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Jos Stam talks about Maya 8.5, nCloth, Nucleus, and waiting for planes in airports.

Jos Stam, Autodesk’s resident Principal Scientist, had three hours spare in a Paris airport after a plane home was delayed. With this time, he decided to nut out a problem that had been plaguing him for some time. He sat down with his laptop, a notepad and some brain cells, and invented yet another one of Maya’s new technologies, nCloth. I asked Jos to explain what led him to this epiphany in generating a new unified simulation framework.

“The construction and motion of cloth is a very difficult problem to solve,” begins Jos Stam. “I was thinking this over before that Paris trip. What bothered me was that at the time, most existing clot models relied on springs. Springs are great for stretchy, bouncy kinds of materials, but not for cloth as cloth doesn't stretch much at all.”

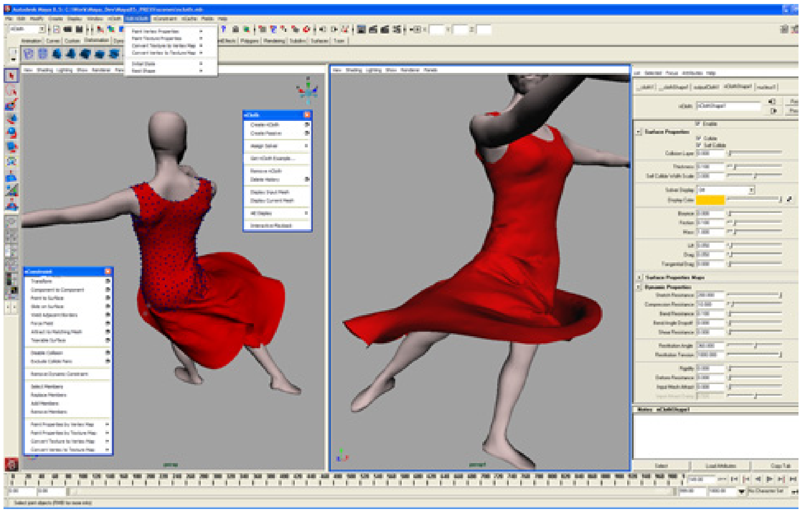
« At SIGGRAPH 2005, Stam was presented with the 2005 Computer Graphics Achievement Award by the Academy of Motion Picture Arts and Sciences.

There were two standard mathematical ways to deal with the problem facing Stam. The first one uses something called ‘explicit integration’. The time step of the simulation could simply be reduced to handle the high frequency oscillations of the springs. The result is slow simulations and small vibrations of the cloth.

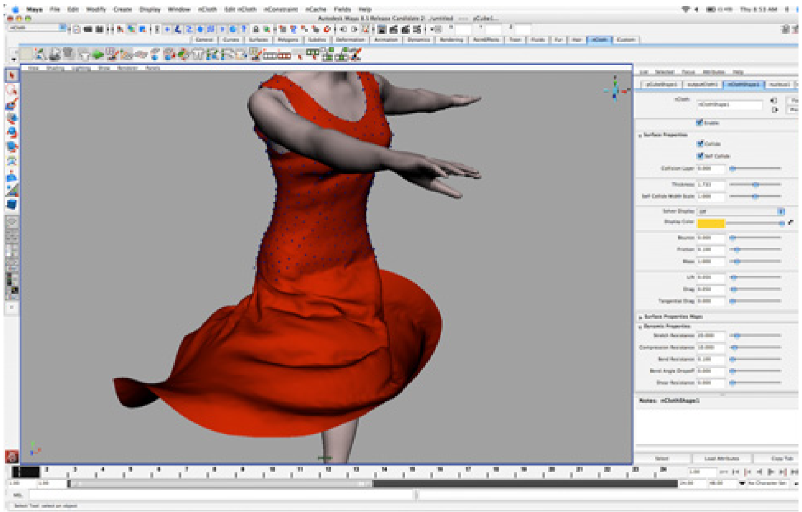
Another alternative is to aggressively dampen the springs. This is the equivalent to an ‘implicit integration’ scheme. “However, that usually results in simulations that lack liveliness,” Stam explains. “My idea was to turn this on its head and go in the opposite direction, creating a solution by replacing the springs with rigid links and then softening them if any stretch is desired. When I was stuck at the airport in Paris, I finally decided to implement this idea.

Usually I code things in 2D first, where cloth exists as a rope. So by analogy, a one-dimensional rope is a 'cloth' in two-dimensional space. Working in 2D when creating prototypes is advantageous because things are easier to visualize, making the simulations more efficient.

