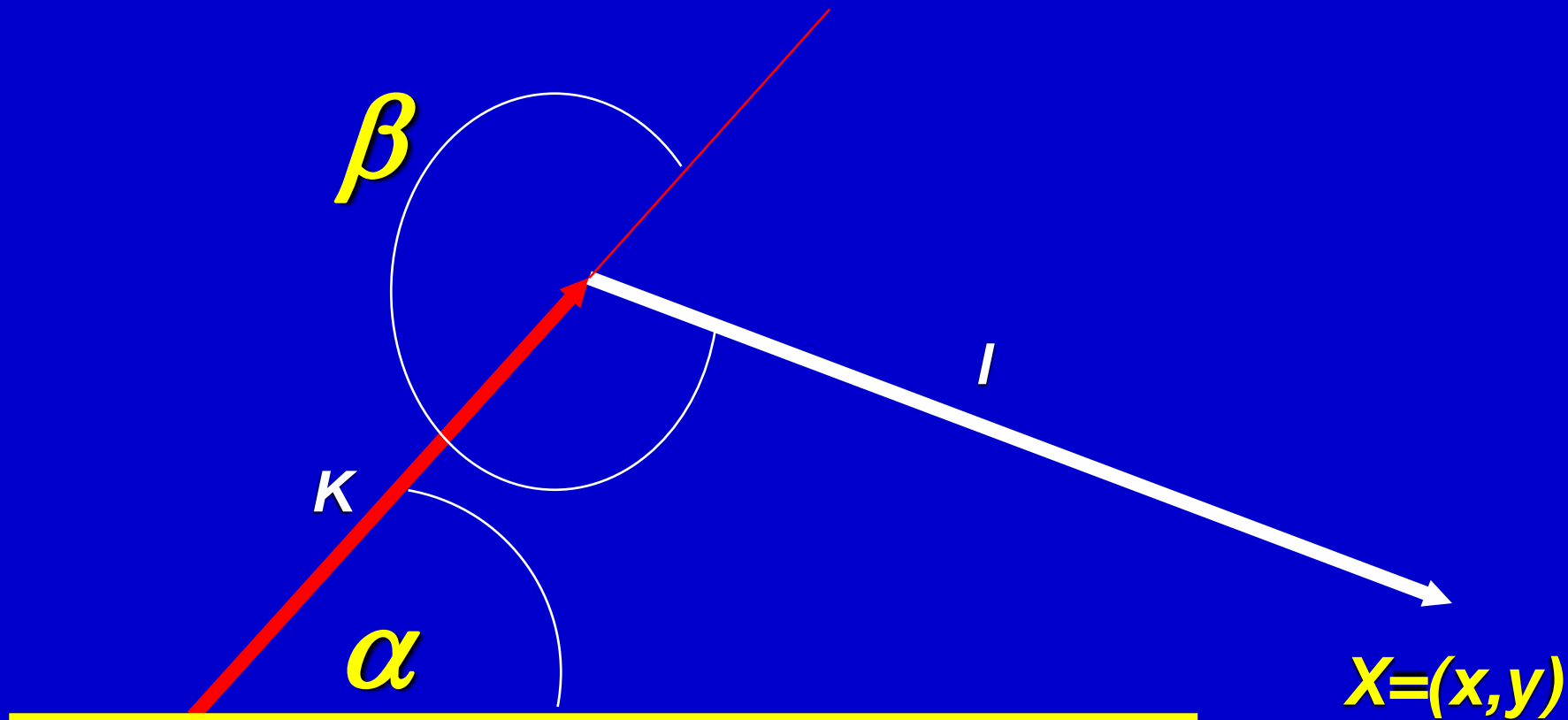
# *Inverse Kinematics*

- *Inverse function  $\theta = f^{-1}(X)$  analytically too complex for practical instances*
- *Iterative solution:*
  - *Start point:  $X = f(\theta)$*
  - *Jacobian matrix:  $dX = J(\theta) d\theta$*
  - *through  $d\theta = J^{-1}(dX)$  partial state vector changes computed*
  - *next iteration step*

