Haptesha: A Collaborative Multi-User Haptic Workspace

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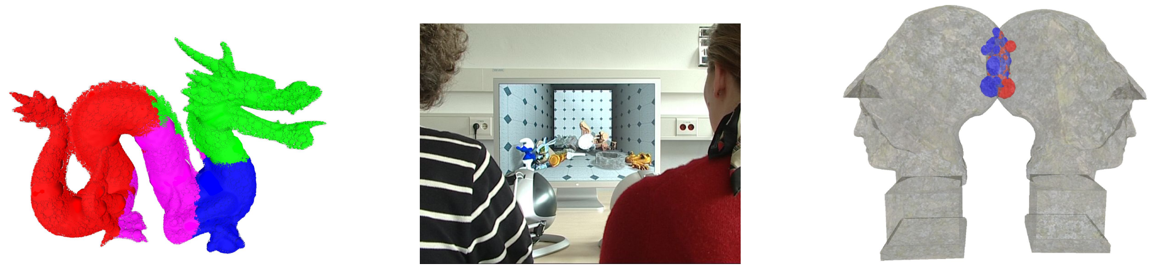

Figure 1: *The collision detection in our haptic workspace is based on sphere packings in arbitrary polygonal objects (left). In the accompanying video you can see our haptic workspace set up for two users and four haptic devices. The scene contains more than 20 objects and a total polygon count of 3 millions running on a simple consumer PC with an Intel Core 2 Duo E6700. The haptic devices allow only three DOFs, but the architecture of our workspace supports full six DOF force rendering (middle). The* penetration volume *defines a novel measure for contact information (right).*

1 Introduction

Haptic is an essential and emerging technology and it can help to improve human-computer as well as, in multi-user scenarios, human-human interactions in many fields like industrial applications, entertainment, education, medicine and arts.

We present a haptic workspace that allows high fidelity two-handed multi-user interactions in scenarios containing a large number of dynamically simulated rigid objects and a polygon count that is only limited by the capabilities of the graphics card.

The main challenge when doing haptic rendering is the extremely high frequency that is required: While the temporal resolution of the human eye is limited to approximately 30 Hz, the bandwidth of the human tactile system is about 1000 Hz. In most haptic scenarios, the computational bottleneck remains the collision detection, whereas the force computation can be done relatively fast.

Thus, the heart of our haptic workspace is our new geometric data structure, called *Inner Sphere Trees (ISTs)*, that not only allows us to detect collisions between pairs of massive objects at haptic rates but also enables us to define a novel type of contact information that guarantees *stable* forces and torques.

2 Inner Sphere Trees

The main idea of the ISTs is that we do not build an (outer) hierarchy based on the polygons on the boundary of an object, like most other BVHs do, but we fill the interior of the model with a set of *non-overlapping* spheres that cover the object's volume densely.

On top of these inner BVs, we create a hierarchy in order to accelerate the collision detection queries. This enables us to define a novel extent of intersection, the *penetration volume*. The penetration volume corresponds to the amount of water being displaced by the overlapping parts of the objects and, thus, leads to a physically motivated and *continuous* penalty force.

Our ISTs and, consequently, the collision detection algorithm are independent of the geometry complexity. Moreover, they support all kinds of object representations, e.g. polygon meshes or NURBS surfaces, whereas their memory consumption is very modest.

For further informations we refer the interested reader to [Weller and Zachmann 2009a] and [Weller and Zachmann 2009b].

3 Conclusions and Future Work

This collision detection scheme together with a novel penalty force approach that is based on the penetration volume, enable us to treat physically based simulation and haptic rendering in a common way. The only difference between dynamic objects and user controlled objects is, that the forces for the latter are rendered to the haptic device instead of using them for the simulation. This allows us to set up our multi-user haptic workspace with support for a large number of haptic devices and a likewise number of dynamic objects with a high polygon count.

However, there are still some challenges left for the future: Until now, our workspace is restricted to watertight objects. We plan to extend our algorithms so that they are also able to handle arbitrary objects, including thin sheets and open geometries. Finally, a challenging task would be to extend our approach also to deformable objects.

References

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