So that is what I wrote at the airport – a simple simulation of ropes with hard links. The problem was really as simple as weaving the code, like wool into a jumper, that I think is easier to understand when you consider my analogy of how I solve 3D cloth simulations in 2D space first."



Multiple solvers can influence each other» bi-directionally and use the same forces and constraints. Ultimately, simulations for cloth, hair, rigid bodies, and particles will all be able to interact seamlessly for maximum believability and control.

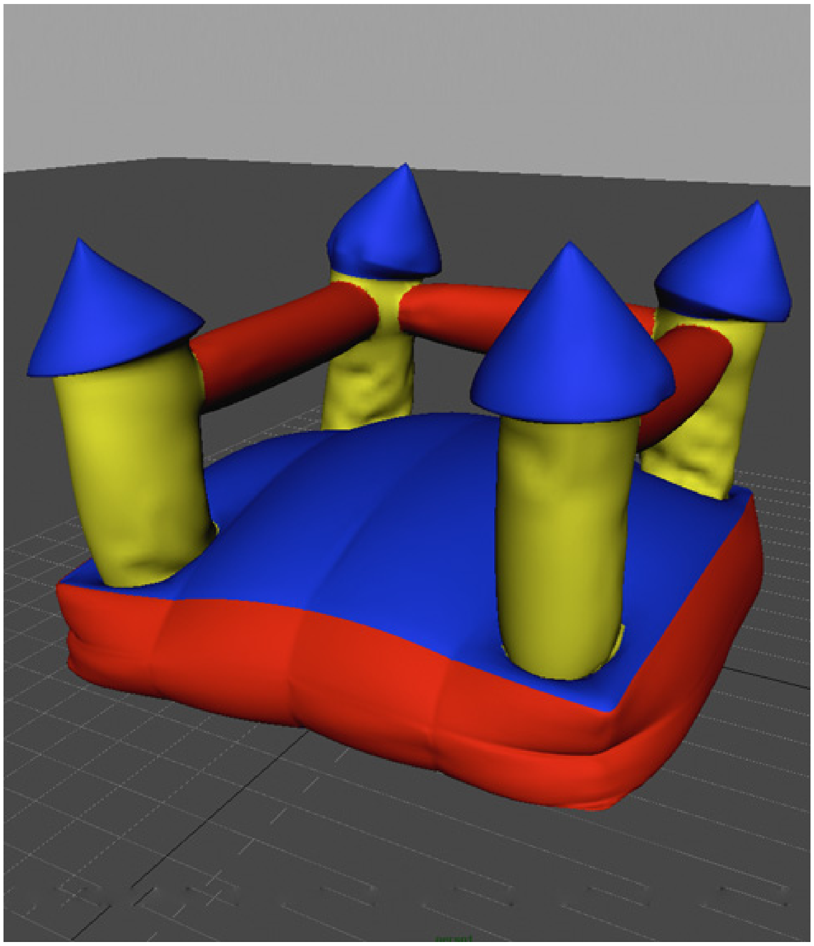


Jos Stam says one of the key insights behind Maya Nucleus is that it doesn't really matter whether you are solving for ropes, cloths, liquids or solids. "Basically, you are solving for a set of particles with constraints between them. In the case of stretch, we want to preserve the distance between certain points of the particle system. It doesn't matter whether they are part of a rope or a cloth. Underneath the hood, al you have is a list of pairs of particles and their desired separation length."

Key Concept
The key concept of the Maya Nucleus unified simulation framework is that the interaction of different elements can be represented by a fairly simple computational model, which is based on interacting particles. The heart of the framework treats the interaction of all elements as a system of particles that collide and exert forces on each other. The complex behaviors of dynamic elements like cloth, hair and water emerge from these simple rules

Collisions
Collisions with objects and self-collisions are anothe reason why cloth simulation is a hard problem to solve. In fact, collisions can be treated as constraints just like stretch. For example, the points of a piece of cloth should never be inside the surface of a colliding object, which becomes a constraint on the particle system. Stam tackled this problem wher Alias was encouraging him to write a cloth solver.

