Mobile Haptic Interface for Large Immersive Virtual Environments: PoMHI v0.5

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ABSTRACT

We present initial results of research toward a novel Mobile Haptic Interface (MHI) that provides an unlimited haptic workspace in large immersive virtual environments. The MHI is featured with omni-directional mobility, a collision-free motion planning algorithm, and force feedback for general environment models.

Author Keywords

Mobile haptic interface, omni-directional wheel, mobile robot, haptic rendering

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces—Haptic I/O

INTRODUCTION

A force-feedback haptic interface has an inherent limit on its workspaces and cannot render virtual objects larger than the workspace. A promising solution for this problem is a Mobile Haptic Interface (MHI) that refers to a force-feedback haptic interface with a mobile base [1][2][3]. The mobile base can move the haptic interface to wherever needed to render large virtual objects, providing an unlimited workspace. The MHI is especially suitable for large immersive virtual environments such as the CAVE™.

In this paper, we present an initial version of POSTECH Mobile Haptic Interface (PoMHI) especially designed to be used in large virtual environments such as the CAVE™. PoMHI V0.5 has omni-directional mobility, a collision-free motion planning algorithm, and haptic rendering capability for general virtual environment models.

SYSTEM ARCHITECTURE

The overall system architecture is shown in Figure 1. The PoMHI communicates with the IS-900 Tracking System (InterSense Inc., USA) to track its configuration (position and orientation). The user wears a head mounted display (HMD) for visual display the configuration of which is also measured using the tracking system. Based on the user's configuration, the laptop inside the PoMHI determines the appropriate configuration of the mobile base and controls it appropriately. Graphic and haptic rendering modules are also managed by the laptop. Communication and rendering update rates are specified in the figure.

HARDWARE

The hardware structure of the PoMHI is shown in Figure 2 that shows four main parts: omni-directional wheels and geared DC motors, a DSP control board and power amplifiers, a laptop, and a desktop 3 DoF haptic interface (PHANToM Premium 1.5A; SensAble inc., USA). In this configuration, the mobile base and the PHANToM are responsible for moving the whole PoMHI to face the user and for providing appropriate force feedback to the user, respectively.

The PoMHI uses three omni-directional wheels for holonomic motion of the mobile base, which is more adequate than a bidirectional mobile robot. The mobile base is controlled by desired linear and angular velocities at each control loop. Running rate of the loop is set to 50 Hz. Once a desired trajectory of the mobile base is determined from the motion planning algorithm (will be explained shortly), the desired velocity of each wheel is calculated based on the

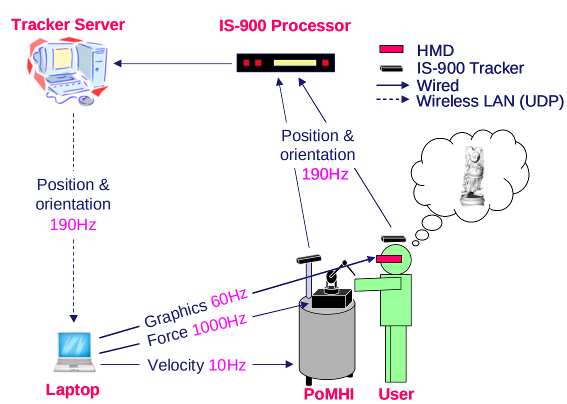

Figure 1. Architecture of the PoMHI.

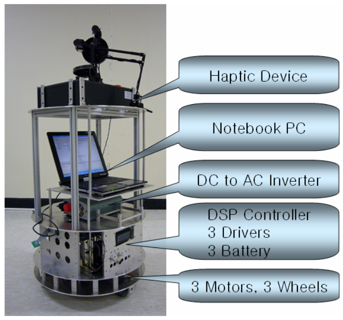

Figure 2. Hardware structure of the PoMHI.

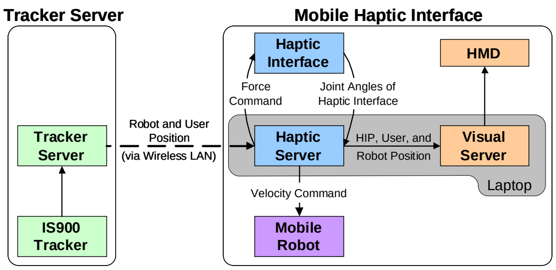

Figure 3. Software structure of the PoMHI.

kinematics of the base. Using these velocities, the mobile robot is controlled under velocity control. An exponential filter is adapted to the velocity calculation. The motors are controlled by the PID control.

SOFTWARE

The overall structure of software modules and their information flows are summarized in Figure 3. The software maintains a general virtual environment model that can consists of a large number of virtual objects. Given the current configurations of the mobile base and virtual objects, our software first determines where to move the mobile base using a heuristic motion planning algorithm. The algorithm is designed to avoid collisions between the mobile base and the user and to place the haptic device in a proper position for force feedback. For this, we use the typical 3D configuration space where the three dimensions correspond to the 2D position and orientation of the mobile base, respectively.

Another important component is a haptic rendering algorithm considering the effect of mobile base dynamics. At present, the mobile base is position-controlled. If the position control is perfect, this means that the inertia of the mobile base approaches to infinity. This allows the effect of the mobile base dynamics on the force perceived by the user to be neglected [1]. Our current force rendering algorithm utilizes this fact and resorts on the static torque-force relationship of the desktop haptic interface. We also confirmed through an experiment using a force sensor that the mobile base dynamics does not significantly affect the final force delivered to the user.

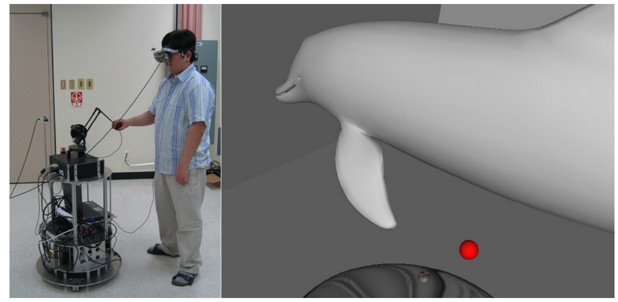

Figure 4. A user is touching a virtual dolphin using the PoMHI. The right figure shows the visual scenes displayed to the user via the HMD. The red sphere represents the current position of the haptic tool.

DEMONSTRATION

Figure 4 shows an example where the user interacts with a virtual dolphin using the PoMHI. The user wears a HMD (left figure) and sees the virtual dolphin in the right figure where the haptic tool position is represented with the red sphere. The circular object in the bottom is a part of the top plate of visually expressed PoMHI (i.e., a polygon model of the PoMHI). The user can explore the large virtual environment with realistic force feedback with the PoMHI.

CURRENT WORK

We are currently working on a next version of the PoMHI. This version has four omni-directional wheels with advanced design and a lift for the desktop haptic interface for the extension of its workspace in the height direction. We are also upgrading the software in terms of more sophisticated motion planning algorithm, more precise kinematics calibration, and force computation algorithm considering the effect of the mobile base dynamics. Once all of these are completed, we will integrate the PoMHI into the CAVE™ that is the most immersive large virtual environment.

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