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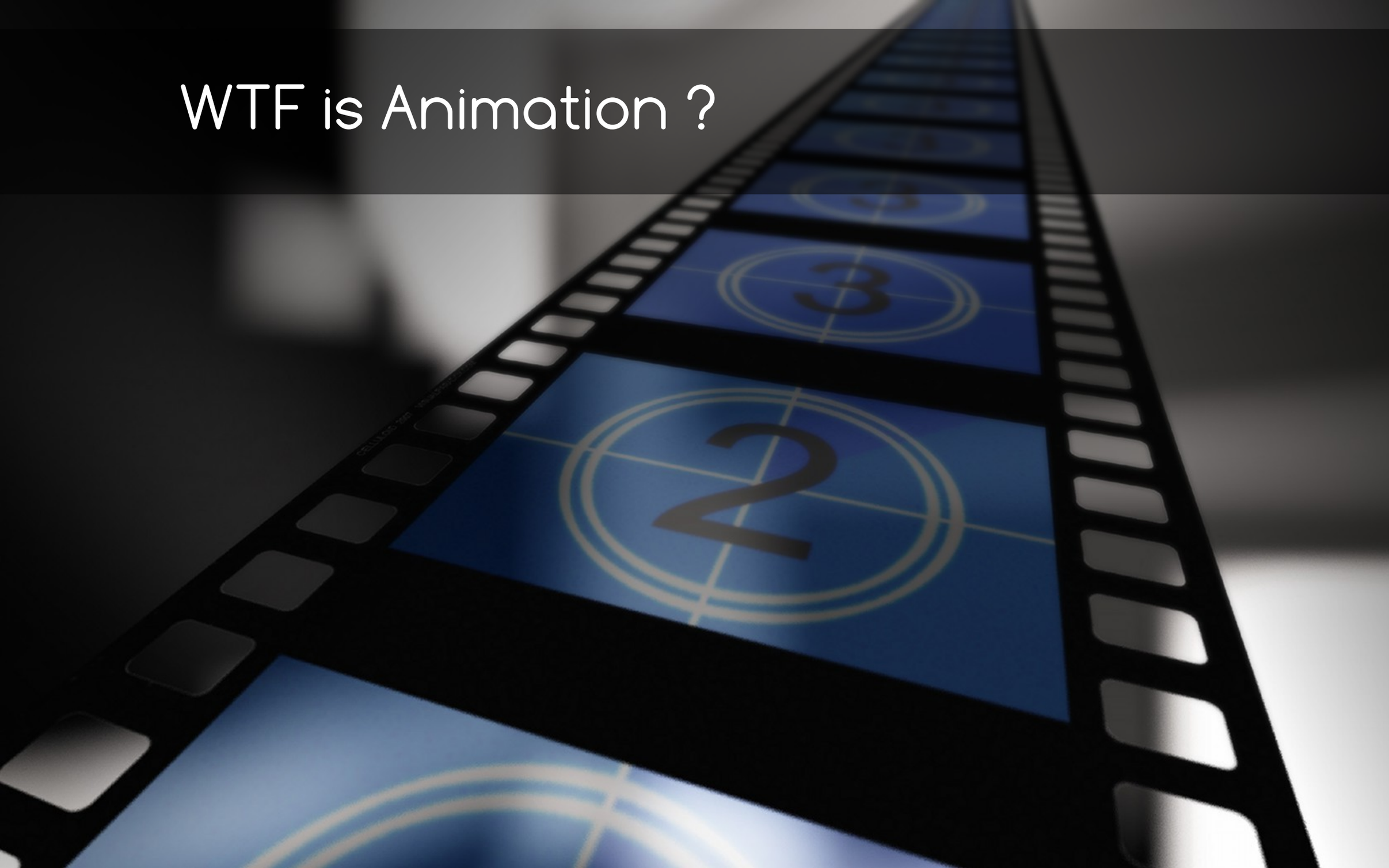
Computer Animation

