A position-based dynamics system for animated character effects

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Figure 1: *(left) Typical animated scene containing multiple simulated elements including hair, cloth, cargo nets and ropes; (right) complex garment model for the character Stoick that mixes cloth, armor, leather, and even his beard in a single interacting cloth model that executes in 0.3 secs per frame on an artist desktop.*

During production of *How To Train Your Dragon 2* we were motivated to improve our technology for character effects such as ropes, chains and cloth. Our goal was to reduce artist iteration time for simulation work while retaining the flexibility required for art direction. Inspired by the success of position-based dynamics in games, we implemented a new simulation pipeline for deformable solids based on a fast, stable simulation engine that has delivered significant improvements.

Simulation

Position-based dynamics is attractive because it produces algorithms that are fast, unconditionally stable, and controllable. The technology is well established in games, virtual reality and special effects where it is used extensively for rigid body dynamics [Bender et al. 2013]. However, position-based solvers are not widely used in film production for deformable solids, and there is little in the literature to indicate the challenges in adopting these methods for feature animation. In this talk we introduce a system based on the *Carbon* dynamics library with novel features for performance, setup flexibility, art directability and control.

Performance is addressed by using parallel nested collision detection that enables aggressive multicore scaling. Parallelism is implemented using Intel Threading Building Blocks. The algorithm is based on order-deterministic dynamic task splitting and recycling. We process collision detection for the entire scene by starting from the broad phase and nesting the narrow phase and contact generation. We show that this approach generates excellent scaling for typical workloads on up to 16 cores.

Setup flexibility is addressed by solving a single heterogeneous system for the interaction of all soft and rigid bodies. Collision constraints and joint constraints between dynamic or kinematic, rigid or deformable objects are handled within a single solver. All object collisions can be modeled using a common set of geometric primitives: points, edges, and single or double sided faces. All primitives may have a user-specified thickness. Faces can be arranged with no requirements for convex decomposition. This heterogeneous systems supports complex cloth models, e.g. mixed soft and rigid bodies for garments that combine elements like cotton and leather that interact within a single simulation.

Art direction for motion is supported via animated position constraints that drive a simulation towards an animated goal shape, while respecting other constraints such as collision surfaces. Artists may also animate the rest shape of a model in order to control effects such as squash and stretch, which require the simulation to adapt to non-physical changes. We deal with pinching, another form of non-physical input, by allowing the character body to be represented internally as another deformable cloth surface. This allows the solver to avoid pinching in areas such as arm-body interaction and produce clean simulation results.

Cargo Nets to Complex Cloth

We demonstrate the performance and output of the system on effects of the type shown in Figure 1. Objects such as the cargo nets and ropes are quick to set up and get a first simulation pass. The cargo net model has 122k degrees of freedom. The simulation required only 10 min set up time between reading the model and the first simulation pass, and iterations took a mere 46 secs for a 156 frame shot on an artist desktop.

The cloth model for Stoick is considerably more complex, consisting of 18 interacting layers, 7 collision meshes, and 85k faces partitioned into areas representing a cloth tunic, cape, leather armor, a large leather belt, and even his braided beard which interacts with his chest and the rest of his clothing. This model executes in 0.3 seconds per frame, an improvement of 60× over our previous simulation technology.

References

Bender, J., Muller, M., Otaduy, M., and Teschner, M. 2013. Position-based dynamics methods for the simulation of solid objects in computer graphics. In *Eurographics 2013 State of the Art Report*, Girona, Spain.