FlexTorque: Innovative Haptic Interface for Realistic Physical Interaction in Virtual Reality

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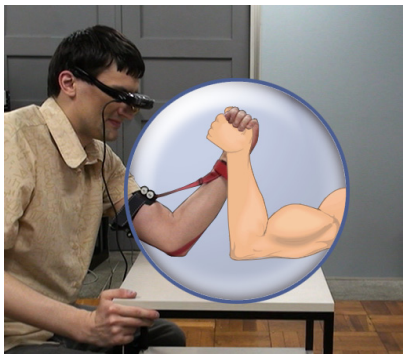

Figure 1: Augmented Arm Wrestling

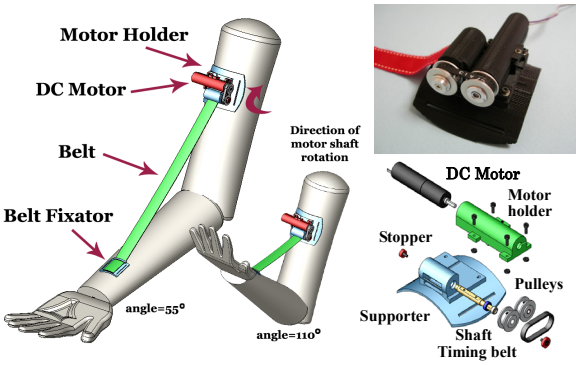

Figure 2: FlexTorque haptic display

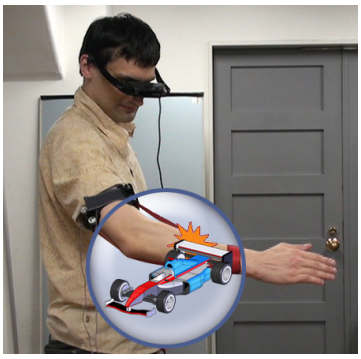

Figure 3: Augmented collision

1 Introduction

In order to realize haptic interaction (e.g., holding, pushing, and contacting the object) in virtual environment and mediated haptic communication with human beings (e.g., handshaking), the force feedback is required. Recently there has been a substantial need and interest in haptic displays, which can provide realistic and high fidelity physical interaction in virtual environment. The aim of our research is to implement a wearable haptic display for presentation of realistic feedback (kinesthetic stimulus) to the human arm. We developed a wearable device FlexTorque that induces forces to the human arm and does not require holding any additional haptic interfaces in the human hand. It is completely new technology for Virtual Reality that allows user to explore surroundings freely. The concept of Karate (empty hand) Haptics proposed by us is opposite to conventional interfaces (e.g., Wii Remote, SensAble's PHANTOM, SPIDAR [Murayama et al. 2004]) that require holding haptic interface in the hand, restricting thus the motion of the fingers in midair.

2 Principle and Technologies

The idea behind the novel torque display FlexTorque is to reproduce human muscle structure, which allows us to perform dexterous manipulation and safe interaction with environment in daily life. When we hold a heavy object in a palm, its weight produces torques in the wrist, elbow, and shoulder joint. Each muscle generates a torque at a joint that is the product of its contractile force and its moment arm at that joint to balance gravity force, as well as inertial forces, and contact forces. The muscle with tendon in series acts like a rope pulling on a lever.

The structure of the developed torque display FlexTorque is presented in Fig. 2. FlexTorque is made up of two DC motors (muscles) fixedly mounted into plastic Motor holder unit, Belts (tendons), and two Belt fixators. The operation principle of the haptic interface is as follows. When DC motor is activated, it pulls the belt and produces force generating the flexor torque T_{flex}. The oppositely placed DC motor generates the extensor torque T_{ext}. Therefore, the couple of antagonistic actuators produces a net torque at the user elbow joint $T_{net} = T_{flex} - T_{ext}$.

The essential advantage of the structure of FlexTorque device is that heaviest elements (DC motors, shafts, and pulleys) are located on the part of upper arm, which is nearest to the shoulder. Therefore, user's arm undergoes very small additional loading. The rest of components (belts, belt fixators) are light in weight and do not load the human muscles considerably. Each unit is compact and light in weight (60 grams). This was achieved due to the use of plastic and duralumin materials in manufacturing the main components. The Supporter surface has concave profile to match the curvature of human arm surface.

3. Applications

The main features of FlexTorque are: (1) it presents high fidelity kinesthetic sensation to the user according to the interactive forces; (2) it does not restrict the motion of the human arm; (3) it has wearable design; and (4) it is extremely safe in operation. These advantages allow a wide range of applications in virtual and augmented reality systems and introduce a new way of game playing. A number of games for sport experiences, which provide a natural, realistic, and intuitive feeling of immersion into virtual environment, can be implemented. The Arm Wrestling game that mimics the real physical experience is currently under development (Fig. 1). The user wearing FlexTorque and Head mounted display (HMD) can play either with a virtual character or a remote friend for more personal experience. The motion of the arm and exerted force are detected by the sensors. The virtual representation of players' arms are shown on the HMD. While playing against a friend, user sees the motion of arms and experiences the reaction force from rival.

The contact and collision with virtual object can be presented through FlexTorque as well (Fig. 3). In case of contact or collision, the net torque produced by the haptic display restrains the further movement of the user's arm. The vibration of the human arm (e.g., simulation of driving a heavy truck) can be realized through alternate repeatable jerks of torque of antagonistic motors. Thus, operator can perceive the roughness of a road surface.

References

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