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A Tactile Shape Display Using RC Servomotors

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Abstract

Tactile displays are used to convey small-scale force and shape information to the tip of the finger. In this paper, we present a 6x6 tactile shape display that uses commercial RC servomotors to actuate an array of mechanical pins. The display has a maximum pin deflection of 2 mm along with a resolution of 4 bits. Pin spacing is 2 mm with a pin diameter of 1 mm. The display can accurately represent frequencies up to 25 Hz for small amplitudes and is slew rate limited at 38 mm/sec for larger amplitudes.

1. Introduction

Tactile displays attempt to realistically simulate skin deformations that occur when interacting with real objects by transmitting small-scale shape information to the fingertip. Teletaction (experiencing the sensation of touching a remote object) and virtual environments are both domains in which an effective tactile display is crucial to establishing a realistic sense of presence. Lederman and Klatzky [1] have shown that when spatially distributed contact forces to the fingertip are removed during contact, spatial acuity, pressure sensitivity, orientation detection and detection of a lump by palpation are all markedly impaired. Roughness perception is also impaired, but only moderately so. These data argue for the potential importance of displaying spatially distributed forces to the skin in domains such as remote medicine, surgical tools for minimally invasive surgery, and virtual training applications.

The dominant tactile display design uses an array of stimulators that contact the skin to achieve a force distribution on the fingertip. Other previous designs have used shape memory alloy (e.g. [2]), pneumatics (e.g. [3]), and voice coil actuators [4]. However, due to tradeoffs between display bandwidth and actuator density, no universally satisfactory solution has emerged.

We have fabricated a tactile display using RC servomotors in order to achieve a high bandwidth, high actuator density, large vertical displacement, and firm static response for a relatively low cost and simple construction. Our display uses the servomotors to vertically actuate a 6x6 array of 36 mechanical pins at a 2 mm spacing to a height range of 2 mm with a resolution of 4 bits. For a vertical displacement of 2 mm, the 10% to 90% rise time is 41ms. Figure 1 shows the entire system, including the latex rubber sheet that serves as a spatial low pass filter.

2. Design and construction

Figure **1**. The full tactile display

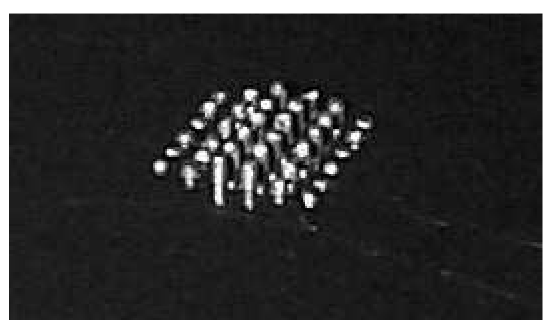

Figure **2**. The 6x6 display showing a two-dimensional sine wave

2.1 Materials

One mm (0.041-inch) diameter steel piano wire was used to fabricate the mechanical pins. Each pin is bent at the end closest to the servo. It then passes through a hole in the plastic arm, forming a hinge by which the pin is attached to its actuating servo. The other end of the pin passes through a top plate of Delrin, chosen to reduce pin friction. The pin tip is also slightly rounded to prevent tearing of a latex cover sheet. The grid of pins, along with the Delrin top plate, is shown in Figure 2.

The servomotors used were small, high performance ball bearing servos normally used in radio-controlled (RC) hobby applications (MX-50HP/BB, Maxx Products International, Lake Zurich, IL). Each servomotor package includes a power amplifier, DC motor, gearhead, position sensor, and closed-loop controller. The electronic interface to the servo is a simple three-wire design of power, ground, and a PWM control signal. The servo model was chosen on the basis of its low weight, small size, and high speed.

2.2 Servo Arrangement

The servos are tightly packed to achieve the desired 2 mm pin spacing. A diagram of six servos is shown in Figure 3, displaying how the horizontal 2 mm spacing is achieved and how the rotational motion of a servo translates into vertical motion of the pin.

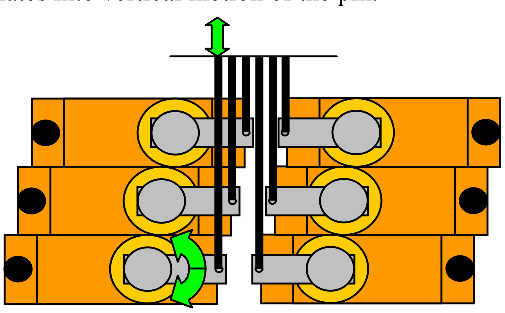

Figure **3**. Configuration of six servos

Figure 4 shows the vertical layout of the servos. The servos are rigidly attached to an aluminum chassis at varying depths. The top plate is also affixed to the chassis.

2.3 Control System

The height of each pin is set by controlling the duty cycle of a pulse width modulated (PWM) voltage signal, which is sent to the corresponding servo. The 36 50Hz PWM waves are generated by a Xilinx programmable gate array mounted on a parallel interface card (XS40-005XL, XESS Corp., Apex, NC). The individual PWM waves are commanded through a PC parallel port. Using this system, we can achieve 4 bits of height resolution over 2 mm.

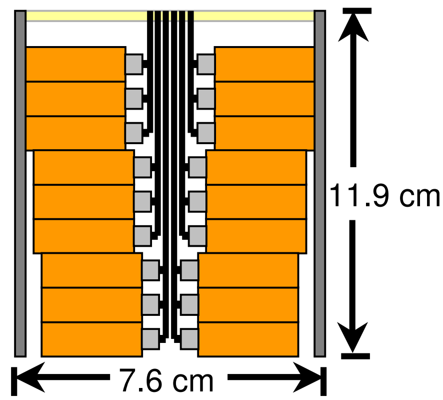

Figure **4**. Vertical configuration of servos

3. Performance

Due to the nature of the servo, the pin motion was slew rate limited. The slew rate was found to be 38 mm per second after determining that both the 10% to 90% rise time and the 90% to 10% fall time was 41 ms for a 2 mm displacement. Thus, for amplitudes less than 0.75 mm, the system can reproduce frequencies up to one-half the PWM frequency, or 25 Hz. For larger amplitudes, the motion is limited by the slew rate. Subjectively, the system readily conveys small shape information at reasonable speeds for manual exploration. Future work will include a comprehensive psychophysical evaluation.

4. References

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