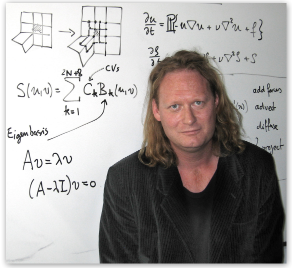
Jos Stam

from Art to Science

from Art to Science and Back



Outline

Profile

Awards

Research

Contributions

Personal Note

Profile

Education

- 1988 — Bachelor's Degree in Computer Science, University of Geneva
- 1989 — Bachelor's Degree in Pure Mathematics, University of Geneva
- 1991 — Master's in Computer Science, University of Toronto
- 1995 — Ph.D. in Computer Science, University of Toronto
- 1995,1996 — Postdoc, INRIA
- 1996,1997 — Postdoc, VTT Technical Research Centre of Finland

Professional Career

- 1997 to 2006 — *Researcher and Principal Scientist*, Alias Wavefront
- 2006 to 2018 — *Senior Principal Research Scientist*, Autodesk
- 2009 to 2018 — *Adjunct Professor*, University of Toronto
- 2019 to now — *Graphics Researcher*, NVIDIA

Personal Quotes

- "I write computer code, think mathematically and dream in images."
- "The motivation behind my research comes both from practical problems and pure intellectual curiosity."
- "I like to combine Art, Mathematics, Science, Computers and other cool exotica."

Awards

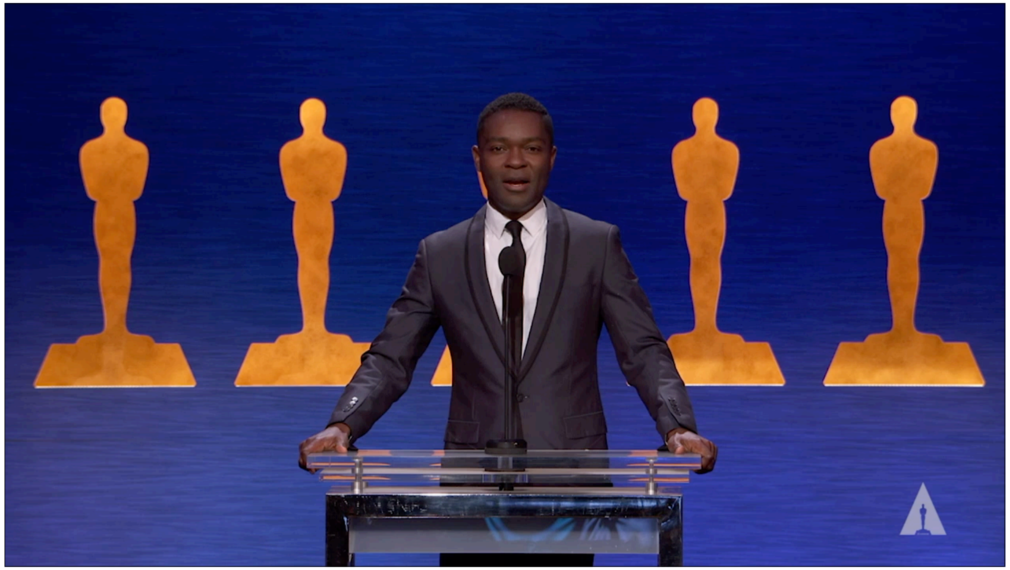
And the Oscar Goes To…

- SIGGRAPH Computer Graphics Achievement Award (2005)
  - contributions to the Field of Computer Graphics
- Academy Award for Technical Achievement (2005)
  - work on subdivision surfaces and their resulting impact in the film industry
- Academy Award for Technical Achievement (2008)
  - design and implementation of the Maya Fluid Effects system
- Academy Scientific and Engineering Award (2019)
  - pioneering advancement of the science of subdivision surfaces as 3D geometric modeling primitives

PS: as many Oscars as Meryl Streep

"Their creation of essential geometric operations and sustained research on the fundamental mathematics of subdivision surfaces helped transform the way digital artists represent 3D geometry throughout the motion picture industry."

– Academy of Motion Pictures Arts and Sciences SciTech Committee



Research

Defining Statements

" For a living I do something called research. This involves many activities. Reading papers and books. Interacting with fellow researchers usually in front of a white board. Attending and presenting at conferences all over the world. Surfing the internet. Basically thinking and experimenting by writing up ideas and coding them. This is an iterative process."

