Toward Developing a Velocity Controlled Tactile Impact Display

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ABSTRACT

This paper presents a novel impact display capable of rendering impact on a fingertip over a range of velocities commonly experienced during everyday manipulation and tactile exploration. An optical range sensor is used to measure the separation between the user's finger and the contact block in which the sensor is embedded. Ordinarily, impact is rendered by imposing a rigid boundary when contact is made with a virtual object, which is experienced by the user through a thimble interface. Our impact display adds the making and breaking of contact to this experience and allows control over impact dynamics by controlling impact velocity.

KEYWORDS: haptic I/O, sensors

INDEX TERMS: impact, velocity control, perception

1 INTRODUCTION

The addition of tactile feedback to a standard force feedback device has the potential to increase performance and the sense of presence during teleportation or interaction with virtual environments [1]. We are investigating the tactile rendering of impact, the initial contact between a user and a virtual object, by coupling a thimble to a Phantom haptic device. This thimble is designed with a cut-out in the area of the fingerpad, as previously shown in [3], that allows a contact block that is rigidly attached to the end of the Phantom to make and break contact with the user's fingertip. Cantilever springs connect the contact block to the thimble (Figure 1).

This device presents an interesting opportunity to investigate methods of recreating the sensations of impact and how this event is perceived. Previous work in impact rendering includes [2]. Our device affords us the opportunity to investigate using virtual objects that are more active than can be generally experienced in virtual environments. That is, we can render impact velocities that aren't necessarily equal and opposite to the current rate of travel of one's fingertip, as would generally be experienced when contacting stationary objects. We can in fact make contact at a range of arbitrary impact velocities as well as control the velocity and/or force experienced during the impact event with the fingertip. If we think of impact from a momentum standpoint, the momentum $P = m v$. In this equation, m and v can arbitrarily contribute to produce a given momentum. So, while it is difficult to simulate objects with large mass given the limited duration that torques can be presented by many haptic interfaces, it becomes interesting to investigate whether varying the impact velocity might have an effect on how massive an object is perceived to be. Hence, the central hypothesis that we seek to test is that increasing impact velocity (when combined with imagery of a stationery object) will cause a direct increase in perceived mass of an object.

The remainder of this paper shows the design of an impact display and embedded range sensor, along with preliminary calibration data of the range sensor and rendered impact velocity data. We conclude with plans for future testing.

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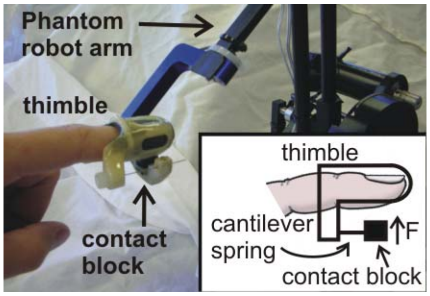

Figure 1. Impact display, consisting of an IR range sensor embedded in an epoxy contact block mounted to a robot arm.

2 ELECTRONICS DESIGN

Infrared range sensing was selected over other methods of range detection (e.g. capacitive sensing) because of its ability to produce a monotonic range-current relationship and its relative insensitivity to minor changes in finger orientation. The IR range sensor chosen was a Vishay TCND5000 with an operating range of 1-14 mm and a peak operating distance at 2.5 mm. The sensor was embedded in an epoxy contact block of approximately 10 mm radius to a depth of about 4 mm. The epoxy used was 20-3302LV transparent epoxy from Epoxies, Etc. Potting the sensor beyond the depth of its peak operating distance ensures a monotonic response across all possible finger positions.

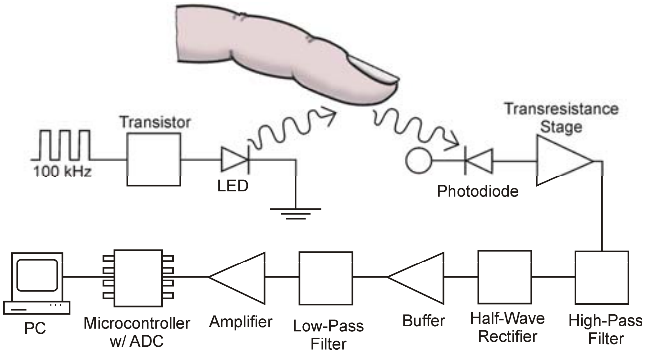

Figure 2. Range sensor signal processing schematic

A signal processing circuit was constructed as shown schematically in Figure 2. The IR emitter is driven with a 100 kHz square wave so that any DC signal (ambient light) can be filtered out. A transresitance stage produces a voltage proportional to the current generated by the IR receiver. This voltage is filtered and amplified to provide a DC voltage that is read by a microcontroller and transmitted to the control PC in real time at 5 kHz over the PC's parallel port. The resulting system is not immune to the effects of ambient light but is sufficiently tolerant to be used reliably in-doors. Test on users with different skin tones and finger shapes suggest that the sensor can be used with any finger. The sensor system was calibrated, producing a 3rd order polynomial calibration curve as shown in Figure 3.

