The vBow: A Four Degrees of Freedom Haptic Musical Controller Human-Computer Interface

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Abstract

This latest version of the vBow adds three degrees of freedom to the previous design, allowing for rotational motion across, vertical motion above, and longitudinal motion along the virtual strings, in addition to the original lateral motion of the bow stroke. Like the previous design, this version of the vBow uses servomotors with encoders and cable systems, to sense bow position and provide haptic feedback to the user.

Figure 1: The vBow.

Motivation

Development of the original version of the vBow was motivated by the need for an expressive virtual violin bow musical controller that accurately sensed performance gesture and provided the haptic feedback that a violinist depends upon when performing (Nichols, 2000).

This latest version of the vBow is meant to augment the expressive possibilities of the previous version, by adding three degrees of freedom, which will map to additional parameters in the bowed string physical model, and will produce other haptic feedback cues.

In addition to functioning as an expressive musical controller, the vBow serves as a tool for testing the expressivity of the bowed string physical model, and the efficacy of the friction model used.

Construction

Like the previous model, this version of the vBow is designed around Maxon Precision Motors servomotors with digital encoders. The linear bearing from the original version has been replaced by a hole drilled through the width of the piece that houses the servomotor and cable system of the original version.

All of the pieces of this new version have been laser cut from half-inch thick acrylic, and further machined on a mill. The capstans were turned on a lathe from an aluminum rod, and the stick of the vBow is the original fiberglass rod of the previous version.

In this version of the vBow, the first degree of freedom remains the same as that of the previous version. This first servomotor and cable system senses bow velocity and direction, and provides for the haptic feedback of friction and vibration associated with drawing the hair of the bow across a violin string.

A cable extends from the tip to the frog, terminated at each end with a ball and shank. The cable passes through a guide hole cut through the width of the housing piece, and wraps around a groove cut into the side of a capstan. The capstan is fastened with a set screw to the shaft of a servomotor, which is secured to the housing.

The cable is tightened with a standard screw and eyelet, ordinarily used to tighten the hair of a bow. The screw fits in a hole drilled into the end of the fiberglass rod, and threads into an eyelet that is screwed into the frog. The eyelet slides inside a slot carved into the bottom edge of the fiberglass rod. As the screw is turned, the eyelet moves the frog closer to the end of the shaft, tightening the cable.

As the vBow moves back and forth, the fiberglass rod passes through a guide hole, drilled through the width of the housing. The cable passes through a guide hole, drilled parallel to the guide hole for the fiberglass rod, and spins the capstan attached to the shaft of the servomotor. As the shaft of the servomotor spins, the digital encoder attached to the servomotor reads the counts per revolution of the shaft, sensing lateral motion across the virtual strings.

The second degree of freedom, for this latest version of the vBow, is constructed from a servomotor and cable system that senses string crossings, and provides for the haptic feedback of detents associated with the hair of the bow making contact with each violin string.

A cable extends along the bottom curved edge of the housing piece, and wraps around a capstan attached to the shaft of a second servomotor. The housing is fastened to a second piece, that hangs down from an arm that extends over a violin-shaped body. These pieces are held together with threaded pins and lock nuts. This second rotation piece houses the servomotor with encoder that senses and provides for the haptic feedback of string crossings.

The cable is fastened to the housing with two screws, which thread into the housing at either end of the curved edge. The arc of rotation for the vBow, measured from the pivot point between the housing and the rotation piece to either the curved edge of the housing or the middle of the cable guide hole, is the same as the arc across the strings of a violin, at the point at which the bow usually crosses the strings.

As the vBow pivots in an arc, the cable attached to the bottom curved edge of the housing spins the capstan and the shaft of the servomotor that is fastened to the rotation piece. As the shaft of the servomotor spins, the encoder senses the rotational motion of the vBow crossing the virtual strings.

Figure 2: Rotational motion across the virtual strings.

The third degree of freedom is built from a servomotor and cable system that senses vertical bow position, and provides for the haptic feedback of string elasticity associated with the hair of the bow pushing into the violin strings.