Jos Stam, 2018

" I am looking forward to some groundbreaking work, something I did not expect was possible or something very original, a novel way of looking at things."

Interview: Jos Stam, SIGGRAPH 2002

Mathematics that Simply Works

- ✓ Deep Understanding of the Problem
- ✓ Suitable Mathematical Concepts
- ✓ Robust Numerical Methods
- ✓ Intuitive Algorithms

Key Idea $\Longrightarrow$ *Application*

Topics of Interest

- Modeling Natural Phenomena
- Physics-Based Rendering
- Fluid Animation
- Dynamics Simulation
- Geometry of Surfaces

Technical Contributions

NATURAE

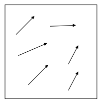
Modelling of Complex Natural Phenomena

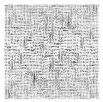
"Everything is approximate, less than approximate, for when more closely and sharply examined, the most perfect picture is a warty, threadbare approximation, a dry porridge, a dismal mooncrater landscape. What arrogance is concealed in perfection. Why struggle for precision, purity, when they can never be attained. The decay that begins immediately on completion of the work was now welcome to me."

Jean Arp, On My Way. Poetry and Essays , 1912-1947.

Jackson Pollock, Untitled , 1951, Ink on Howell paper.

Fire and Gaseous Phenomena



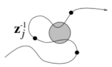


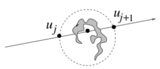
- Multiscale Motion Fields → *control*
  - Given $\mathbf{u}$, Solve for θ
- Diffusion of Density and Temperature → *spread*

$$\frac{\partial\theta}{\partial t} = -u\nabla\theta + \kappa_\theta\nabla^2\theta + S_\theta - L_\theta$$

advection diffusion creation dissipation

- Global Illumination on Blobs → rendering
  - Indirect Illumination
  - Ray Warping





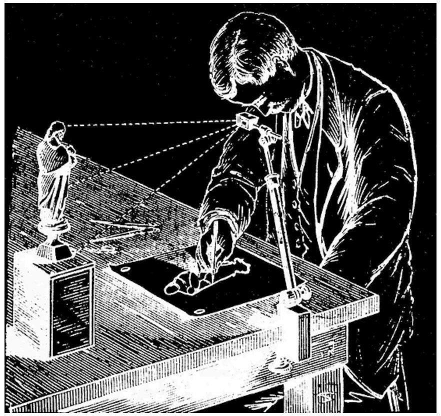
Jos Stam, Eugene Fiume (1995) SIGGRAPH

Bonfire - Sequence

Bonfire - Animation

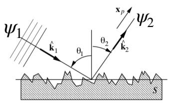
© 1995

UMBRA ET LUX



Diffraction Shaders

- Wave-Like Phenomenon
- Reflection depends on Microsurface
  - Two-dimensional Random Height Field
- Use Waves to Model both:
  - Propagation of Light
  - Microsurface (Fourier Analysis)
- Wave Theory of Light
  - Helmholtz's Equation
  - Kirchhoff Integral (relates reflected ψ_2 to incoming ψ_1 fields)
- Key Idea:
  - Fourier analysis computes the Kirchhoff integral of surface scattering
- Shader $\longrightarrow$ computing Fourier Transforms



$$\mathbf{v} = \hat{\mathbf{k}}_1 - \hat{\mathbf{k}}_2$$
$$\mathbf{p} = \hat{\mathbf{k}}_1 + \hat{\mathbf{k}}_2$$

$$\psi = e^{ik\hat{\mathbf{k}}\cdot\mathbf{x}}$$

$$\nabla^2\psi + k^2\psi = 0,$$

$$\psi_2 = \frac{ike^{ikR}}{4\pi R}(F\mathbf{v} - \mathbf{p}) \cdot \int_S \hat{\mathbf{n}}\, e^{ik\mathbf{v}\cdot\mathbf{s}}\, d\mathbf{s},$$