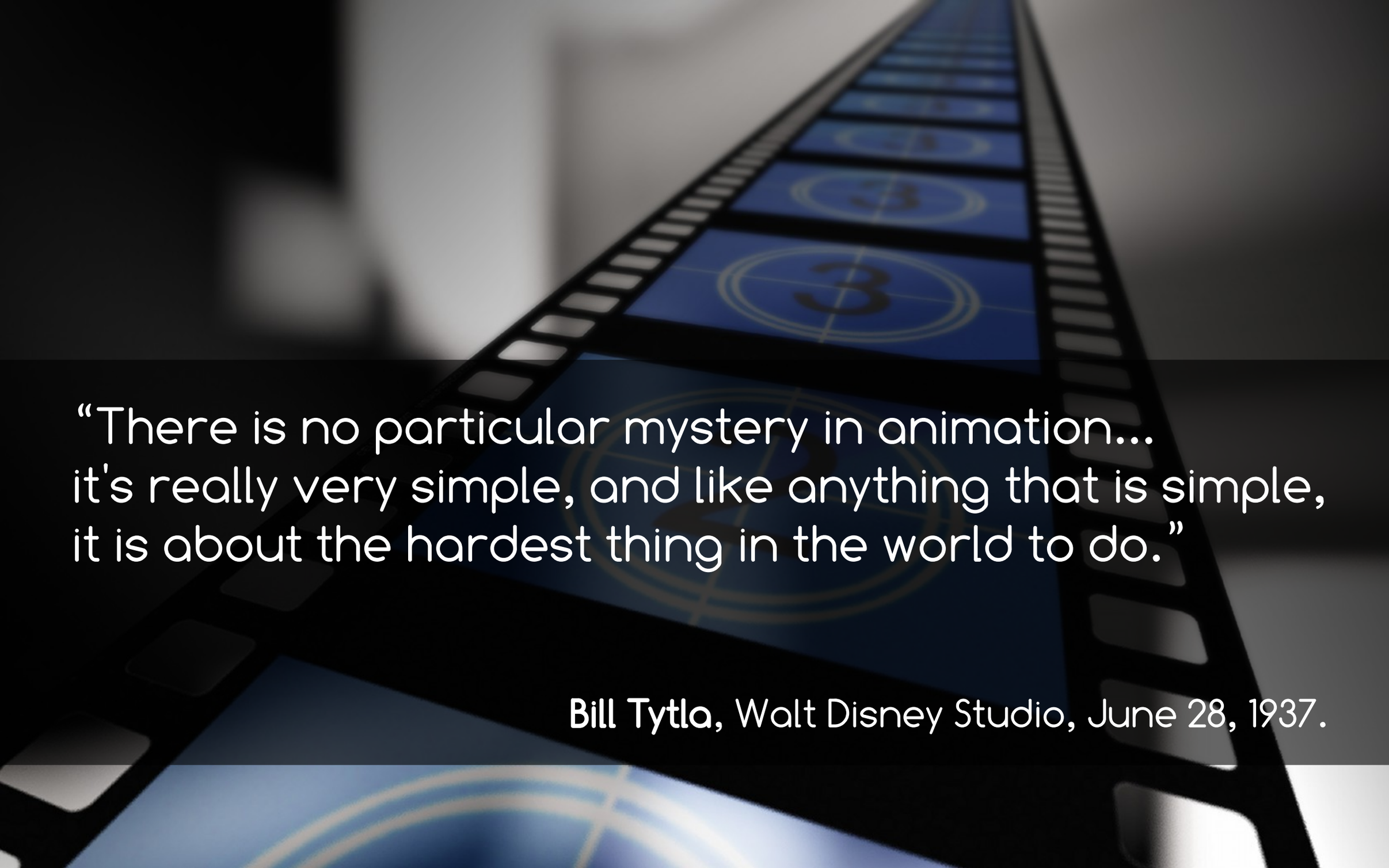
2010

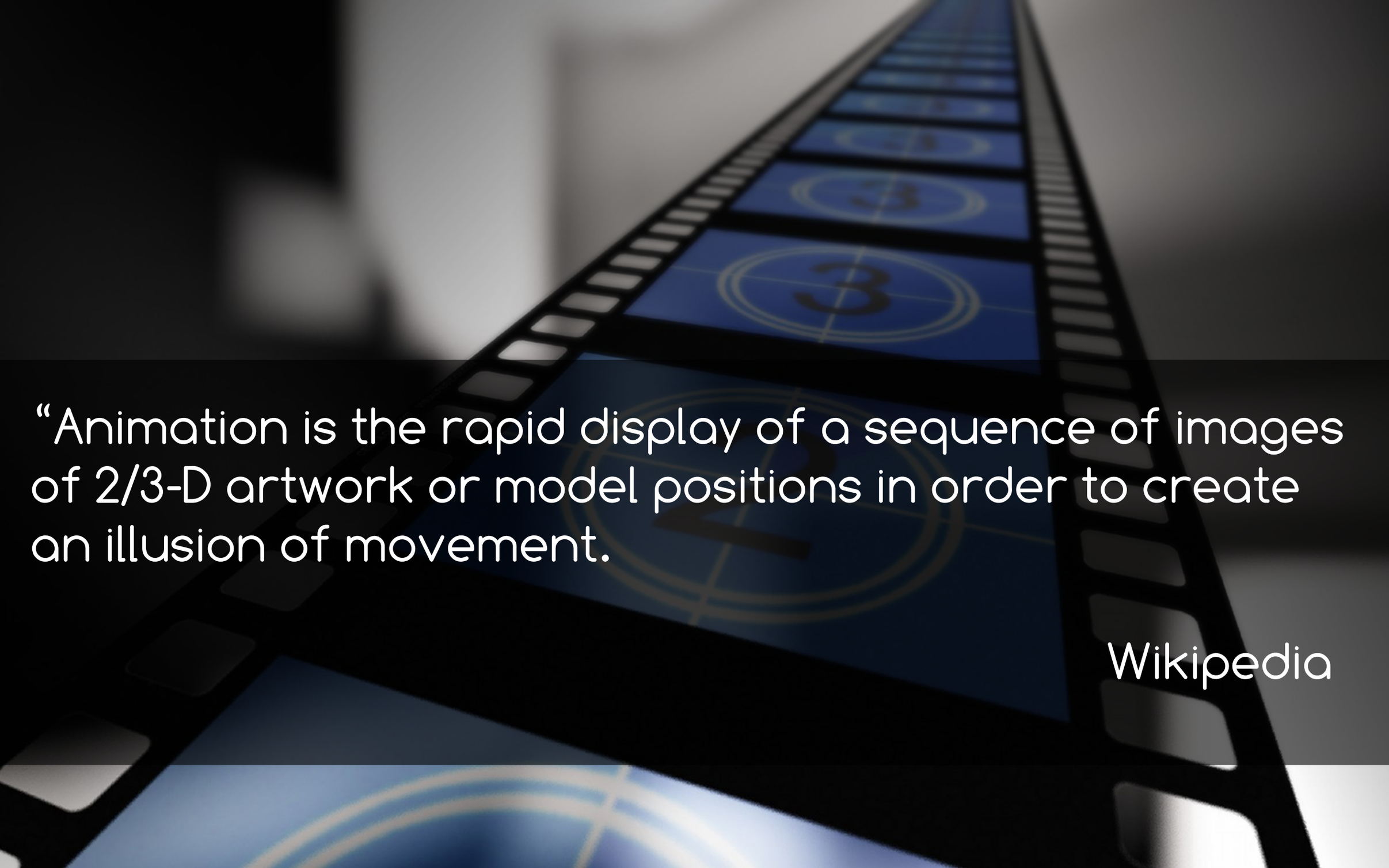
Outline of this Lesson

- Introduction to Computer Animation
- Common animation techniques
- Cutting edge tools and packages
- Gurus and the State of the Art
- Lecture schedule
- “Terms and conditions”of this lecture

WTF is 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, Walt Disney Studio, June 28, 1937.



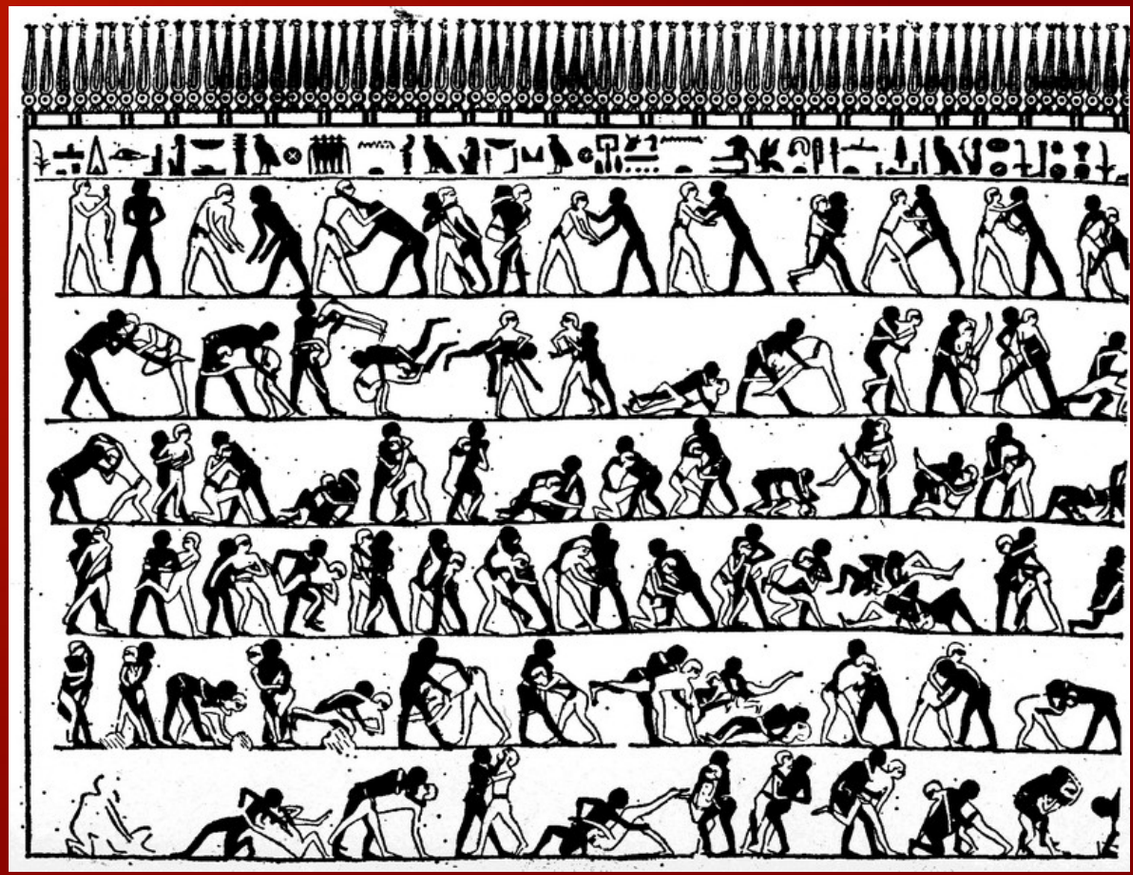
“Animation is the rapid display of a sequence of images of 2/3-D artwork or model positions in order to create an illusion of movement.