« Cloth is inherently hard to model because it is a strongl self-affecting system; self-collisions fight with stretching bending, shear and collisions with other objects such as



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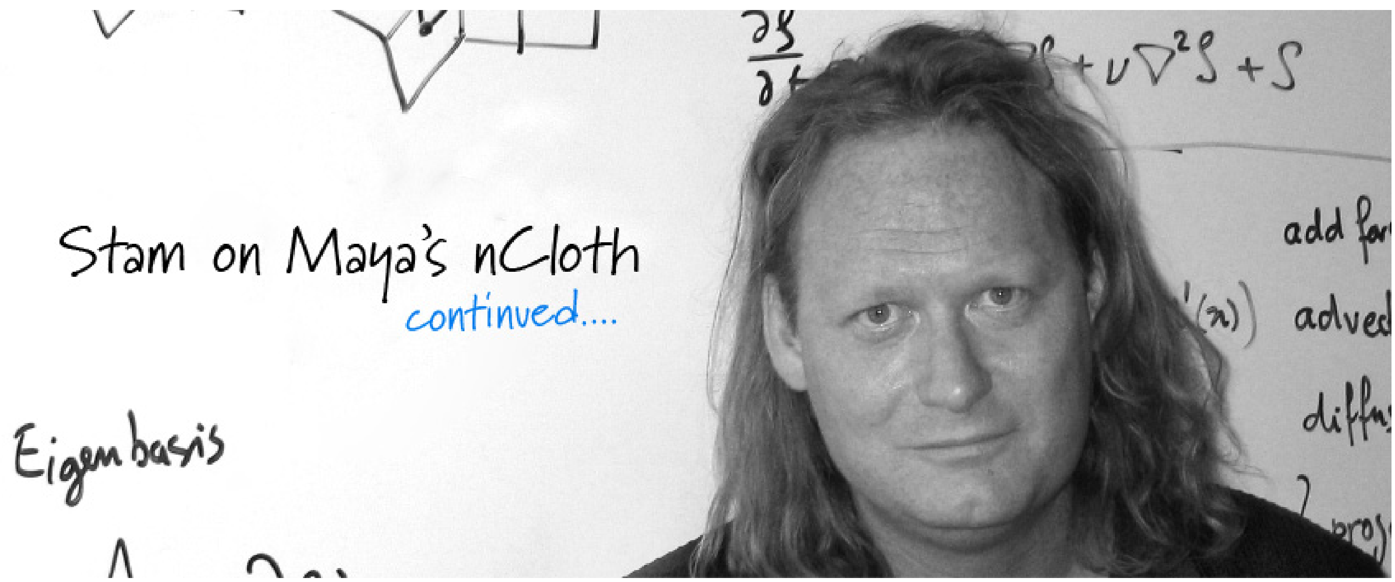


Another challenge was the collision handling of fast moving objects. A lot of previous techniques simply pushed cloth vertices out of a colliding object. But that didn't always work for the Maya team.

For example, imagine a fast bullet crossing a piece of cloth in one simulation step: the bullet will be in a valid state at the beginning and the end of the simulation step. The right approach is to consider what happens in space-time, which is four-dimensional. This is the approach Jos Stam took in Maya Nucleus.

Stable
What is cool about Maya nCloth is that it is quite stable. Nucleus creates the simulations via an iterative process. This process allows the simulation to recover if a failure occurs by iterating from the point just previous to the failure and then restarting the simulation. The key concept behind this is that we always maintai the previous positions of the particles and solve for the new velocities until all the constraints such as stretch, bending and collisions are satisfied.

