THE VBOW: TWO VERSIONS OF A VIRTUAL VIOLIN BOW CONTROLLER

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Abstract

The vBow is a haptic musical controller human-computer interface, which simulates the force-feedback of a bow on a violin string, while driving a bowed-string physical model. It is both a musical instrument for expressing the musical gestures of a performer, and a tool for testing friction and vibration models, and the responsiveness of physical model sound synthesis.

INTRODUCTION

There are currently two versions of the vBow. The first version has been used to develop and experiment with a friction and vibration model, and to test the expressivity of a bowed-string physical model. The second version has been designed to expand on what was learned with the first version, to include most of the gestural degrees of freedom of a violinist's bow stroke, and to drive more parameters of the bowed-string physical model.

CONSTRUCTION

Both versions of the vBow are constructed from machined acrylic and aluminum pieces, Maxon Precision Motors servomotors with digital encoders, and Sava Industries cable. The first version also uses a Berg Manufacturing linear bearing and wood base.

Version 1

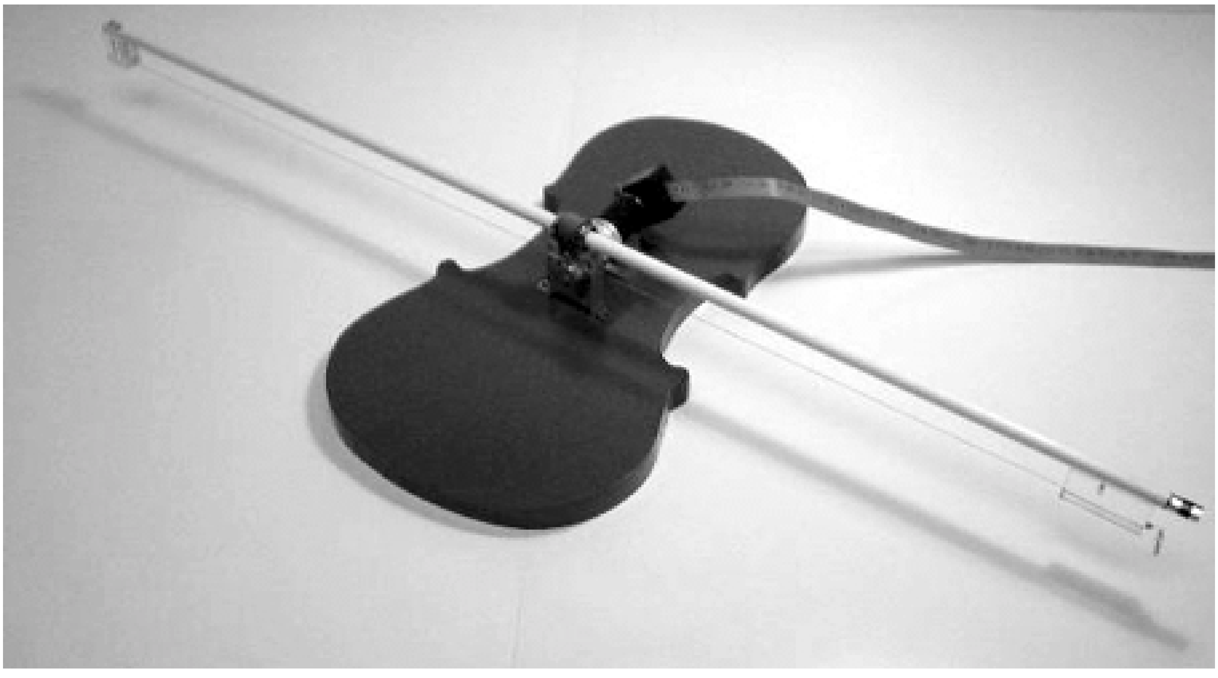

Figure 1: The vBow version 1.

The hardware for the first version is based on a single servomotor and cable system. The servomotor is mounted to a housing, which is fastened to a violin-shaped base, for stability. A guide hole for the cable is drilled through the width of the housing, at the height of where a bow contacts a violin string. The cable passes through the guide hole, and wraps around a capstan, which is secured to the shaft of the servomotor, and spins within a hole drilled through the depth of the housing. At the top of the housing sits a linear bearing, through which a rod passes. At each end of the rod are a frog and tip, to which the ends of the cable are secured [1].