Wikipedia

Very brief History of Animation

- 5200 BC
  - A bowl found in Iran with 5 images of a goat

- 4000 BC
  - An Egyptian burial chamber mural



Very brief History of Animation

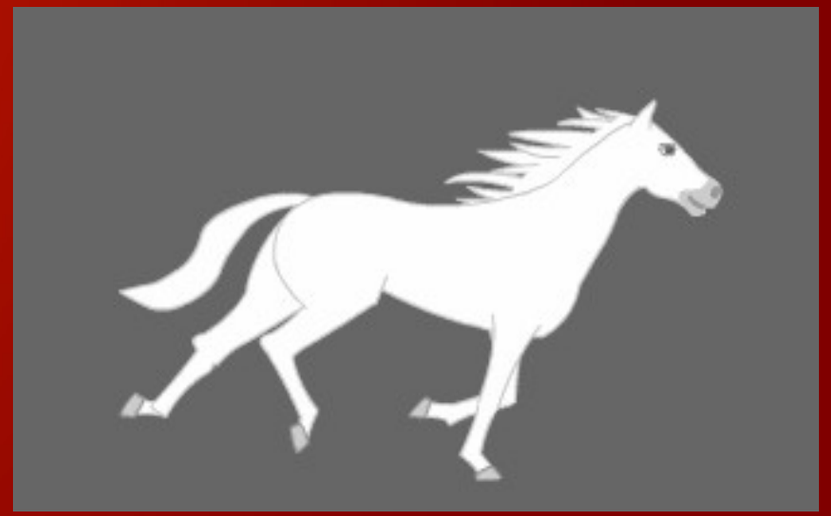
- 1800 AD
  - Flip Book – the first animation device

- 1888 AD
  - "Roundhay Garden Scene" the first known celluloid film

Traditional Animation techniques

Full Animation

- Technique
  - Every frame is hand drawn or photographed
- Pros/cons
  - High quality results
  - Very expensive and time consuming
- Famous movies
  - Pinocchio (United States, 1940)
  - The Lion King (US, 1994)

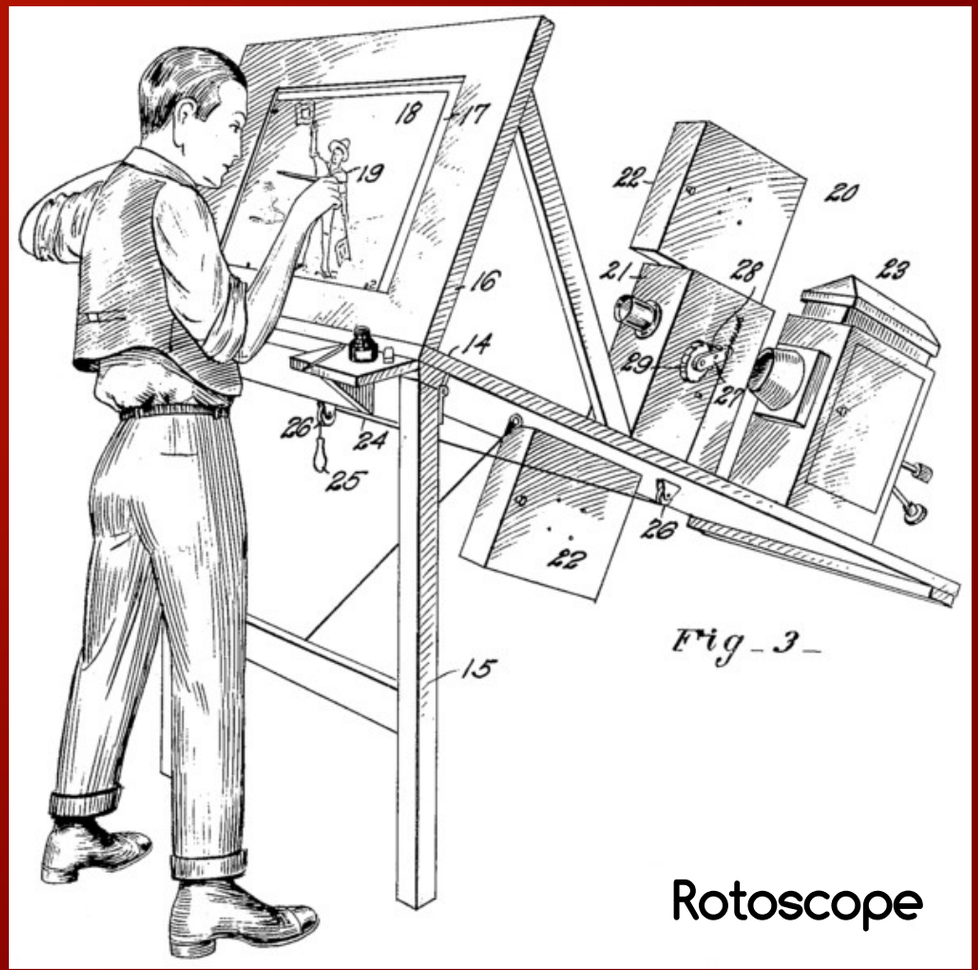


Limited animation

- Technique
  - Use less detailed and more stylized drawings
  - Compose objects from more layers and reusable parts
  - Repeat and zoom scenery
- Pros/cons
  - Less quality motions. Smart animator = good results
  - Less budget and time spent
- Famous movies
  - Yellow Submarine (UK, 1968)
  - Most of Anime in Japan

Rotoscoping and live-action/animation

- Rotoscoping
  - is an animation technique in which animators trace over live-action film movement, frame by frame
- Live-action/animation
  - is a technique, when combining hand-drawn characters into live action shots
- The Lord of the Rings (US, 1978)
- Space Jam (USA, 1996)