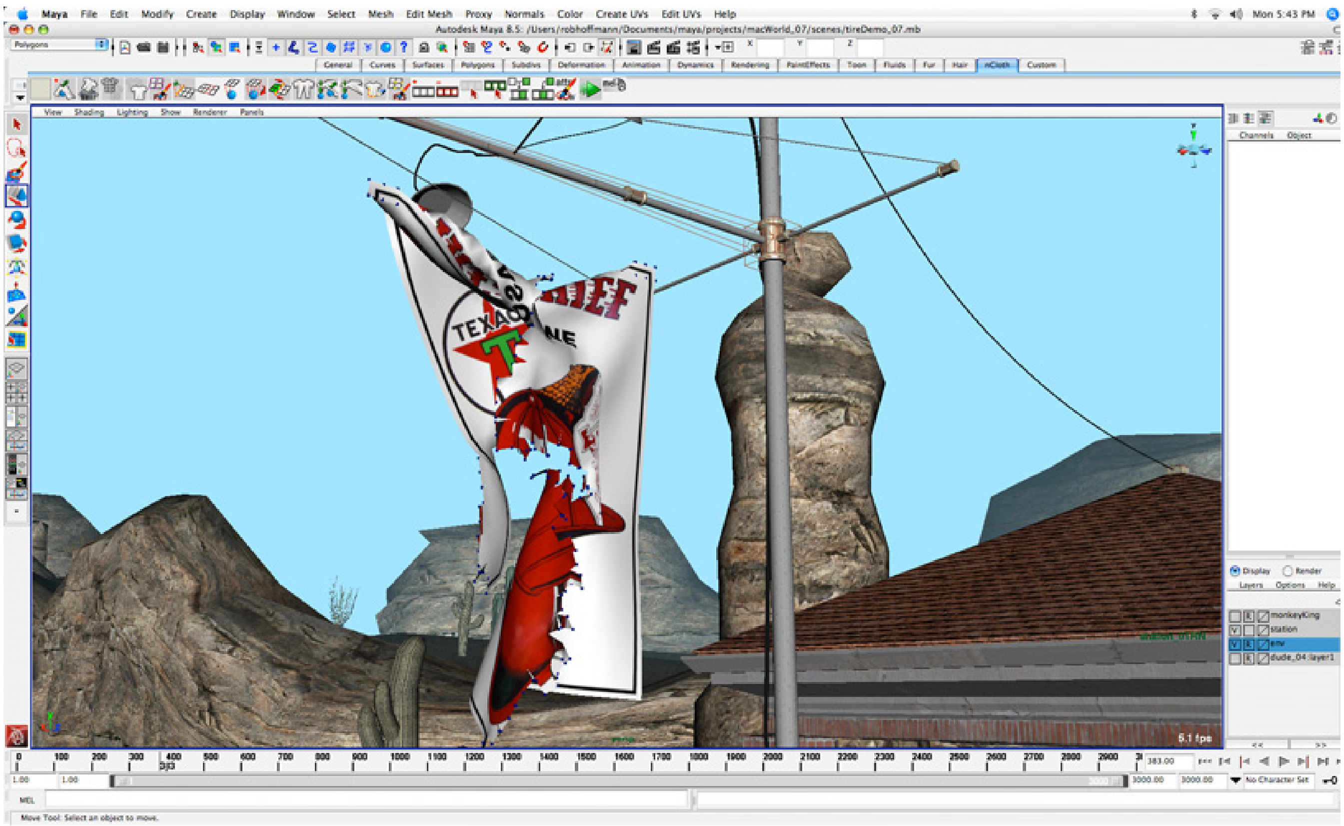
"Yet again, this approach is not restricted to cloth," he explains. "With Maya Nucleus, we resolve collisions between points, edges and triangles in space-time. More precisely, we add some thickness to these primitives, so we end up with spheres, thick edges and thick triangles.

So liquid particles can collide with cloth triangles and rope edges. The core collision code can manage a mix of these primitives without focusing on whether they are liquids, ropes, or cloths."

(below) Cloth is inherently hard to model because it is a strongly self-affecting system; self-collisions fight with stretching, bending, shear and collisions with other objects such as an animated character.

Of course, is not always possible. In these situations, Maya Nucleus will return the best possible velocities. Once that is done, the new positions are computed by adding the velocity to the old positions.
The problem of directing the motion of the cloth is an important on in production. In Maya nCloth animators can guide the motion of the cloth using an attracting mesh.

At every time-step the cloth simulation takes into account all othe factors such as stretch and collisions, but also tries to remain close to the attracting mesh. The amount to which it is attracted to the mesh can be controlled by the animator. Another way to contro the cloth movement and feel is through cache blending. Animators can cache different versions of the cloth simulation and then blenc between them.



Air pressure
The air pressure; wind, air thickness and speed are also part of Jos Stam's research. The work was developed with Duncan Brinsmead also on the Maya Nucleus team. He first suggested that they add these functions to Maya Nucleus. Jos Stam then worked out the math and coded it. "We developed a model for lift and drag for the cloth responding to a wind field," Stam explains.

"What is cool is that we can get very interesting behavior such as ripples without the need to model the air accurately. Even a simple directional wind field model will produce interesting flapping behavior because the drag and lift constraints are fighting the stretch constraint. We also added a simple volume conservation model to the cloth. Referencing back to the law of gases, we recall that pressure is inversely related to the volume of the mesh. Through this model we can simulate air bags, balloons and even simple parachutes." Maya Nucleus is a standalone library that was almost completely implemented by Stam and is independent of an product. "It is a core library with an API, which is mostly geared towards Maya," explains Stam. "But in principle it could potentially be used in many other products."

Autodesk encourages research and the pursuit of new ideas like the ones that led to Maya Nucleus and Maya nCloth. "In fact," says Stam, "the whole Maya Nucleus project was a pretty ambitious and risky project to productize. Indeed, I am enjoying my work very much. Even though this work started out when I was still part of Alias, Autodesk has really embraced Alias spirit and keeps a sharp eye on innovation."

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