Drone Based Kinesthetic Haptic Interface for Virtual Reality Applications

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Abstract. A drone is capable of actively generating kinetic energy and can apply force in a required direction. If a drone can interact physically with a user in a well-controlled manner, it can effectively become a haptic force feedback device. In this demonstration we will highlight the capabilities of a drone based haptic device through a bouncing ball application. Here the user can play with a virtual ball and the drone renders the impact force of the ball on the user's hand. For the scope of this demonstration during free fall, the ball is assumed in ideal 1D motion and only the force of gravity acts on the ball. The ground impact is calculated for an immovable surface and the rebound force is based on the energy conservation factor.

Keywords: Haptic interfaces · Encountered-type · Drone · Kinesthetic · Virtual reality

1 Introduction

Many conventional haptic interfaces are always tethered, either to a surface i.e. grounded or to the user i.e. ungrounded, to exert force. In case of grounded devices, the workspace is fixed and limited in space due to the mechanical restrictions of the device. Ungrounded haptic devices are connected directly to the user's body and use it for reaction support. However, this means only the "relative-force" between different parts of the body can be harnessed and passive haptic feedback is present from wearing/holding the interface. The usability of the device is remarkably decreased in both cases. To transcend the above-mentioned limitations, these design goals have to be realized:

1. The device should not be connected to the user or grounded, thus removing the need for user augmentation and mobility limitations.

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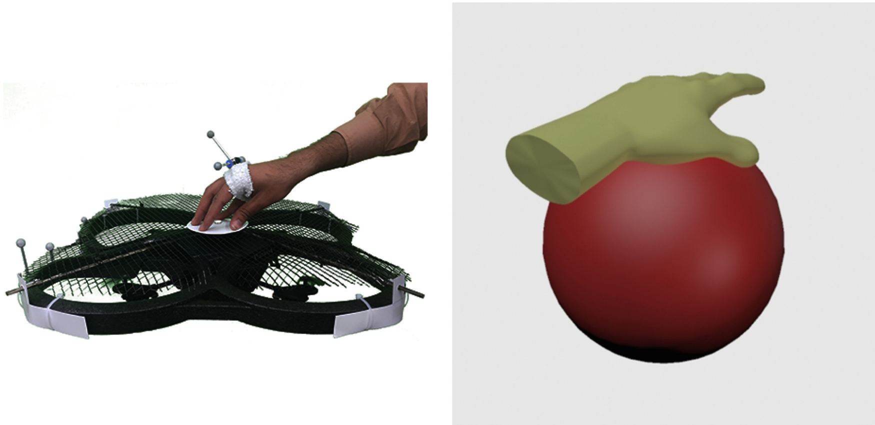
2. It maintains haptic transparency in the absence of contact with virtual objects, by providing an encounter type interaction.
3. The device can be capable of furnishing an unlimited workspace, so the user can interact with a VR or AR environment without any restrictions.

An ideal drone based haptic device can achieve these goals [1–5]. There are many benefits of this concept. Mainly the system is not required to be affixed elsewhere to provide grounded-force. If the user and the drone can be tracked together, the system can provide an encountered-type interface by becoming a suitable end effector. This means it will only be coupled to the subject's hand when required and can produce absolute transparency. Since the drone is untethered, there is the possibility to create an infinite workspace, potentially increasing the usability of the system.



(a) The user feeling the impact force of the virtual ball, rendered in the upwards the user.

(b) The virtual environment as seen by direction by the drone.

Fig. 1. The bouncing ball applications is developed by utilizing the force feedback from the device.

2 Implementation

The AR Drone 2.0 from Parrot is used in this application. The upwards motion is utilized to develop force in the respective direction. Equations developed in [1] are employed to control the force output of the drone. A safety cover designed from aluminum mesh protects the user during the interaction. The user wears an Oculus Rift headset to experience the virtual reality application. The HMD, drone and the participant's hand is tracked using the Optitrack V120 Trio motion capture system. The virtual environment is created using Unity 3D.

3 Demonstration

The demonstration explores the capabilities of a drone based haptic device. The basic concept of the bouncing ball application is shown in Fig. 1. The user is told to gently push the ball, this initiates the simulation. In the virtual environment the user can see the ball fall, hit the ground and rebound. In the real world the drone assumes a slightly lower position, waiting for the rebound phase of the simulation. Near the end of the rebound phase, the drone approaches the users hand and applies an instantaneous force based on a physics model. As the simulation ends, the drone again returns to its lower position while the ball falls away. The user may reset the simulation by touching a virtual button.

Variables such as energy conservation on ground impact, mass of the ball and value of gravity can be customized to create a unique simulation. These variables can be used to create a variety of different balls and even balloons. The bouncing ball model is a classic example of physics and is taught in many high school and undergraduate classes. By placing a force sensor on the drone, we can even measure and adjust the simulation based on the user's force.

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