Rotoscope

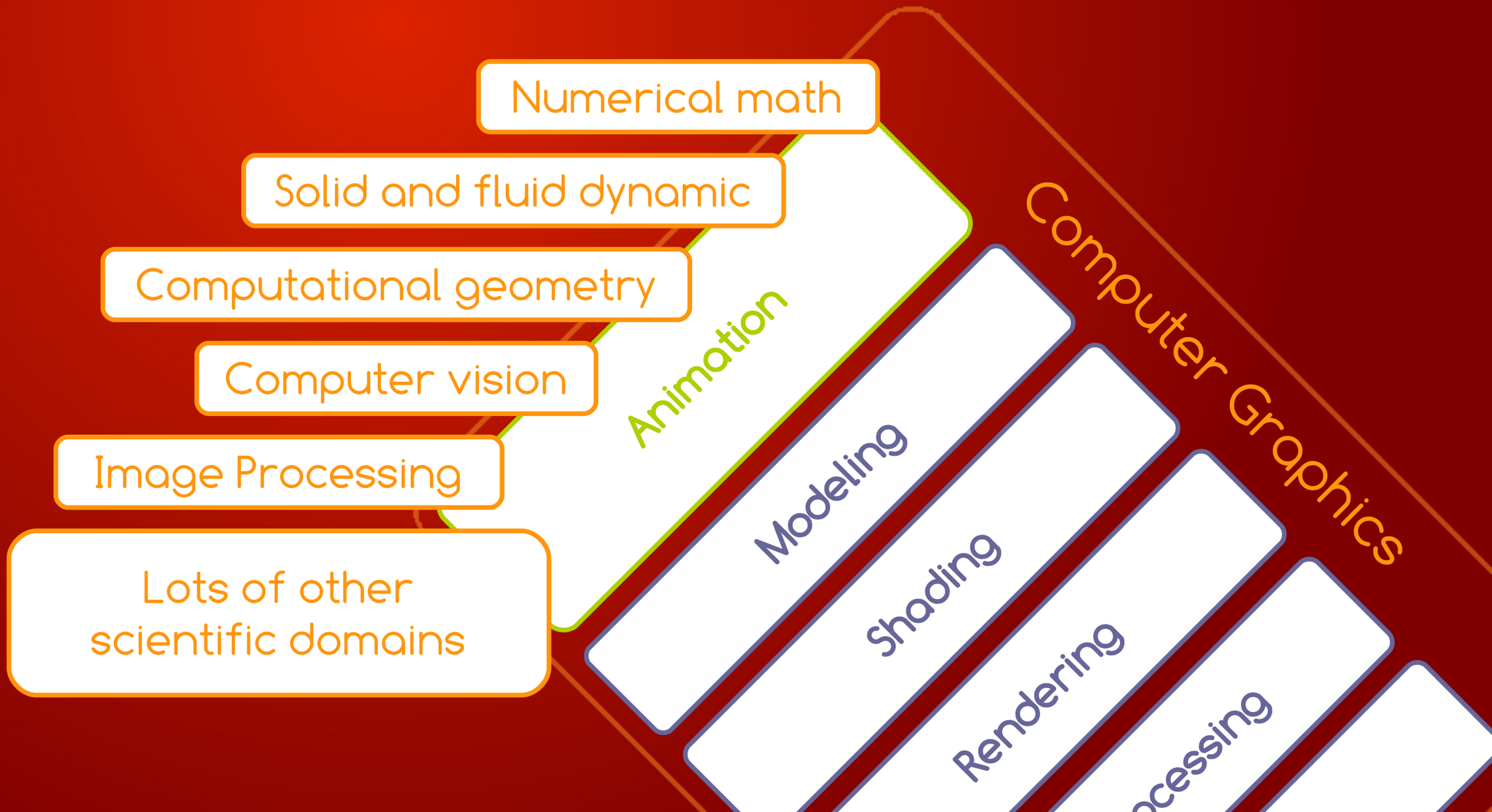
It is the art of creating moving images with the use of computers

Computer Animation

What is Computer Animation ?

- It is a part of Computer Graphics
- It is a set of algorithms and techniques to animation synthetic objects
- It is a collection of software packages for creating digital moving media
- Can be Offline → movies, ads
- Can be real-time → virtual world, games
- It is a place where art meets science

Who are its friends ?



What are Common Animation Techniques

- Key-framing and parameter interpolation
- Skeleton and Skinning
- Motion capture
- Forward and inverse Kinematics
- Procedural techniques
- **Physically based techniques**
- Other special methods

Key-framing and parameter interpolation

- Comes from traditional frame-based animations
- Trivial principle
  - Define object states (positions...) only in KEY frames
  - Let the computer calculate the in-between frames by interpolating state variables (positions...)
- Interpolation types
  - Simple linear interpolation (insufficient in most scenarios)
  - Spline (cubic bezier) interpolation (commonly used)
  - Spherical (linear/bezier) interpolation (for quaternions)

Skeleton and Skinning

- Inspired by skeleton system of animals
- Basic work-flow
  - Create skeleton (connect bones to each other)
  - Animate skeleton using any animation technique
  - Create “skin” - usually a polygonal mesh of animal
  - Apply skinning – map vertices to bones using weights
- Skeleton is usually a articulated structure of bones
- Skinning weight define how much each vertex “belongs” to a given bone

Motion Capture

- Inspired by Rotoscoping, capturing frames by cameras
- Marker-based work-flow
  - Attach reflex markers on key parts of actors body (knees...)
  - Create skeleton and assign marker points
  - Capture video-sequence of moving actor (multiple cameras)
  - Use image based techniques to find 3d position of markers
  - Animate the skeleton by the reconstructed path data
- Pros: faster, simpler, more precise
- Cons: Marker retouching, complex motion = many markers

Motion Capture

- Inspired by object recognition of human visual system
- Marker-less work-flow
  - We don't need markers, the whole geometry is reconstructed from multiple cameras
  - 3d geometry is analyzed, automatic skeleton can be created
  - Reconstructed geometry is matched onto animated geometry
- Pros: Complex motion (of skin) can be captured
- Cons: Complicated vision algorithms necessary, geometry matching is not always possible. Need more computational power

Forward and inverse Kinematics

- Forward (direct) kinematics
  - Put objects into transformation hierarchy
  - Animate each transformation directly (eg by key-framing)
  - Problem: Figure wants to reach a cup on a table by hand, but how to interpolate transformations to get natural motion ?
- Inverse (backward) kinematics is the answer
  - Define effector (eg a plam on hand)
  - Directly animate only effector (simply hit the cup)
  - Other parts in the transformation hierarchy are calculated by optimizations (more details during next lesson)