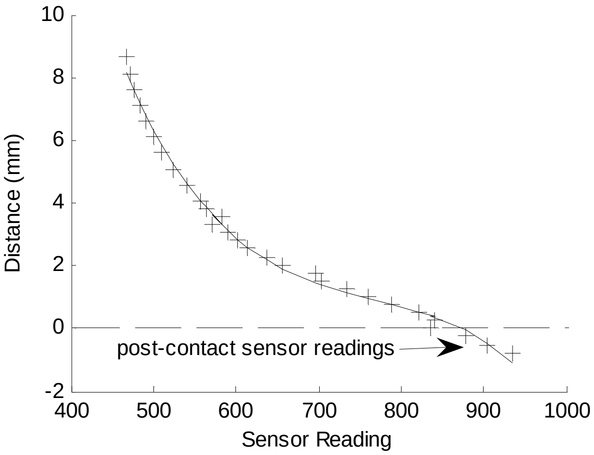

Figure 3. IR range sensor 3rd order calibration curve

3 TESTS OF VELOCITY RENDERING

Mounted on a Phantom robot arm, the contact block with embedded range sensor allows the measurement of finger position without contact. All experiments were conducted with one dimensional, up and down, finger motion. Additional range sensors could extend the device's capability into multiple dimensions, as was accomplished by different means in [4]. A simple proportional controller was written to maintain a constant distance between the contact block and the finger. In effect, this provides gravitation and inertia cancelling without a complex controller; the Phantom follows the finger with only very small forces exerted by the user. While the device currently forces the user to maintain a fingerpad-down posture, the contact block would maintain its distance in any orientation.

When commanded, the contact block is driven up towards the finger at a controlled velocity. Figure 4 shows impacts rendered at varying velocities while the finger remains relatively stationary. The distance between contact block and finger is closed smoothly and with fairly constant velocity. The higher velocity impacts show a brief upward finger motion exceeding the velocity of the contact block. The cause of this aberration is being investigated. Possible explanations include finger reflex response and change in sensor orientation. After contact is made, the range sensor continues to register decreasing distance as the contact block is pressed into the fingerpad. In this region, the range sensor reading is an indirect measure of applied force (see also Figure 3). Figure 5 shows impact on a moving finger. For reference, we have measured finger velocities during exploration and hard tapping at about 0.25 m/s and 0.5 m/s, respectively.

4 CONCLUSION AND FUTURE WORK

We have constructed and tested a tactile impact display capable of rendering arbitrary impact velocity. Future work will characterize users' perception of impact velocity and investigate rendering stiff surfaces and moving objects. Initial tests will involve a user tapping on a surface of constant stiffness with varying impact velocity. Towards this goal, we will implement on-line sensor calibration and develop improved control methods.

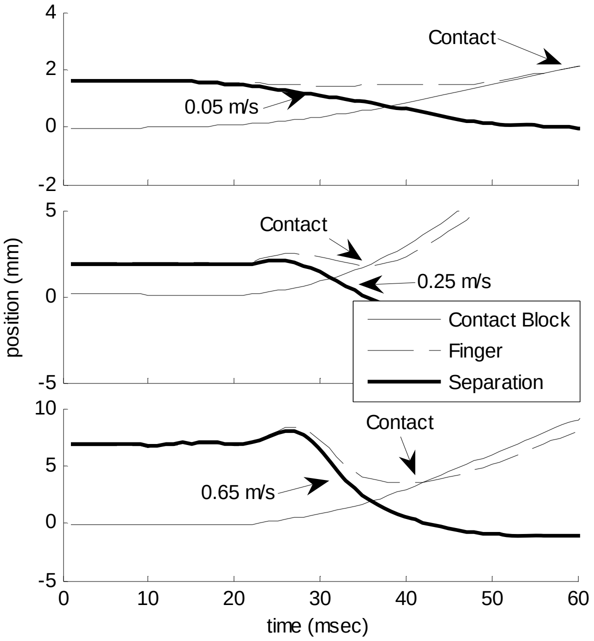

Figure 4. Three impact velocities rendered on a stationary finger.

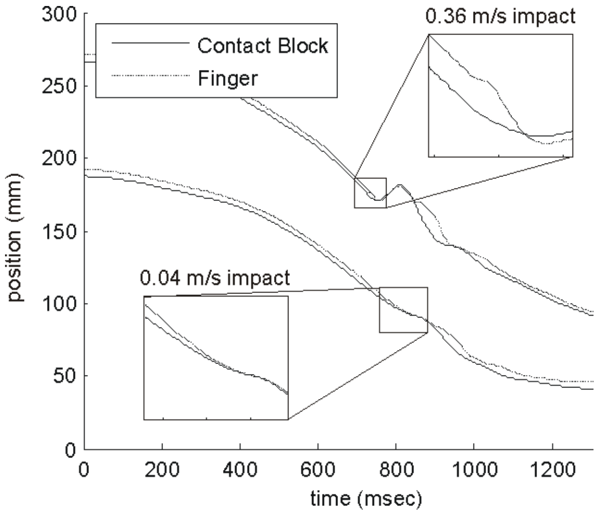

Figure 5. Two impact velocities rendered on a moving finger.

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