On Accurate Modeling of Contact States in Real Time

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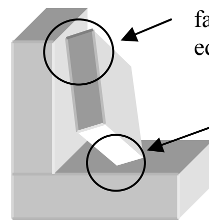
Information of contact state topology, geometry, and physics among objects and motion constrained by contacts is fundamental to many applications, ranging from real world robotic operations, to simulation of motion involving contact in a virtual world, and to haptic interaction with a virtual world. While for certain tasks, partial or approximate model of contact is sufficient, for tasks such as robotic assembly, virtual prototyping, planning for assembly, and telerobotics operations augmented and guided by virtual manipulation, topologically, geometrically and physically accurate model of contact states is required.

A high-level contact state as opposed to a low-level contact configuration captures the geometrical and physical constraints of contact often shared by two or more contact configurations. A natural and thus most common way of representing such a contact state between two objects *A* and *B* is in terms of a set of *contact primitives*, where each contact primitive is defined by a pair of contacting topological surface elements (i.e., faces, edges, and vertices) of *A* and *B* respectively.

However, when a collision between *A* and *B* is detected, how to identify the corresponding contact state correctly or accurately is not a trivial problem both in real world (due to uncertainty) and in virtual environments (due to digital errors). The following figure shows a simple example, where for each contact region (indicated by a circle), there is more than one possible contact primitive, but *not all* combinations of possible contact primitives from the two contact regions respectively form valid contact states. In virtual environments, how accurate is the identified information of geometric contact state directly affects the accuracy and correctness of the physical model of contact (i.e., contact force and moment).



In dynamic simulation, there is a rich literature on computing physically accurate contact forces and moments together with contact geometry, but the computation costs are usually too high to yield real-time results, especially for complex contact states and in the presence of friction. On the other hand, real-time performance is essential to tasks requiring real-time human interaction with virtual environments, such as haptic interaction, augmented reality involving manipulation, and teleoperations.

In this presentation, we introduce our work on accurate identification of contact states between non-convex polyhedral objects in virtual environments as well as physically accurate modeling of the corresponding contact forces and moments for haptic rendering, all in real-time. The physical model of contact takes into account compliant motion, friction and gravity. Key to the accuracy and real-time efficiency of our approach is utilizing the knowledge of valid contact states from automatically generated contact state graphs based on our prior work.

Main areas of future research include extending our current work to non-polyhedral objects, articulated objects, and deformable objects. How to achieve both accuracy and real-time performance in modeling complex contact states (i.e., those involving multiple contact primitives) between more complex objects continues to be a major research challenge.