Procedural Techniques

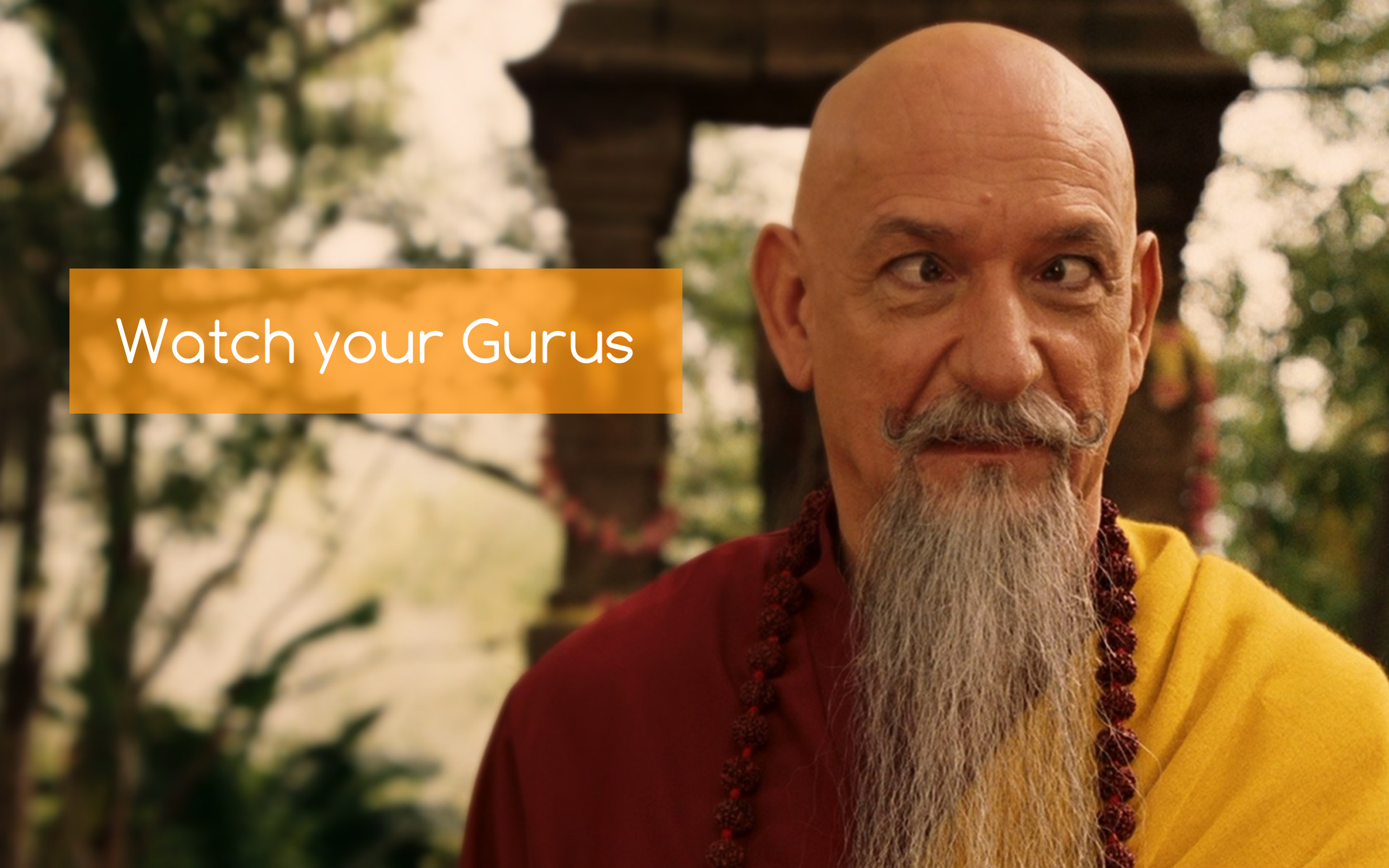
- Motivations
  - Simulate natural phenomena without complex physics
  - Nature has a fractal structure => use stochastic iterative functions to create models => simple parametrization
- Principle: Animation of objects is reduced to changing parameters
- Use L-systems for biological structures
- Use simple wave equations for ocean motion
- Use simple morphing and warping to “squeeze” objects

Physically based Techniques

- Goal: Realistic simulation of natural phenomena
  - Natural motion of Rigid and soft bodies
  - Plausible fire, explosions and smoke
  - Freezing, melting, boiling and bubbling fluids
  - Fracturing and gluing solids and granular materials
- Motivation
  - Physical motion is too complex for traditional techniques
  - Replace expensive VFX with simulations
- Sounds cool ? Just wait
  - This lecture focuses mainly on these techniques

Other special methods

- Motion planing and path finding
- Crowd and flock simulation
- Motion control of physically based animations
- Complex behavioral and intelligent character motion
  - http://www.naturalmotion.com
- Music (MIDI) driven animations
  - http://www.animusic.com
- Want more ? Just Google it


Watch your Gurus

Ron Fedkiw

- Associate Professor at Stanford
- Lead researcher at ILM
- More than 100 important scientific papers
- More than 20 successful PhD students
- VFX expert
- Research
  - Computational Physics
  - Computer Graphics
  - Biomechanics

Matthias Müller-Fischer

- Post doc at ETH Zurich
- Research Lead PhysX SDK at NVIDIA
- Head of research AGEIA Technologies
- Co-founder of NovodeX AG
- More than 20 important publications
- Research
  - Computer Graphics
  - Computational chemistry
  - Combinatorial algorithms

and what
do we need ?

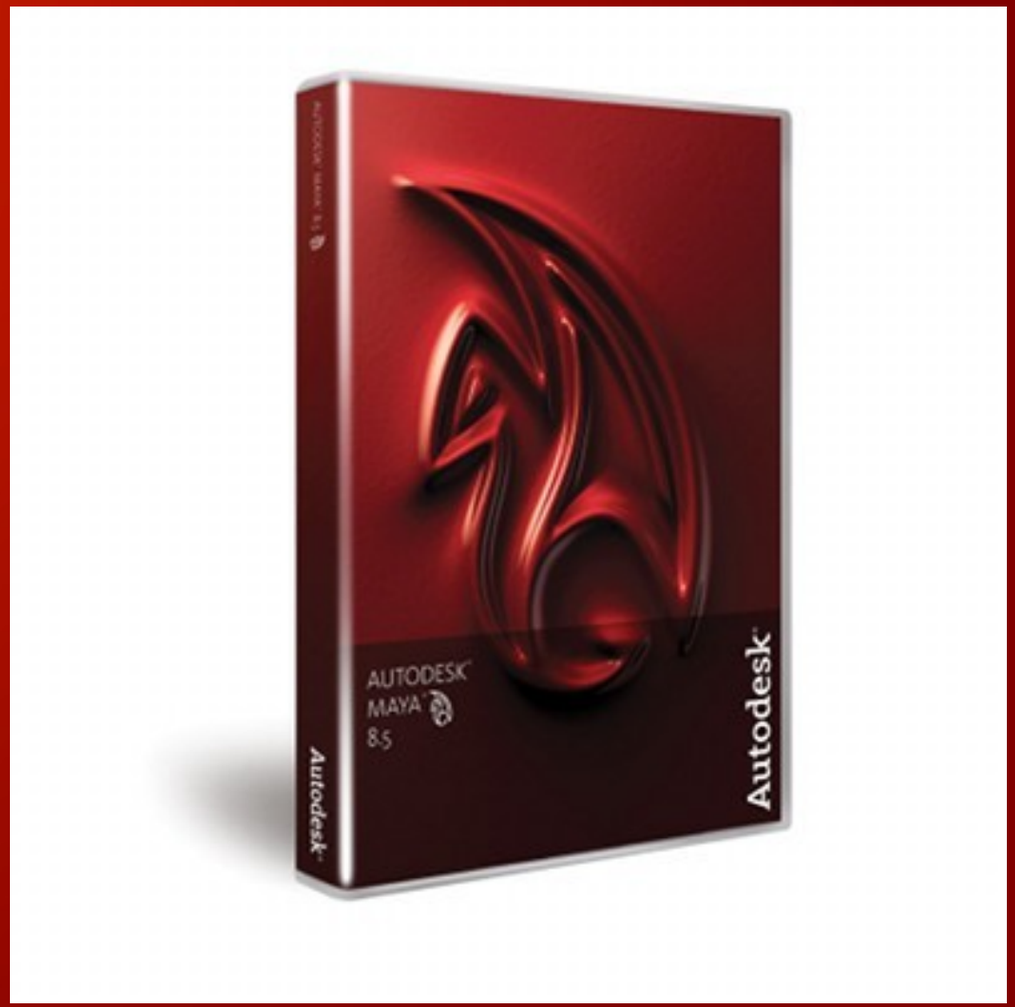
What tools do we have ?

