Contact interaction

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Many research fields are concerned with contacts between objects or between a human and an object. As a first generality, one can say that contact makes the distinction between existence or absence of short distance physical interaction. Furthermore, the notion of contact means a short distance interaction between two physical entities. Short distance means a distance converging to zero between the contours of each bodies. It is not a trivial concept as it implicitly addresses the ranges of spatial scales of the underlying physical phenomena.

When the two interacting bodies are real physical bodies, such interaction corresponds to a trivial one, occurring at every minute of everyday life. In the range of macroscopic physics, interaction contacts are directly correlated to the impossibility for to objects to occupy the same spatial place. Consequently, it is supported by non-penetration interactions such as collisions, more or less instantaneous or sticky.

Another important case is when robots are interacting with real physical objects. In this case, two main categories of issues have to be addressed: (1) the mechanical design of the interface between the robot and the manipulated object, including the choice of actuators and effectors, must lead to a suitable solution for proper interaction contacts; (2) the management of the robot's software for object manipulation, which, by means of control methods and theories, must lead to an efficient manipulation of the manipulated body.

When the two interacting bodies are virtual physical objects, the computer simulation can aim at rendering at the best the interaction contact behaviours, as they will occur in the real reference situation. Simulations are thus confronted to the main bottleneck of collision detection algorithms [→ Collision detection algorithm], as developed in real time computer graphics reality [Baraff, 1995], or in virtual reality [Salisbury et al., 2004].

When one of the two interacting bodies is real and the second virtual, the interaction contact between both necessarily requires haptic devices composed at least by sensors, eventually extended by actuators such as in tactile or force feedback devices. Consequently, it can be considered indeed that the haptic device plays the role of a medium between the human and the simulation "world" that is inside or behind the computer [Cadoz, 2004]: this is what has to be called a "mediated contact situation".

Historically, haptic science first focused on collision contacts with rigid simulated objects. One of the major challenges of haptics is still the simulation of very stiff contacts, such as when hitting a metal plate with a rigid object. Due to hardware limitations, both in low-level computer hardware and software and in the design of the haptic device itself, it is very difficult to obtain very stiff contacts in haptics. Another important technical limitation in haptics is the fact that, in most applications, the haptic interaction is only possible through punctual interaction. This means that the hand of the user interacts with simulated objects via a simple point.

From the user's point of view, the hardware and software limitations presented above constitute issues for user perception. It was shown that the discrimination of static stiffness is impossible above 1700 to 3200 N/m for manual perception, but that the discrimination of surface stiffness was still possible for higher values, much above the achievable stiffness values by haptics hardware [Lawrence et al., 1996].

Considering hardware limitations, several works have proposed workarounds as new techniques for improving the perception of hard contacts with current haptic hardware limitations. For examples, Lecuyer et al. have

proposed a technique to improve the perception of contacts when using an under-actuated haptic device in virtual reality [Lécuyer et al., 2005]. The technique was based on modifications of the viewpoint in the visual representation of the virtual scene depending on the orientation of the contact normal. [Kuchenbecker et al., 2005] worked on an evenemential "playing" of force profiles by a haptic device triggered by collision detection.

It would not be until recently that more focus was put on the simulation of surface properties. On the side of human perception, studies about the perception of textures and surfaces properties have begun in the late 90s, and currently more and more hardware designs try to propose new solution for the simulation of complex surface properties.

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