Arrayed Air Jet Based Haptic Display: Implementing An Untethered Interface

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ABSTRACT
This paper presents the basic idea of an air pressure based force feedback interface and an initial implementation. The goal of this project is to realize an untethered human interface for virtual reality systems that never constrain the user’s activity. To achieve this goal, we implement a force feedback system that utilizes air jets. The first system used a single air jet to provide the sense of hitting a soft object. The latest system uses multiple air jets arranged in a matrix to express the surfaces of three-dimensional virtual objects. This paper also introduces an application that supports two hand operation. By eliminating tethers, which bother users, VR technologies are expected to become effective tools for everyday life.

Keywords
Untethered interface, Haptic interface, Air pressure control, Virtual environment

INTRODUCTION
Virtual reality (VR) technologies, which allow users to interact with computer-generated virtual objects or environments, offer the possibility of realizing tools that can enhance our life. Unfortunately, most current VR technologies can be used only in special environments such as experiment rooms or company showrooms. Compared to the tools used in everyday life, many devices in VR systems tether the user by demanding the use of wires or heavy body devices. When adding VR technologies to tools for everyday life, it is critical that the resulting human interface does not constrain the user’s activities. The aim of this research is to realize an “untethered” interface.

Among the many components of the Virtual Reality interface, force feedback technology is one of the hardest to make untethered. This is because the conventional wisdom is that the users must physically contact the interface device to receive the feedback force. The majority of current force feedback devices use rigid arms [1], wire-loaded handles [2], or gloves [3]. Because the worn devices are heavy or the devices need to be physically connected by an arm or a wire, they prevent the users from moving freely and so are bothersome. Our research goal is a force feedback interface that eliminates with all tethers.

We proposed a force feedback method based on the use of air pressure toward an untethered human interface [4] that is easy to use in everyday life. The basic idea of this method is that an air jet impacts the “air receiver” held by the user to provide force feedback. The user feels the air jet not as wind, but as a force. Since the feedback force is created by air, this system does not constrain users with arm- or wire-based devices. The prior implementation used air released from a single nozzle to provide the sensation of hitting a soft object.

In this paper, we expand the method to express the “feel” of touching three dimensional virtual objects by using air jets from multiple nozzles arranged in a matrix. It greatly broadens the applicability of the air-jet based untethered interface.

ARRAYED AIRJET HAPTIC DISPLAY
This paper’s system employs an array of air jets in a two dimensional matrix (see Figure 1). The arrayed air jet in current system is a 10 by 10 planar matrix of vertical nozzles placed at 4cm intervals. The air flow through each

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nozzle is controlled independently. For simplicity, the strength of the air-jet is constant.

In the current implementation, a wired magnetic sensor and a head mounted display are used for sensing and display, respectively. The air receiver is attached to the end of a stick held by the user. The system detects the position and direction of the air receiver via the magnetic sensor, and checks if the receiver has touched a virtual object. If the receiver contacts an object, the system releases air from the appropriate nozzle. While the receiver remains in contact with the virtual surface, the system continues to release air. If the air receiver is moved across the object’s surface, the system activates the next nozzle. The user feels thus the impact of the air at the position and height of the calculated contact points. The user “feels” as if he/she is touching the object’s surface, shown by the head mounted display.

We designed the virtual objects to make them deformable, so that the receiver is not seen as passing through the virtual object when touched; the deformation matches the soft feel provided by the air jet.

**PRELIMINARY EVALUATION**

To confirm the effectiveness of this method for presenting virtual objects, we evaluated the “feel” of touching virtual objects. 10 employees in our laboratory compared three interfaces: vision only, a vibrator plus vision, and the proposed method plus vision. Our results showed this method provided the subject with a better feel of the virtual object compared to the two other interfaces. Moreover, the use of deformable surfaces enhances the realism provided by the proposed interface.

Most subjects reported that they enjoyed the soft feel of touching the objects by this method. We observed many subjects were excited, and spent a lot of time examining the objects even after they answered all questions in the trials.

**TWO HAND APPLICATION**

To further broaden the applicability of this method, we are expanding the system to support two-hand operation.

This application is implemented as follows. Two air receivers are tracked and checked if they contact virtual objects by the system independently. If one or both receivers contact objects, air is released from the appropriate nozzles based on the contact positions of each receiver.

Figure 2 shows the system. We found that the two-hand operation made it easier to perceive the distance between two objects or the size of objects. Since we tend to touch objects from both sides when discovering the size of an object, it is necessary to add horizontal force, which is not provided in the current implementation. We plan to conduct experiments to better understand how well it can support the user’s perception of objects’ size.

Because of the system’s simple construction, it is easy to add more air receivers, as many as space permits. In the same way, the system can be easily expanded to support more than two users, by simply adding HMDs that create the appropriate views for the new users.

**CONCLUSION**

This paper demonstrated an arrayed air jet based force feedback system to realize an untethered human interface that is easy to use in everyday life. We introduced an application that supports operation with both hands.

To realize a fully untethered force feedback interface based on air-jets, we are currently building a system that employs a projection display and computer-vision-based sensing technologies.

**REFERENCES**