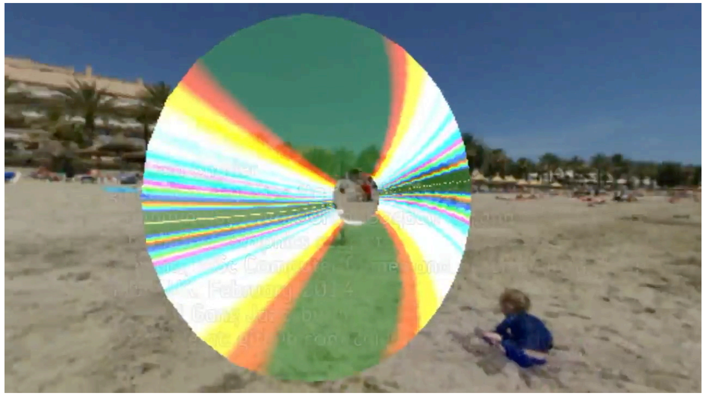
$$|F(\theta_1')|^2\ G(\mathbf{k}_1, \mathbf{k}_2)\ S(\mathbf{k}_1, \mathbf{k}_2)\ (D(\mathbf{v}, \lambda) + r\mathrm{Env})$$

fresnel — **geometry** (FFT) — shadowing — **distribution** — environ

Jos Stam (1999) SIGGRAPH

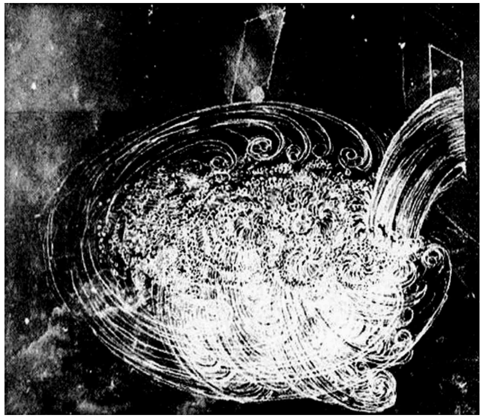
CD-ROM

GPU Gems



realtime capture

FIRMUM FLUIDUM



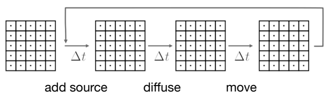
Stable Fluids

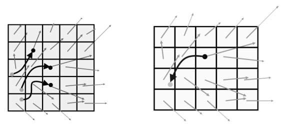
- Fluid Mechanics:
  - *Navier-Stokes Equation*
    velocity $\mathbf{u}$, density ρ
- Algorithm:
  - Add Forces / Source
  - Diffuse
  - Move
  - Conserve Mass (*Helmholtz-Hodge Decomposition*)
- Key Ideas
  - Combine Particles and Grids (*Semi-Lagrangian Solver*)
  - Trace Back in Time (*Method of Characteristics*)
- Unconditionally Stable and Simple

$$\frac{\partial \mathbf{u}}{\partial t} = -(\mathbf{u}\cdot\nabla)\mathbf{u} + \nu\nabla^2\mathbf{u} + \mathbf{f}$$

$$\frac{\partial \rho}{\partial t} = -(\mathbf{u}\cdot\nabla)\rho + \kappa\nabla^2\rho + S$$