# Both Kinematics in 2D

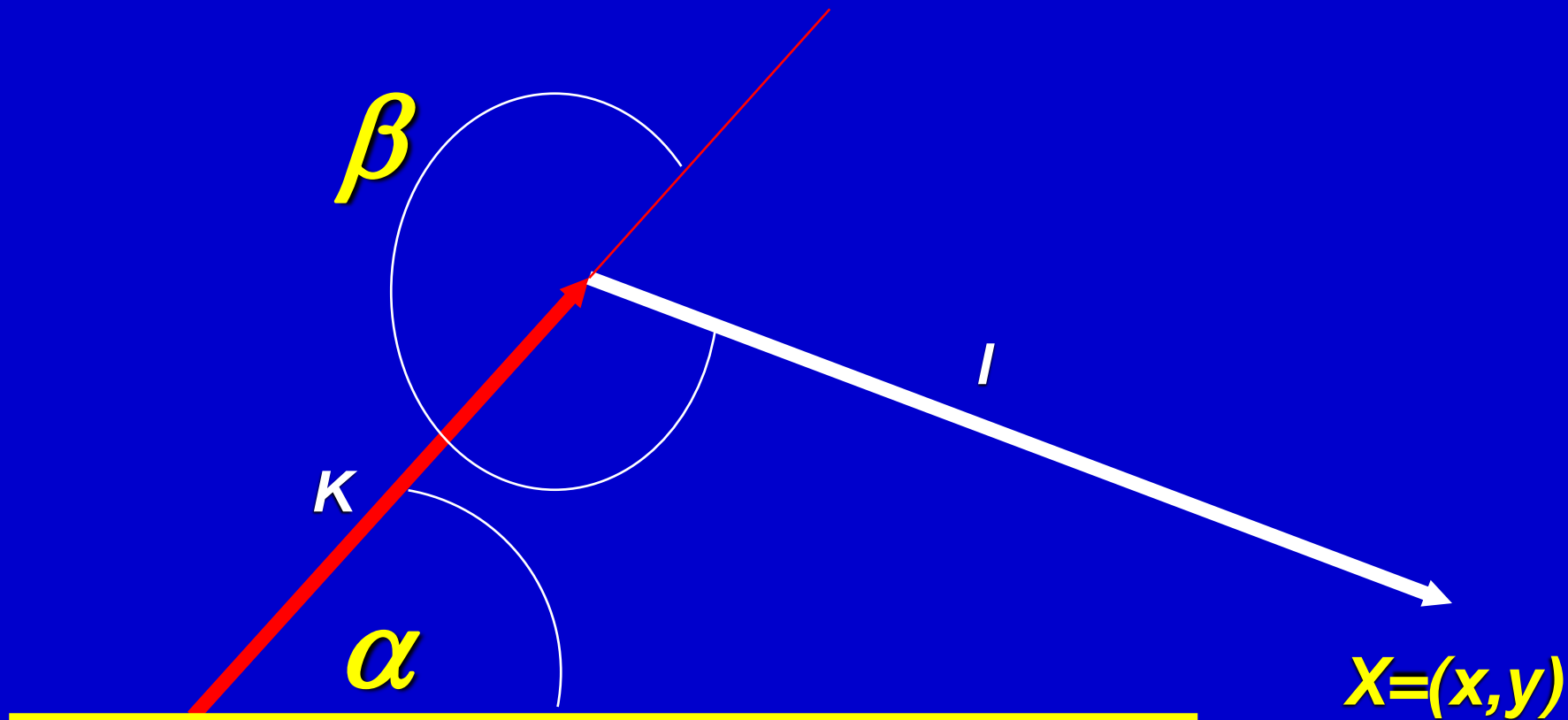


# FWD Kinematics in 2D



□ 
$$X = ( k \cos \alpha + l \cos (\alpha + \beta), k \sin \alpha + l \sin (\alpha + \beta) )$$