Autodesk 3dsmax

- Full featured 3d tool
- Industry standard
- Commercial product
- Features
  - Key-framing, skinning
  - Inverse kinematics
  - Rigids, Cloths, fluids
  - Procedural animation
  - Character animation
  - … and much more

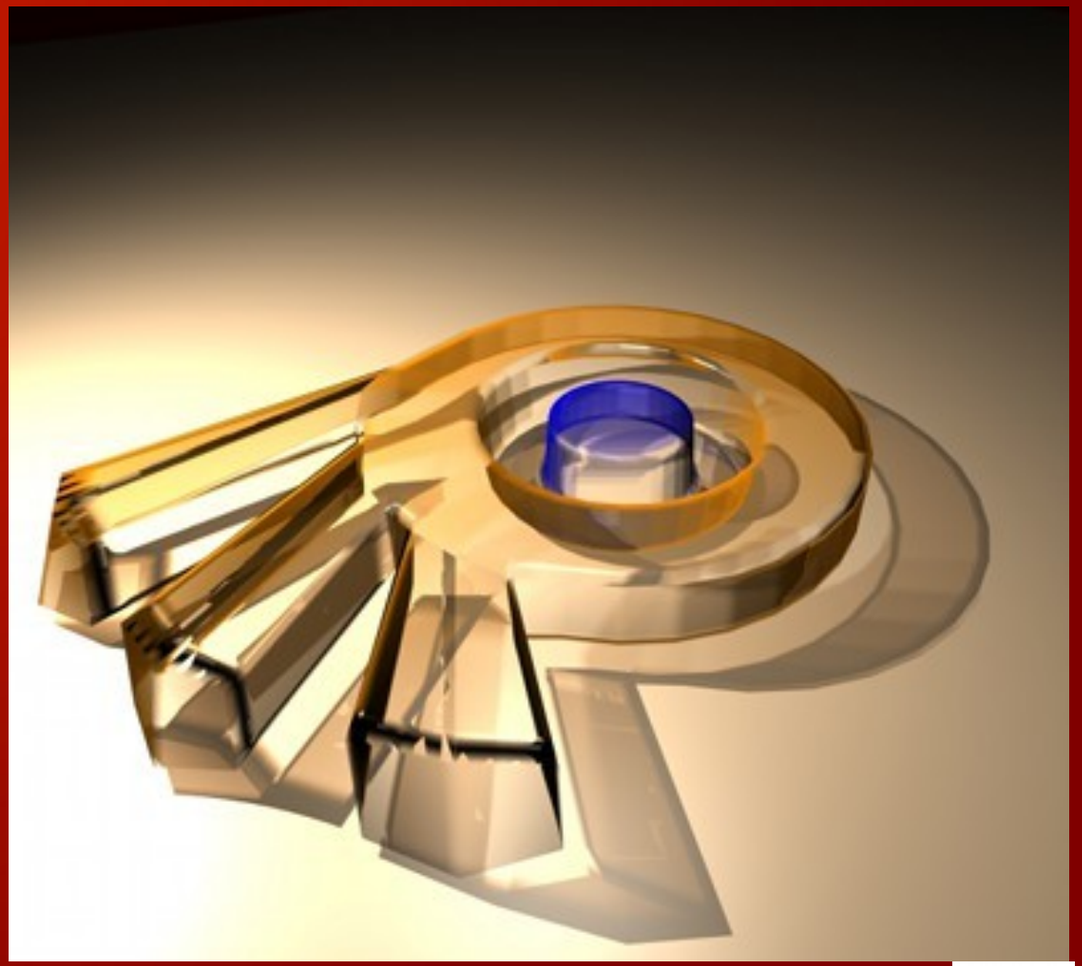
Autodesk Maya

- Full featured 3d tool
- Industry standard
- Commercial product
- Features
  - Key-framing, skinning
  - Inverse kinematics
  - Rigids, Cloths, fluids
  - Procedural animation
  - Character animation
  - … and much more



Blender

- Full featured 3d tool
- Free open product
- Features
  - Key-framing, skinning
  - Inverse kinematics
  - Rigids, Cloths, fluids
  - Character animation
  - … and much more



Realflow

- Specialized VFX tool
- Commercial license
- Industry standard
- Focus on Simulations
  - Fluids, Rigids, Cloths…
- Used in a dozen of movies for special effets

naturalmotion endorphin

- Specialized tool for
  - Behavioral animation
  - Intelligent characters
- Becoming industry standard
- Commertial license
- Used in VFX and computer games (euphoria)

Adobe flash

- State of the art 2d animation tool
- Commercial license
- Animated web-pages, logos, presentations, banners, games
- Alternatives
  - Ajax Animator (SVG), ToonBoom, AnimeStudio
- Flash + ActionScript + Flex → Complete platform

What can you expect from this Lecture ?

This Lecture...

- Will focus on simulating natural phenomena
- Will show you what are hot topics
- Will Improve your skills in
  - Newtonian physics
  - Computational geometry
  - Algorithms and data structures
- Hopefully will not be boring
- Was finished just few minutes ago

What do I expect from

YOU ?

:: Your presence
:: Show your project
:: Pass final term
:: Pass oral exam

Your presence here ?

- To be or not to be - on these lessons – that's the question
- Positive motivation
  - It's time to improve your skills
  - It's time to impress with your project
  - It's time to prepare for master exams
- Negative motivation: “1,2,3 is OK, more is Fx”
  - Each missed lesson is -10 points
  - Missing 4 and more lessons is fatal Fx


Show off
your Magic

The End

It's time for...
but don't forget what you just learned

This lecture ...