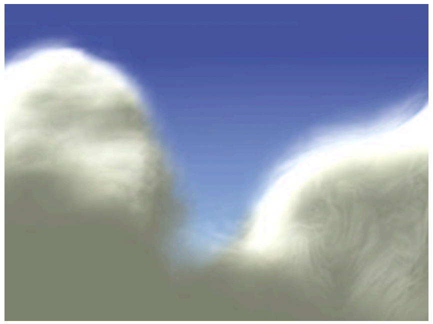
advection diffusion sources

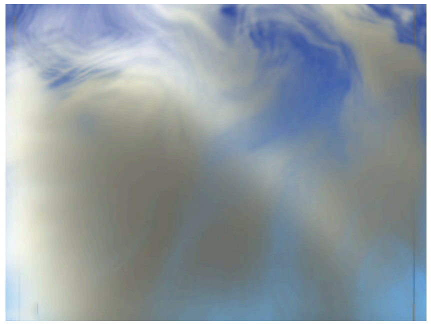




Jos Stam (1999) SIGGRAPH

3D Clouds



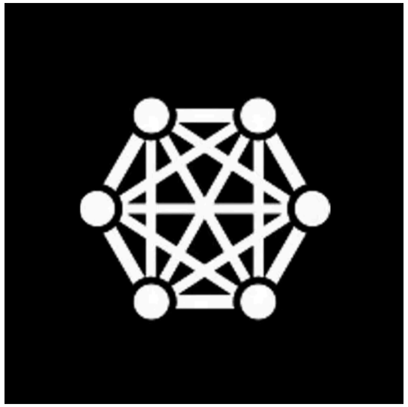


- SGI Octane - R10K processor and 192 Mb RAM

Real Time Simulation

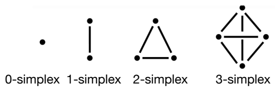
interactive demo by Spectron

NUCLEUS



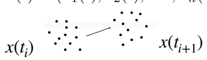
Unified Dynamical Solver for CG

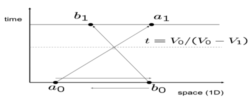
- Rigid Bodies / Cloth / Fluids
- General Shape Model
  - Simplicial Complex
- Dynamics of Complexes
  - Newton's Law $\boxed{\ddot{x} = -\nabla f(x) + f_e}$
- Robust Simulation (*Sympletic Methods*)
  - Implicit on Velocity
  - Explicit on Position $\begin{pmatrix} v^1 \\ x^1 \end{pmatrix} = \begin{pmatrix} 1 & -h \\ h & 1-h^2 \end{pmatrix} \begin{pmatrix} v^0 \\ x^0 \end{pmatrix}$
- Collisions (*Space-Time Hierarchical*)
- Deformations (*Constraints*)



$$x(0) = x_0$$
$$\dot{x}(0) = v_0$$

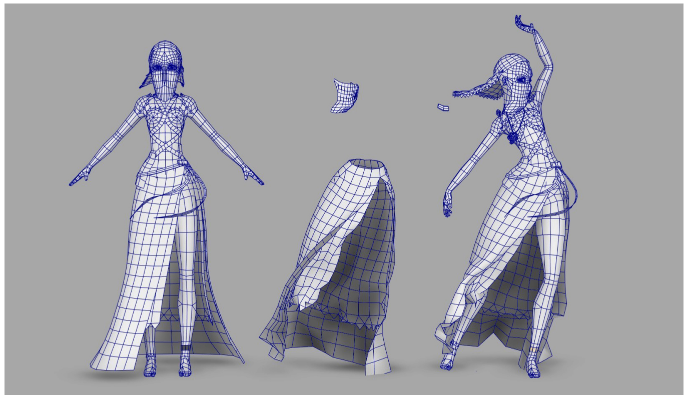
$$x(t) = (x_1(t), x_2(t), \cdots, x_n(t))$$



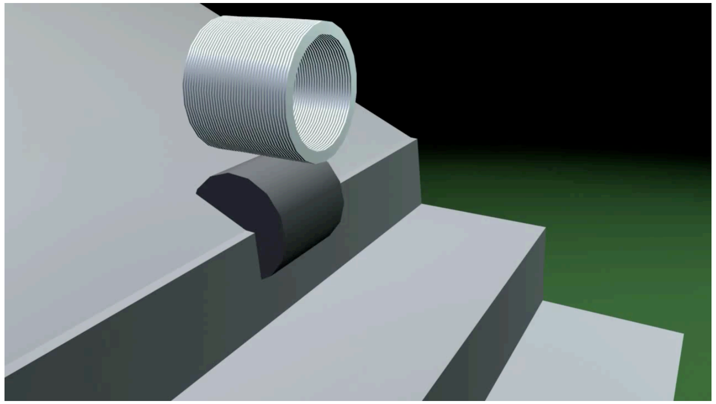


Jos Stam (2009) SIGGRAPH

Dancing Girl - nCloth

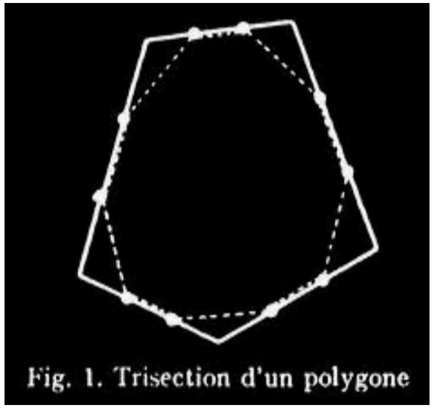


Slinky Animation



Autodesk Maya

SUPERFICIES

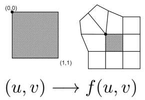


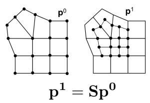
Evaluation of Subdivision Surfaces

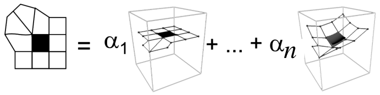
- Exact Evaluation
- Key Idea
  - Subdivision is Like Scaling
- Eigenvectors form a Basis