A cable wraps around the circular base of the arm piece, fastened on one end by a screw, and terminated at the other end with a ball and shank, which fits in a guide hole drilled through the height of the part. The cable wraps around a capstan attached to a third servomotor, that is fastened to the longitudinal piece below. The arm and longitudinal piece are held together with another threaded pin and additional lock nuts.

As the vBow moves up and down, the cable attached to the circular end of the arm spins the capstan and the shaft of the servomotor that is fastened to the longitudinal piece. The encoder on this third servomotor senses the vertical motion of the vBow rising above or pushing into the virtual strings.

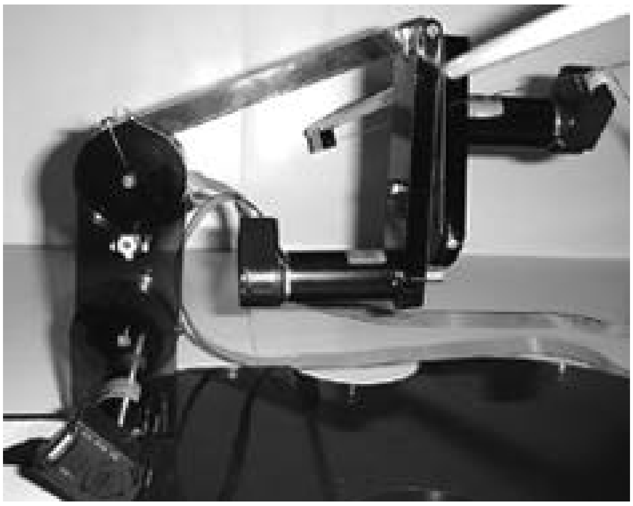

Figure 3: Vertical motion above the virtual strings.

The fourth and final degree of freedom, of this version of the vBow, uses a servomotor and cable system that senses longitudinal bow position, and provides for the haptic feedback of longitudinal friction associated with pushing the hair of the bow along the length of the violin strings.

A cable wraps around the curved base of the longitudinal piece, secured at either end of the curved edge with two screws. The cable wraps around a capstan, that is fastened to the shaft of a fourth servomotor, below the curved edge of the longitudinal piece. This servomotor is secured to the base piece below, which is screwed in turn to the violin-shaped body. The longitudinal and base pieces are held together with another threaded pin and additional lock nuts.

As the vBow moves forward and backward, the cable attached to the curved edge of the longitudinal part spins the capstan and the shaft of the servomotor that is secured to the base piece. The encoder for this final degree of freedom senses the longitudinal motion of the vBow sliding along the length of the virtual strings, in relation to the virtual bridge and fingerboard.

Figure 4: Longitudinal motion along the virtual strings.

Because the pieces are held together securely with threaded pins and lock nuts, and the cable systems are tightened with screws, the vBow proves to be a mechanically stable device.

Application

The previous version of the vBow has been used to test the expressiveness of the bowed string physical model and the effectiveness of the friction and vibration model used (Nichols, 2001).

This version will be used to further test the expressivity of the bowed string physical model, allowing for a variety of attacks, and sul ponticello or sul tasto effects. The current model will also allow for double and triple stops.

The current version will also be used to experiment with the haptic feedback associated with string crossings, bow pressure, attack velocities, and the friction of longitudinal motion in relation to bow pressure.

Development

The synthesis software for the previous version of the vBow was developed using the bowed string physical model under development at CCRMA (Serafin, Smith, and Woodhouse, 1999), written as a Synthesis ToolKit (STK) object (Cook and Scavone, 1999). The control software was written using the C++ libraries that accompany the Win32 driver for the ServoToGo data acquisition and servomotor control card. This software was developed using Microsoft Visual C++, running under Windows 98.

The synthesis software for the current version of the vBow is under development, using STK with the Advanced Linux Sound Architecture (ALSA), running under the RTLinux operating system. The control software is being written using the Quality Real-Time Systems (QRTS) ServoToGo software development kit for RTLinux.

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