The vBow: A Haptic Musical Controller Human-Computer Interface

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Abstract

The vBow senses the violinist's bow stroke through the encoder of a servo driven by a cable, which is wrapped around a capstan attached to the shaft of the motor, and secured to either end of the virtual bow. The servo engages the bow, simulating friction and vibration of the string on the bow, according to the velocity of the performer's stroke. The result is a musical controller capable of simulating the complex interaction between a violinist's bow stroke, an acoustic violin's physical response, and the violinist's reaction to the force-feedback of the acoustical system.

Motivation

Previous electronic musical controllers have either added technology to acoustic instruments to translate the expressive qualities of the instrument into digital data, or employed systems of sensors to capture the performance gestures of the player, to provide the computer musician with an expressive electronic musical controller. The advantage of the former case is that the force-feedback of the acoustic instrument, upon which the traditional player depends and his technical training has been based, is retained. However, the translation of an acoustic signal into a digital protocol is prone to error, and quantizes the expression of the instrument, limiting the expressive range of the performer. In the latter case, the expression of the performer may be more accurately and fully translated, but the haptic response of the instrument is lost. The vBow (Figure 1), a virtual violin bow musical controller, uses a design based on robotic technology to both accurately capture gestural expression and provide haptic feedback to the performer.

Construction

The vBow is designed around a Maxon Precision Motors RE Ø25 servomotor with a digital encoder, and a Berg Manufacturing linear ball bearing. The servo was selected for its stall torque and operating range, so that it would be able to withstand and simulate the friction for the normal range of force for a violin bow, as detailed in the research by Askenfelt (1989: 513-514). The digital encoder provides 500 slots per turn in two channels, allowing 2000 counts per revolution. The linear bearing uses four evenly spaced rows of ball bearings, along its interior wall, to facilitate smooth travel through the bore.

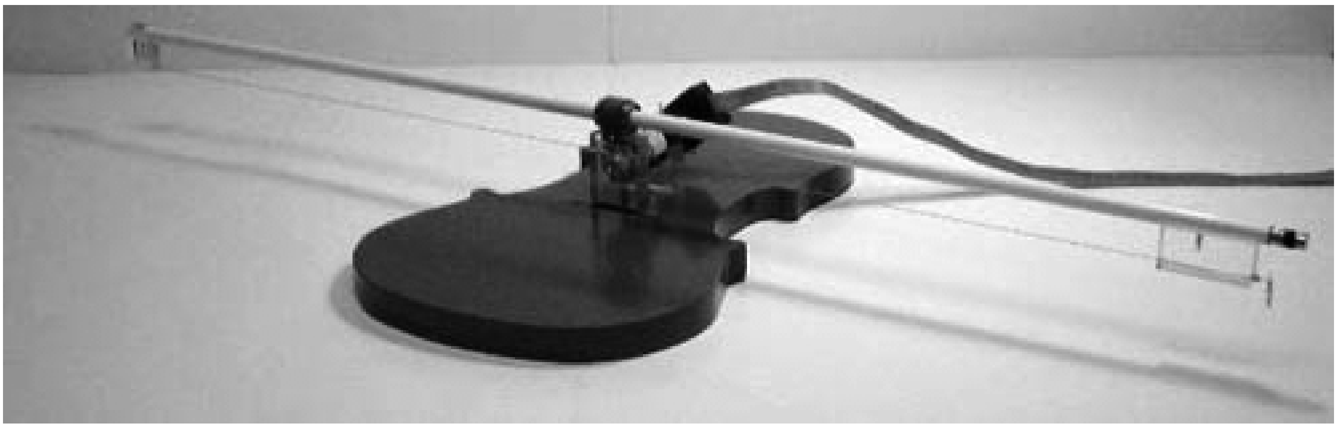

Figure 1: The vBow.

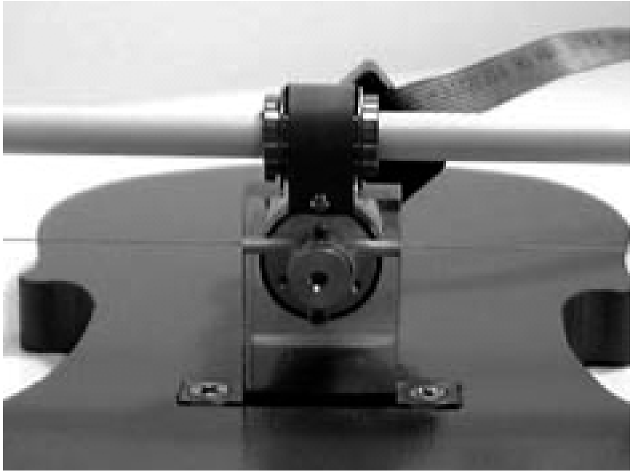

Figure 2: The housing for the linear bearing and servo, with holes for the capstan and cable.