- Will focus on simulating natural phenomena
- Will show you what are current topics
- Will improve your skills in
  - Newtonian physics
  - Computational geometry
  - Algorithms and data structures
- Hopefully will not be boring

Obsah

Student Projects

- Stránka Ráno do práce
- Stránka The_good_the_bad
- Stránka Kiwi Animácia KiWi
- Stránka Knihy Animácia Knihy
- Stránka Motorka

D-E-A-D-L-I-N-E-S

- Written exam (optional): **deadline 19.1.2014, 8:00, classroom A**
  - Instead of (optional) oral exam, you can get (-20 ... +20) points due to a written exam.
  - It will be similar to final term, but less complicated.
- Coders (Cxx): **deadline 26.1.2015**
  - Send to onderik@sccg.sk finished application and some note if source code should be private (zipped source + executable.)
  - Executables will be public on this page. Sources only if author allow it.
  - If you send it earlier you can get feedback how to improve your application
- Animators (Axx): **deadline 26.1.2015**
  - Upload your animation video on youtube (or some alternative online service)
  - Send to onderik@sccg.sk link to your animation (link to youtube)
  - If you send it earlier you can get feedback how to improve your animation

What you Need to Pass

- Attend lessons. All lessons attended is +10 points. One missed +0 points. 2 missed 0 points, 3 missed 0 points, 4 and more is Fx.
- Show your project (mandatory, 60 points) See later.
- Solve all homework problems (mandatory each one >=30%, 30 points)
- Pass final term (mandatory, 10 points) You will need to solve several problems discussed during lessons.
- Pass oral/written exam: (optional, +/-20 points) If you feel you are better, convince me ! You can get +20 points or loose -20 points.
- Summary
  - Attendance = +10..0 or -100 (Fx)
  - Homework = +30..10 or +10..0 (Fx)
  - Project = +60..0
  - Final term = +10..0
  - Oral/written exam = +20..-20

- Grades
  - A = 92-130
  - B = 84-91
  - C = 76-83
  - D = 68-75
  - E = 60-67
  - Fx = 0-49

- **VIEW RESULTS**

How to Arrange your Project

- Take 2 friends and Team up
- Role1: The Coder
  - Choose a given animation algorithm
  - Code up hot demo app and show it
- Role2: The Artist
  - Choose some authoring tool and create hot physically based demo reel
- Projects: Projects.pdf

Lesson01 "Introduction to Computer Animation"

- Introduction to Computer Animation
- Common animation techniques
- Cutting edge tools and packages
- Gurus and the State of the Art
- Lecture schedule
- "Terms and conditions" of this lecture
- Lecture notes: lesson01.pdf

Lesson02 "Basic methods in Computer Animation"

- Problem definition and motivations
- Key-framing and parameter interpolation
- Quternions, orientation
- Skeleton and skinning animation
- Forward and inverse kinematics
- Procedural techniques
- (Motion capture)
- Lecture notes: lesson02.pdf
- Štátnicová téma: Animácie pohybu a orientácie, interpolačný spline na animáciu pohybu, reparametrizácia splinu podľa dĺžky krivky, quaternion a orientácia, interpolácie dvoch a viacerých quaternionov.

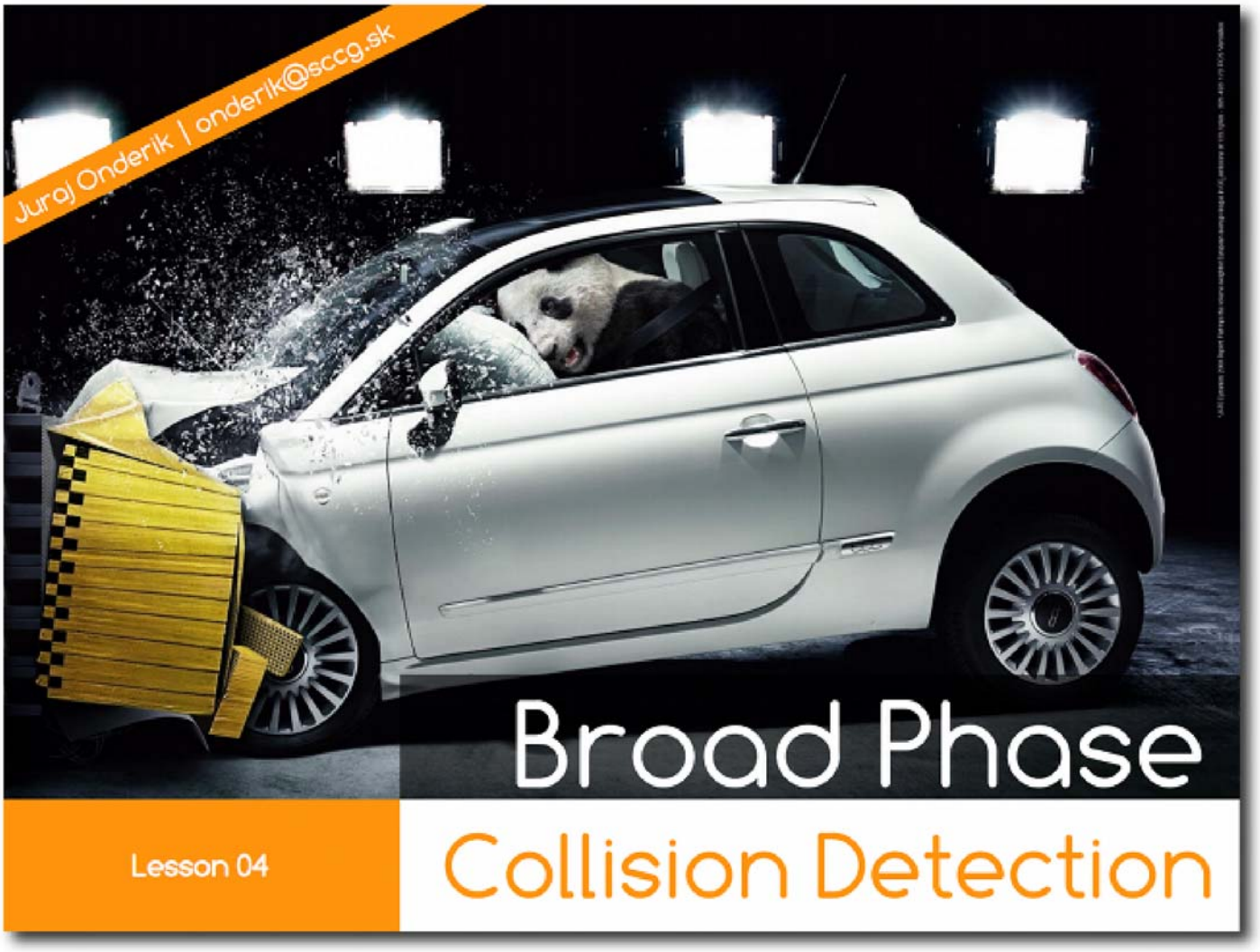
Lesson03 "Particle Systems"

- Newton dynamics of particles
- Ordinary differential equation (ODE) solver
- Particle - obstacle collision detection
- Practical design of particle system
- Demos / tools / libs
- Lecture notes: lesson03.pdf
- Štátnicová téma: Numerické riešenie diferenciálnych rovníc, Eulerova metóda, Runge-Kuta metóda, podmienka stability na voľbu časového kroku.