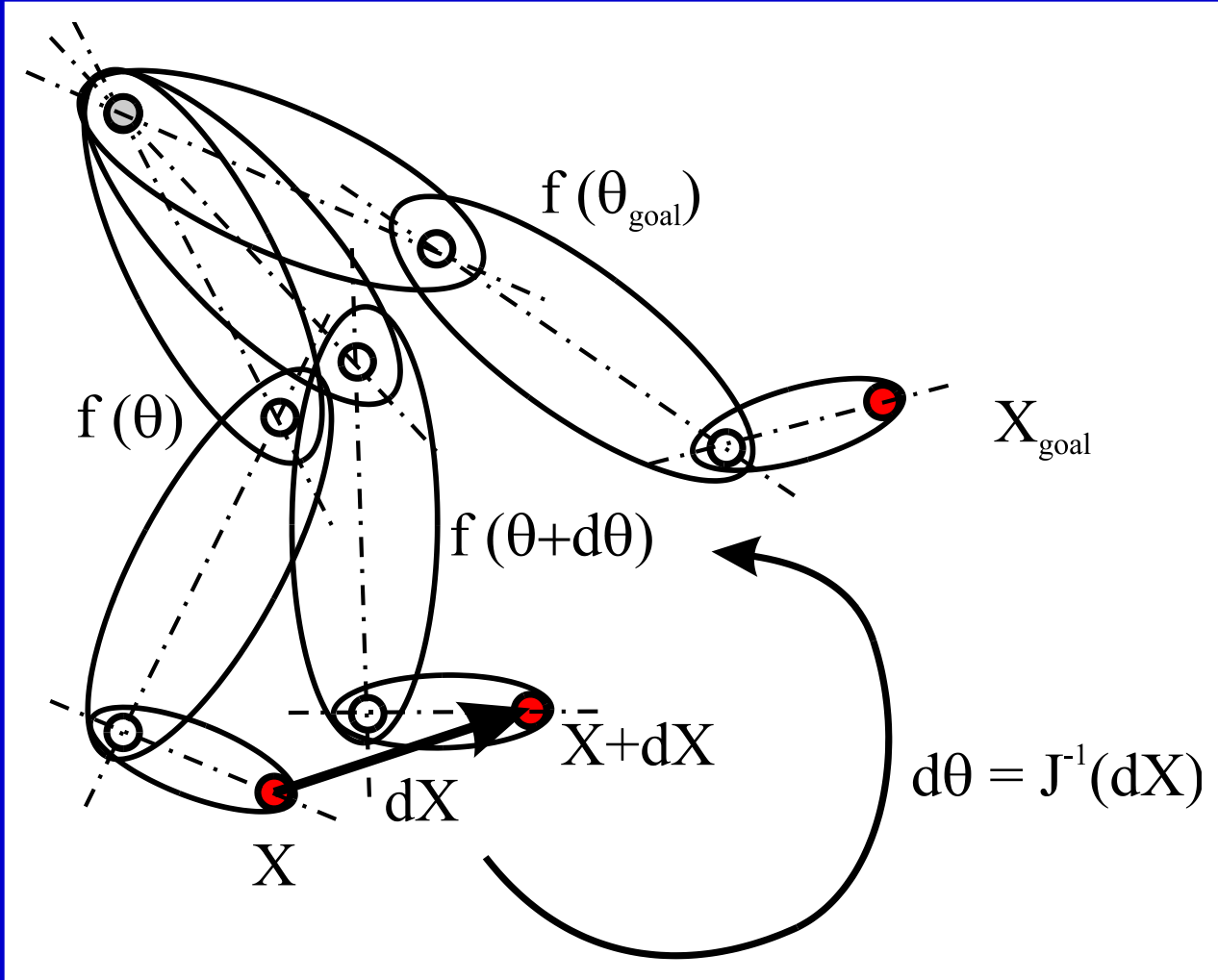
# FWD Kinematics in 2D



□ 
$$X = ( k \cos \alpha + l \cos (\alpha + \beta), k \sin \alpha + l \sin (\alpha + \beta) )$$