Both the servo and linear bearing are secured to a housing (Figure 2), machined from acrylic, which also contains guide holes for the cable. A metal strap is used to secure the linear bearing to the face and back of the housing, while retainer rings, which fit into grooves cut into the outer wall of the linear bearing, secure the bearing to the sides of the housing. A strip of craft foam ensures that the metal strap firmly holds the bearing against the housing, preventing unwanted vibration. Both the metal strap and servo are fastened to the housing with screws which fit into holes drilled through the depth of the housing. The whole assembly is secured, with stainless steel screws, to a violin-shaped base, which serves as a stable foundation.

Figure 3: The capstan and servo with encoder.

In another hole drilled through the depth of the housing fits a capstan, turned from an aluminum rod, which is secured to the shaft of the servo with a set screw (Figure 3). The 1x7, nylon coated, stainless steel Sava Industries cable, selected for its minimum breaking strength, wraps around the capstan, within a groove cut into the side of the capstan. The diameter of the capstan surface within the groove was determined, along with the stall torque of the motor, by the optimal range of force for the system.

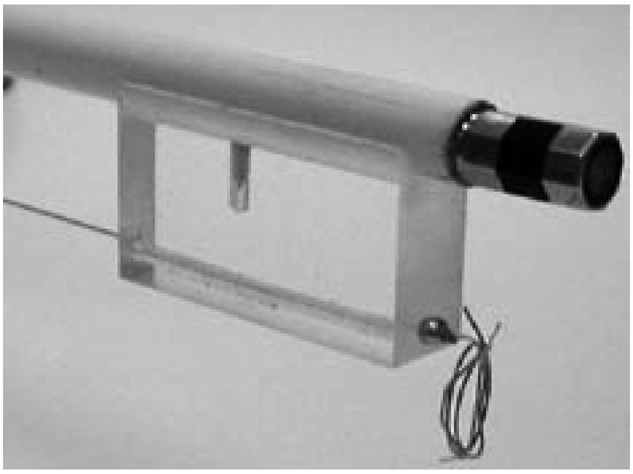

Figure 4: The frog with cable tensioner.

The virtual bow is constructed from a smooth fiberglass shaft, which serves as the stick of the bow, and two blocks, machined from acrylic, which serve as the tip and frog of the bow. The cable passes through holes drilled through the length of the tip and frog, and is terminated at either end by a stainless steel ball and shank. The tip of the bow is attached with screws to the fiberglass shaft, while the frog slides along the bottom of the shaft. The frog is attached to the shaft by a standard bow tightening screw and eyelet, which fit into a hole and slot drilled out of the fiberglass shaft, and serve as the cable tensioner (Figure 4).

The bow moves smoothly, with the shaft traveling through the linear bearing, and the cable, threaded through the guide holes in the housing, and wrapped around the capstan, spinning the shaft of the motor.

Performance data sensed by the encoder and haptic feedback instructions for driving the servo will be bussed through parallel data streams to and from a Servo To Go data acquisition and servo control ISA card, installed in a Pentium III, 600 MHz PC, running Windows 98.

The vBow will be used to drive the bowed string physical model (Serafin and Smith, 2000), through the violin body resonance waveguide mesh model (Huang, Serafin, and Smith, 2000), using the friction model (O'Modhrain, Serafin, Chafe, and Smith, 2000) currently being developed at CCRMA, by members of the STRAD group.

Improvements

Three additional versions of the vBow are planned.

The second version of the vBow would measure and provide haptic feedback for crossing and bowing multiple strings. It would use a potentiometer at a pivot point, to measure bow position across strings, and additional control software for the motor of the first version, to simulate the feel of crossing strings and the friction and vibration of multiple strings on the bow. This version would also measure bow force, with a pressure sensor at the base of the vBow housing.

The third version would provide for longitudinal motion, along the length of the virtual string, using another servo and cable system to compensate for the mass of the bow and housing.

A final version of the vBow would lift the original housing off of the base, suspending it from a small robotic arm, that would incorporate the degrees of freedom from the second and third versions into a unified design.

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