Lesson04 "Soft bodies, Cloths and hair”

- Problem definition and motivations
- Modeling solids with stress and strain
- Extending Mass-spring model for cloth and ropes
- Massive (self) collision and resolution for cloths
- Mesh-less deformations
- Modeling solids with infinitely stiff springs
- Demos / tools / libs
- Lecture notes: lesson04.pdf
- Štátnicová téma (Lesson 3,4): Časticové systémy, rovnice pohybu prvého rádu, integračné metódy na výpočet rýchlosti a pozície, stavový vektor systému, vonkajšie sily, obmedzujúce podmienky – constraints, sily odozvy, kolízie častica - rovina.

Lesson05 "Broad Phase Collision Detection"



- Problem definition and motivations
- Hierarchical grids and spatial hashing
- Sweep and prune and radix sort
- Pair management – a practical guide
- Demos / tools / libs
- Lecture notes: lesson05.pdf

Lesson06 "Mid Phase Collision Detection"

- Problem definition and motivations
- Generic Bounding Volume Hierarchy (BVH)
- Tandem BVH traversal
- Proximity evaluation of primitive geometries
  - External Voronoi regions
  - Sphere x Capsule x Box x triangle collisions
- Approximate convex decomposition
- Lecture notes: lesson06.pdf

Lesson07 "Narrow Phase Collision Detection"

- Problem definition and motivations
- Proximity queries for convex objects (Minkowski space)
- GJK based algorithms (GJK, EPA, ISA-GJK)
- Voronoi-Clip (V-Clip) Algorithm
- Signed Distance Maps for collision detection
- Demos / tools / libs
- Lecture notes: lesson07.pdf
- Štátnicová téma (Lesson 5,6,7): Detekcie kolízie, Z buffer algoritmus, nutná a postačujúca podmienka kedy nie sú dve telesá v kolízii, deliaca rovina, hierarchie obálok, sily odozvy (response forces).

Lesson08 "All Saints' Day (no lesson)"

- No lesson

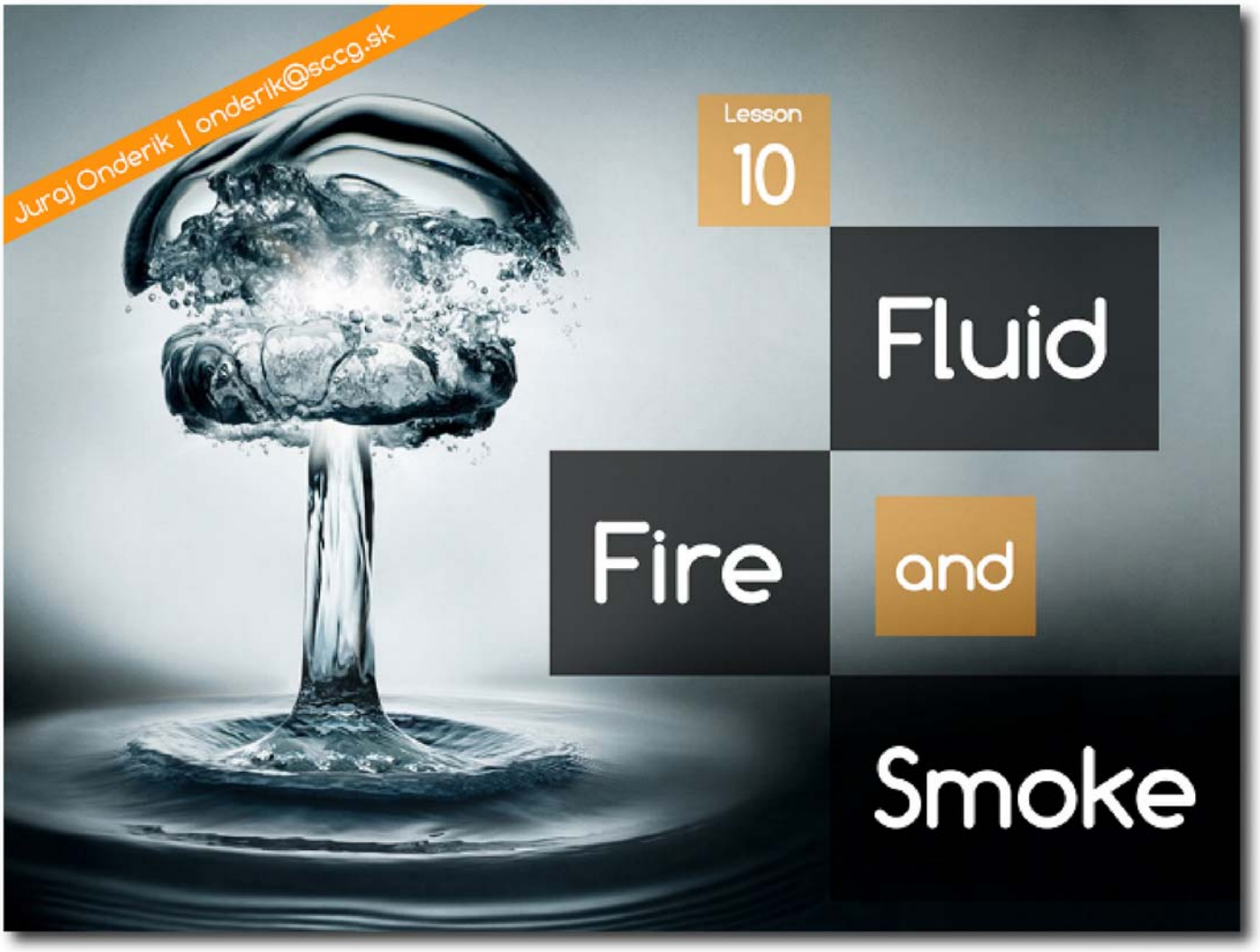
Lesson09 "Rigid body Dynamics”

- Problem definition and motivations
- Dynamics of rigid bodies
- The equation of unconstrained motion (ODE)
- User and time control
- Mass properties of polyhedral objects
- Demos / tools / libs
- Lecture notes: lesson08.pdf
- Štátnicová téma (Lesson 9): Dynamika tuhých telies, rovnice pohybu, rýchlosť, zrýchlenie, uhľová rýchlosť a uhľové zrýchlenie, matica inercie.

Lesson10 "Rigid body Collisions and Joints”

- Problem definition and motivations
- Simplified collision model
- Impulse based collision equation
- Friction-less collision resolution
- Algebraic collision resolution for Coulomb friction
- Linear and angular joint formulations
- Demos / tools / libs
- Lecture notes:lesson09.pdf

Lesson11 "Fluid, Fire and Smoke”



- Problem definition and motivations
- Navier-Stokes equations for fluid dynamics
- Grid based MAC method
- Particle based SPH method
- Neighbor search for coupled particles
- Modeling smoke and fire with fluid
- Demos / tools / libs
- Lecture notes: lesson10.pdf

Lesson12 "Final term"