# *Inverse Kinematics*

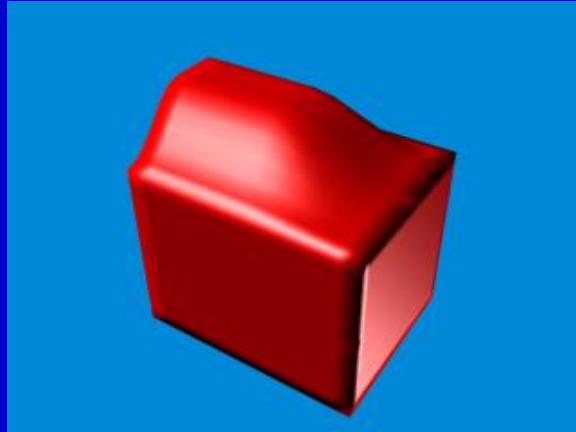
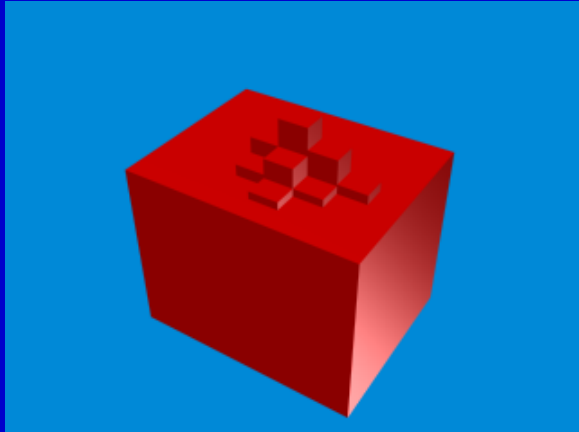
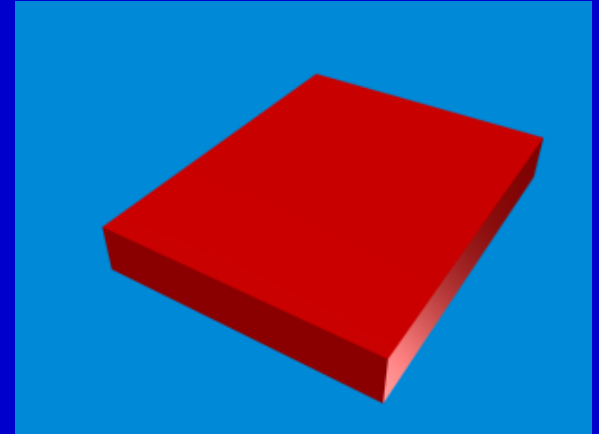
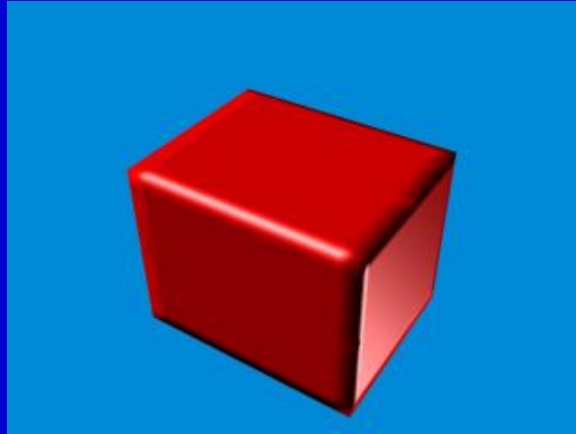
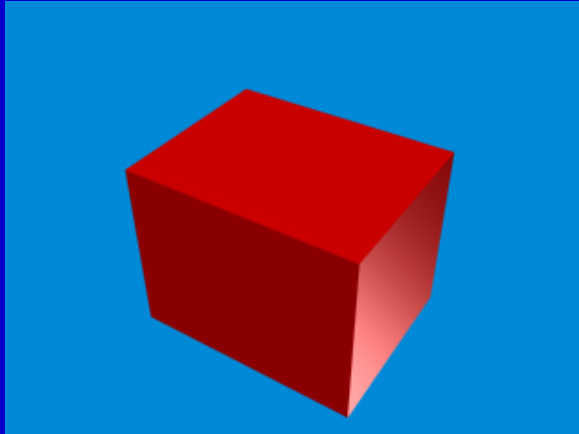
- *Inverse function  $\theta = f^{-1}(X)$  analytically too complex for practical instances*
- *Iterative solution:*
  - *Start point:  $X = f(\theta)$*
  - *Jacobian matrix:  $dX = J(\theta) d\theta$*
  - *through  $d\theta = J^{-1}(dX)$  partial state vector changes computed*
  - *next iteration step*





# *Soft Object Animation*

- *Animating surface*
- *Representation-dependent methods*
  - *Deforming of B-Reps*
  - *Deforming parametric objects*
- *Representation independent methods*
  - *Non-linear global deformation*
  - *Free Form Deformation (FFD)*



