Toward virtual touch: investigating encounter-type haptics for perceived quality assessment in the automotive industry

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Keywords: Virtual reality, Haptics, Automotive industry

Introduction

In a Virtual Reality simulation, haptic devices allow tangible interaction with the virtual environment by providing a physical feedback to the user. Most of the devices usually have to be permanently held by the user and do not allow for touching virtual objects in a natural fashion. Yet, many applications require hand-free interaction. This is particularly the case with simulations that require tactile exploration of the physical properties of virtual objects such as car interior assessments. Encounter-type haptic devices (ETHD) allow such a hand-free interaction, but most of the current systems feature only a restricted workspace and low endpoint stiffness. We present here an early prototype of an ETHD designed to allow a user to touch and feel large and stiff virtual environments such as a car cockpit (see Figure 1).

Figure 1. Use of an ETHD to touch the material of a virtual seat.

Motivation

In the automotive industry, perceived quality and sensory studies experts are in charge of identifying and choosing relevant materials and shapes associations to ensure the coherence and homogeneity of a whole project from a perceptual point of view [1]. These evaluations highly rely on 1) vision and 2) touch modalities [2].

Today, early material selection starts on a panel of 50 samples, uncorrelated to the vehicle shape. Very soon though, physical mock-ups are required to further investigate materials and shape associations. During the life cycle of a vehicle project, up to 5 or 6 high-fidelity physical mock-ups are required to take into account every evolution of the project. Yet, such high-fidelity physical mock-ups are extremely expensive to produce. In addition, any modification is a time consuming and expensive task and thus tends to be limited.

Digital mock-ups do not suffer from these drawbacks. They are easier, cheaper and faster to produce, and benefit from digital flexibility. Modifications on digital mock-ups are much easier and much faster to perform, allowing the exploration of much more hypotheses than traditional physical mock-ups do. In the case of perceived quality, this means being able to assess much more possible combinations of shapes and materials, and explore new trends in almost no time. Nevertheless, the requirements on the digital mock-up fidelity for sensory analyses are very high. While current immersive visualization systems can provide a satisfying level of realism, touch simulation remains significantly harder. Despite recent technical and scientific advances in touch simulation, high fidelity tactile simulation still remains very challenging and does not currently meet the requirements for sensory studies.

Therefore, touching real materials are still required for perceived quality assessments. That is why we investigated on encounter-type haptics, which combine both the flexibility of programmable active haptic devices and the inherent ability of passive haptics [3] to provide both high fidelity tactile and kinaesthetic feedback.

Related work

The concept of encounter-type haptics was first described by Bill McNeely [4]. Such devices rely on a mobile physical prop - usually actuated by a robot - that constantly track the user hand and encounter it only when needed, e.g. to simulate a contact between the user and the virtual environment.

More recently, possibly due to the advances in HMD technologies, ETHD have gained a lot of research efforts. For example, [5] and [6] demonstrated systems able to render surface characteristics including texture, position and temperature. They use a robotic arm that can be fitted with a variety of endpoints with different surface textures on each side. Depending of the user hand position, the surface with the appropriate material is oriented towards the user and aligned with the virtual object, so the user can feel different surface characteristics of virtual objects.

Design of a novel encounter-type haptic device

Nevertheless, none of these systems meets the requirements of the application described above, both in terms of stiffness and workspace. We thus have started the development of an encounter-type haptic device compatible with the requirements of a car cockpit review. This includes 1) a high stiffness end effector to be able to integrate a set of real rigid materials, 2) a large workspace to allow physical interaction all around a seated user 3) a fast moving robot to prevent to user to wait for the robot to reach the anticipated contact point and 4) all of this has to be performed with the user safety in mind.

From a hardware point of view, we chose to use a 6DoF UR5 robotic arm from Universal Robots [7]. It features a reach radius of 850mm, a 5kg payload and a $1 m.s^{-1}$ maximum velocity. Most importantly, UR5 is an industrial cobot, which ensures user integrity at any time. Its endpoint is shaped as a half dodecahedron featuring 6 similar area surfaces. The haptic rendering algorithm computes in real-time the closest triangle to the user hand, and sets the endpoint target according to the normal of the triangle and the desired synthesized material. Robot control is achieved through the Universal Robots API.

Conclusion and future work

We have developed an early prototype of a new ETHD able to meet the requirements of a car cockpit review. Though only an early prototype, the system has already been successfully demonstrated during the DSC2017 conference[1] where it received particularly encouraging feedbacks. The prototype will be soon transferred to Renault Technocentre for an evaluation period among different work teams. The development of the prototype emphasized scientific and technological locks that need to be addressed before deploying such systems, including path-planning, finger tracking, specific interaction techniques and user tracking.

Ultimately, such a system has the potential to formalize sensory studies processes carried on digital mock-ups for subjective assessments of shapes and materials in a car cockpit.

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