Version 2

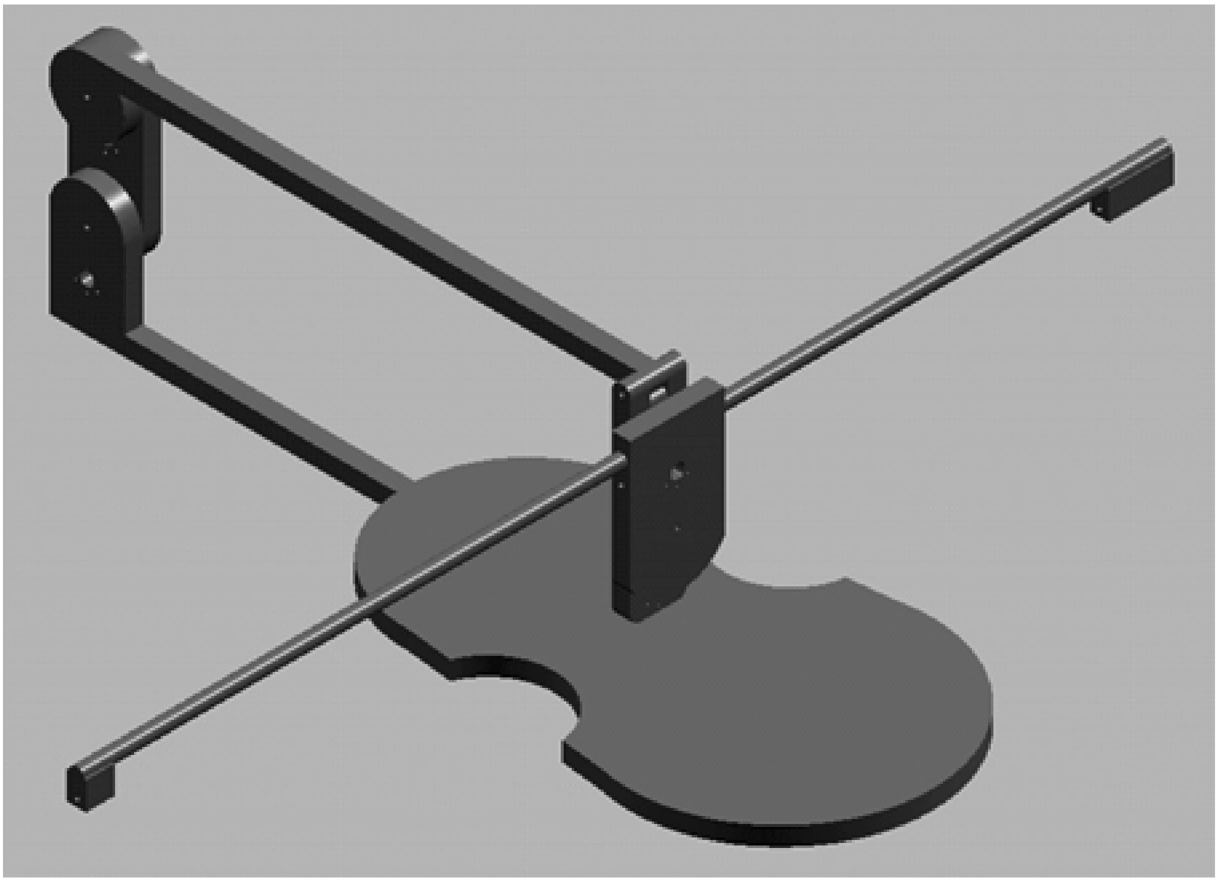

Figure 2: The vBow version 2.

The second version of the vBow uses the housing, and the single servomotor and cable system from the first version. The housing is suspended from the end of a robotic arm, which is anchored at the end of the neck of the violin-shaped base, where the scroll would be.

In this version, the housing has been modified. The linear bearing has been replaced with a hole drilled through the width of the housing, parallel to the cable guide hole. The bottom of the housing has been rounded at the same radius as the curve of a bridge on a violin. The stick and cable guide holes are positioned so that they rotate at the same radius as the curve at the bottom of the housing, on the opposite side of the axis. The result is that the vBow rotates across an arc that is the same as the arc of a bow crossing strings which are strung over a violin bridge.