# ***SIGGRAPH Animation***

## ***SIGGRAPH Animation Course:***

<http://www.siggraph.org/education/materials/HyperGraph/animation/anim0.htm>

## ***SIGGRAPH Course Notes:***

- [http://www.siggraph.org/education/materials/siggraph\\_courses/s96\\_course30.pdf](http://www.siggraph.org/education/materials/siggraph_courses/s96_course30.pdf)
- [http://www.siggraph.org/education/materials/HyperGraph/animation/character\\_animation/principles/prin\\_trad\\_anim.htm](http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/prin_trad_anim.htm)
- [http://www.siggraph.org/education/materials/HyperGraph/animation/character\\_animation/principles/lasseter\\_s94.htm](http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/lasseter_s94.htm)
- [http://www.siggraph.org/education/materials/HyperGraph/animation/character\\_animation/motion\\_capture/motion.htm](http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/motion_capture/motion.htm)



# Key-frame Animation Workflow

- **1. Develop a script or story for the animation**
- **2. Lay out a storyboard, that is a sequence of informal drawings that shows the form, structure, and story of the animation.**
- **3. Record a soundtrack**
- **4. Produce a detailed layout of the action.**
- **5. Correlate the layout with the soundtrack.**
- **6. Create the "keyframes" of the animation. The keyframes are those where the entities to be animated are in positions such that intermediate positions can be easily inferred.**
- **7. Fill in the intermediate frames ("inbetweening", "tweening").**
- **8. Make a trial "film" called a "pencil test"**
- **9. Transfer the pencil test frames to sheets of acetate film, called "cels". These may have multiple planes, e.g., a static background with an animated foreground.**
- **10. The cels are then assembled into a sequence and filmed**

# *Camera Elements in any Scene*

- *Field of View*
- *Transitions*
- *Camera Angle*
- *Camera moves*
  - *Panning*
  - *Dolly shot*
  - *Crane shot*
- *Lenses*
  - *Zoom Lenses and the Vertigo Effect*
- *Depth of Field Effects*

# Field of View (fov)



- <http://www.siggraph.org/education/materials/HyperGraph/animation/cameras/movies/vertigo.avi>



# Walt Disney's Principles

- *In the 1930's... principles were developed to make animation, especially character animation, more realistic and entertaining... can & should be applied to 3D computer animation...*
- **1. Squash and Stretch** - defining the rigidity & mass of an object by distorting its shape during an action
- **2. Timing and Motion** - spacing actions to define the weight and size of objects and the personality of characters
- **3. Anticipation** - the preparation for an action
- **4. Staging** - presenting an idea so that it is unmistakably clear
- **5. Follow Through and Overlapping Action** - the termination of an action and establishing its relationship to the next action
- **6. Straight Ahead Action and Pose-to-Pose Action** - The two contrasting approaches to the creation of movement
- **7. Slow In and Out** - the spacing of the in-between frames to achieve subtlety of timing and movement
- **8. Arcs** - the visual path of action for natural movement
- **9. Exaggeration** - Accentuating the essence of an idea via the design and the action
- **10. Secondary Action** - the action of an object resulting from another action
- **11. Appeal** - creating a design or an action that the audience enjoys watching
- **⇒ Personality in character animation is the goal of all of the above.**



# ***Animation On-Line 1***

***E-book: WWW Animation Book***

***<http://www.cis.ohio-state.edu/~parent/book/outline.html>***

***Entertainment and New Media Guide (Careers)***

***<http://www.skillsnet.net/core.cfm>***

***Computer Animation annual conference***





# Animation On-Line 2

## **SIGGRAPH Animation Course:**

<http://www.siggraph.org/education/materials/HyperGraph/animation/anim0.htm>

## **SIGGRAPH Course Notes:**

- [http://www.siggraph.org/education/materials/siggraph\\_courses/s96\\_course30.pdf](http://www.siggraph.org/education/materials/siggraph_courses/s96_course30.pdf)
- [http://www.siggraph.org/education/materials/HyperGraph/animation/character\\_animation/principles/prin\\_trad\\_anim.htm](http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/prin_trad_anim.htm)
- [http://www.siggraph.org/education/materials/HyperGraph/animation/character\\_animation/principles/lasseter\\_s94.htm](http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/lasseter_s94.htm)
- [http://www.siggraph.org/education/materials/HyperGraph/animation/character\\_animation/motion\\_capture/motion.htm](http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/motion_capture/motion.htm)



***Thank You...***

*... for Your attention.*



# *Visualisation, Rendering and Animation*

*2 VO / 1 KU (2001-2004)*

---

*Heinz Mayer, Franz Leberl & Andrej Ferko*

[ferko@icg.tu-graz.ac.at](mailto:ferko@icg.tu-graz.ac.at)

Short podcast version 2020