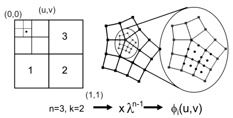
  $S(u,v) = \alpha_1 \phi_1(u,v) + \ldots + \alpha_n \phi_n(u,v)$
- Computation
  - Determine wich Tile *(u,v)* lies
  - α_i : linear combination of *CV*'s

  $f(u,v) = \sum_{i=1}^{K} \alpha_i \phi_i(u.v)$



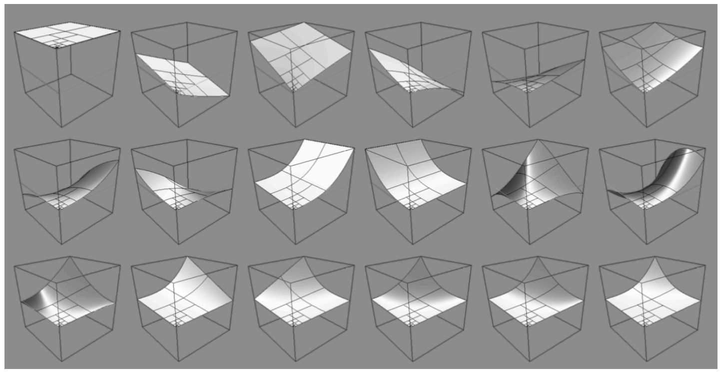






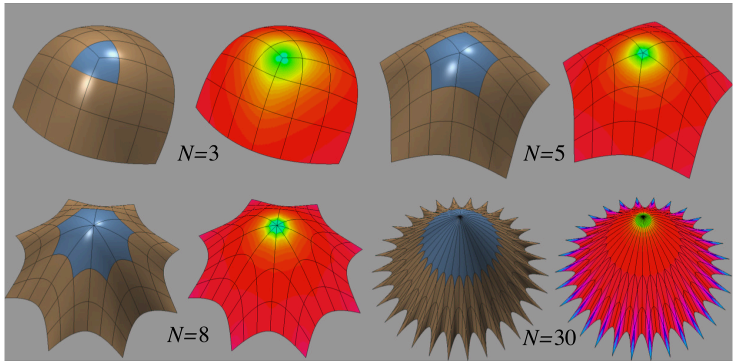
Jos Stam (1998) SIGGRAPH

New Basis Functions



- 18 Basis functions for Catmull-Clark with N=5

Near Extraordinary Vertices

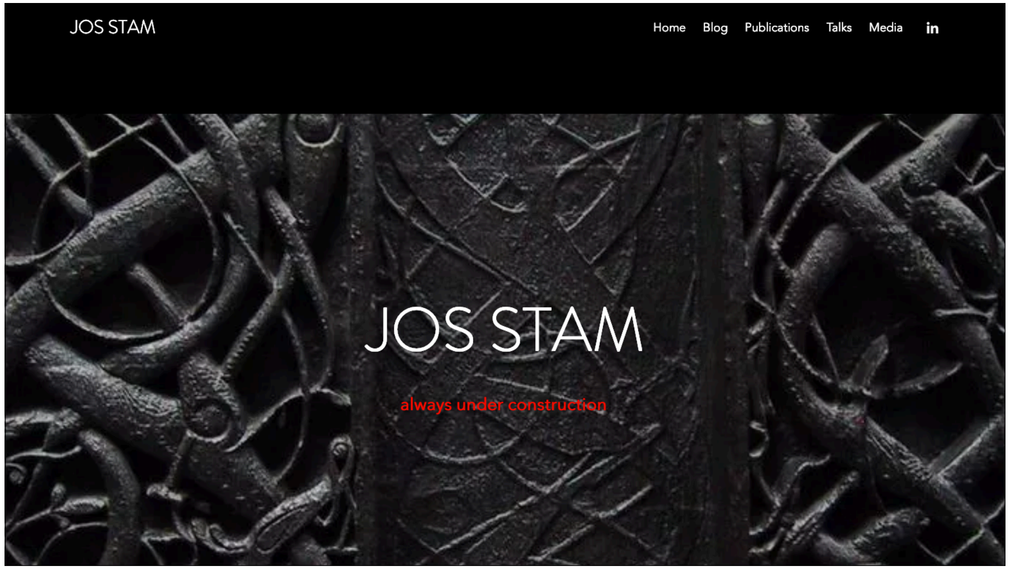


- Patches evaluated (left) - Curvature Plot (right)

A Personal Note

U. of T.

After Sibgrapi 2008



EXOTICA