A cable has been added to this bottom curve of the housing. The cable wraps around a capstan, attached to the shaft of a servomotor, which is fastened to the rotation piece at the end of the robotic arm. This servomotor and cable system will sense string crossings and provide the haptic feedback of detents, when the vBow comes into contact with a virtual string.

The rotation piece is rounded on the upper corners, so that it does not collide with the arm piece when the vBow moves vertically. The servomotor attached to the rotation piece is positioned low enough that the vBow stick can push the longitudinal piece along the length of the virtual string, but high enough to provide clearance above the violin-shaped base, when the vBow is pushed into the elasticity of the virtual string.

Another cable attaches to the round base of the arm part. The cable wraps around a capstan, attached to the shaft of a servomotor, mounted to the longitudinal piece. This servomotor and cable system will sense vertical position and provide the haptic feedback for attacks and bow pressure.

The fourth servomotor and cable system will sense and provide haptic feedback for longitudinal motion along the virtual strings. The cable attached to the rounded base of the longitudinal part wraps around the capstan, attached to the shaft of the servomotor, mounted to the base piece, which is in turn secured to the end of the neck of the violin-shaped base.

The stick, frog, and tip are identical to those of the first version, with the exception of the distance between the cable and stick, which has been shortened to feel more natural for the violinist's bow grip.

All of the parts have been laser cut from acrylic, and further machined on an end mill. The capstans have been turned from an aluminum rod.

APPLICATION

The vBow was designed in reaction to a perceived need for a violin bow controller which could be used to expressively drive a bowed-string physical model in real time, without the use of MIDI. The decision to make the vBow a haptic device was in response to the research conducted at CCRMA, that shows an improvement of the playability of a bowed-string physical model when the force-feedback of a friction model is added to the system [2].

Version 1

As the performer draws the bow of the first version, the rod passes smoothly through the linear bearing, the cable turns the capstan on the shaft of the servomotor, and a digital encoder reads the rotations of the servomotor. The output of the encoder and input of the servomotor are connected to a data acquisition and servomotor control card installed in a PC. The servomotor rotations read by the encoder, and decoded by the data acquisition card, are converted into bow direction and velocity data by programming, which uses the data to drive a bowed-string physical model. The programming then sends control data through the servomotor control card, to the servomotor, which turns the capstan and engages the cable, to simulate friction and vibration on the virtual bow.

The physical model responds to the vBow in the same way you would expect a violin string to respond to a bow. If the bow stroke is fast, the high velocity values cause the physical model to produce a thin violin timbre full of high partials, similar to a flautando sound. If the bow stroke is slow, the physical model produces a scratching noise, similar to the sound of a bow scraping across a string too slowly to produce a steady state vibration. Finally, if the bow stroke is at an optimal speed, the physical model produces a clear violin timbre.

The friction and vibration model produces a haptic feedback similar to the feel of a violin string vibrating on a bow, with the friction of the hooks on the hair of the violin bow catching and releasing the string.

Version 2

The second version of the vBow will use four servomotor and cable systems, similar to that of the first version, to sense four types of bow motion. In addition to the bow stroke direction and velocity sensed by the first version, the second version will sense rotational bow position across multiple virtual strings, vertical bow position and pressure into the virtual strings, and longitudinal bow position in relation to the virtual bridge. The rotation across virtual strings will allow for playing double and triple stops, while the vertical motion will allow for various attacks and amounts of pressure into the string. The longitudinal motion will allow for sul tasto and sul ponticello effects with the bowed-string physical model.

Similarly, the second version will provide additional haptic feedback to the performer. The same servomotor which senses string crossings with its encoder will provide detents to simulate the feel of crossing to a virtual string, while the original servomotor of the first version will provide multiple vibrations when playing on more than one string. The servomotor with encoder which senses vertical bow position and pressure into the virtual strings will provide the haptic feedback of resistance and elasticity when the vBow comes into contact with the virtual string. Finally, the servomotor and encoder which senses longitudinal motion will provide additional friction as the vBow slides along the length of the virtual strings.

CONCLUSION

The first version of the vBow has proven to be a useful tool for experimenting with friction and vibration models, and for testing the playability of bowed-string physical models. The second version will add to the utility of the instrument, providing more degrees of freedom, which will more accurately sense the musical gestures of the performer, and providing more haptic cues to the performer, which will improve the playability of the physical model.

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