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Motion Space Reduction in a Haptic Model of Violin and Viola Bowing

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Abstract

A haptic model of bowing the violin and viola is presented that focuses on just the geometry of the contact point between the bow hair and the string, giving a simplified description that focuses on aspects which the performer thinks about consciously. The model allows artificial constraints on the bow motion to be provided, giving the player physical feedback if one dimension of the contact point becomes incorrect, while allowing full movement in other dimensions.

1. Introduction

String instruments such as the violin and viola are hard to play. One of the main challenges with these instruments is bowing: the position, velocity, and force on the bow are all three-dimensional, and control of the bow is complex and difficult. While practicing or learning to play an instrument, it is often useful to focus on just one aspect of bowing, but problems in other aspects may lead to confusing effects. It is helpful to abstract away from the aspects of bowing that are not currently at issue, so that the performer or student can focus on a particular problem area. This is impossible to do with a real instrument, but a haptic model of a virtual system (player plus instrument and bow) offers a solution.

The violin and viola are both played while standing with the instrument aligned along the left arm as it stretches out to the left. The bow is held in the right hand at the "frog" (lower tip of the bow), so that the bow hair contacts one of the four strings. The bow should remain at a 90 degree angle to the string, and the point of contact should lie between the bridge and the fingerboard.

Although the geometry of the bow and instrument is relatively simple, the hand and arm motions needed to attain the right geometry are complex, making it difficult to keep the bow under control. Good bowing technique requires an understanding of the required motion at every point of the stroke, as well as practice in order to develop the ability to produce the motion.

We have developed a haptic model for bowing that allows the motion of the bow between the bridge and fingerboard (i.e. motion parallel to the strings) to be limited artificially, while normal bow motion orthogonal to the strings is allowed. This model allows the user to practice bowing normally, except there is tactile feedback when the bow position becomes incorrect. String teachers often provide similar feedback, but the haptic model can be used without having a teacher present.

2. A Haptic Model for Bowing

A virtual environment based on a bowing model has been implemented, using a PHANToM force feedback haptic device from SensAble Technologies. The system includes a virtual platform representing the contact between the bow and a string. This object can be thought of as a flat surface viewed from the side, which slants from the top left to the bottom right of the virtual environment and screen. The user holds the pen or stylus attachment to the PHANToM, as if it were the handle of the bow, and moves it across the virtual platform.

The haptic device is mounted on a table, which is required to give a solid support. The player of the virtual instrument sits in a chair, which must be adjusted so that the haptic stylus has a range of movement from a point ahead of and above the player's left shoulder to a point above the left knee. The PHANToM gives a range of motion that is slightly less than a full bow stroke with a real instrument, but it can model a partial stroke well and gives a reasonable approximation to a full stroke. The computer that controls the haptic device is also on the table, with the monitor visible to the user.

Our model aims to provide haptic feedback to the user similar to the bow passing over a string. The virtual environment needs to be realistic to be believable and for skills

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learned during simulator training to be transferable to the real task. An initial prototype was developed that allows a string player to bow on a platform representing one string, the violin E string or viola A string, bowing at an angle of 67 degrees. A range of haptic properties, which can be manipulated in the GHOST programming environment, were combined and adjusted. The haptic device allows us to model the feel of the bow on the strings, so that the motion is as realistic as possible. The feel of the bow stroke is determined by four functions that can be selected by the player: stiffness, dynamic friction, static friction, and damping. The model was developed in consultation with experts, in order to tune the model so that it gives a realistic feel.

The stylus provides both input from the user, and output in the form of forces generated by the haptic device under software control. The forces produced by the system have two purposes: modeling the constraints inherent in the system, and modeling artificial constraints introduced to help the player to handle one aspect of motion correctly.

The main inherent constraint is that the bow cannot be pushed down through the string. There is a narrow central rectangular playing platform, with two other rectangles on either side that have been slightly raised to help constrain the bowing within the playing platform. The current simulation represents bowing on one string at a time, but the angle of the platform can be adjusted to represent a different string.

Artificial constraints are intended to help the player to focus on one aspect of bow control. One such artificial constraint has been implemented. This concerns the optimal positioning of the contact point between the bow hair and string. The path followed by the bow is divided into three parallel rectangles, or grooves, each of which represents a distance from the bridge and can be used to guide the bow. Force feedback from the haptic device allows the stylus to move only along the middle groove: it cannot jump out of one groove and into the next without raising the stylus to a significant height. The grooves are also shown graphically on the computer monitor. Initially, the student selects the middle groove, and the model keeps the stylus within that groove. The effect of this is to keep the contact point midway between the bridge and the fingerboard.

The aim of the artificial constraint is to enable the student to perform the correct bow motion without distraction, secure in the knowledge that an error in positioning will be felt immediately as the bow leaves the proper groove.

We ran an experiment in which seven experienced string players tested a version of the model developed to identify the haptic property values that determine the realism of the system. The results indicated that a realistic feel of the bow could be achieved by tuning a small number of parameters. We also discussed with the participants their views on the usefulness of providing of computer assisted guidance in a simulated environment, in particular the use of artificial constraints in focusing on a key skill. It turned out that some of the players had independently tried various techniques for teaching students to open and close the elbow when bowing, and that they agreed that the haptics model could provide support for this activity.

3. Related work

Several researchers have developed haptic tools that are related to bowing string instruments, and there is also research in robotics that is particularly relevant to our approach of artificial limitations of motion. A technique called *virtual fixtures* [2] allows a user controlling the robot to feel the environment with some aspects of motion restricted artificially. Feygin, Keehner and Tendick [1] define *haptic guidance* as a paradigm in which the user is physically guided through the ideal motion, giving a kinesthetic understanding of what is required, and found that haptic guidance was effective in training. Our approach uses a combination of these ideas: the bowing model allows the user to feel the contact with the strings as a string player would (haptic guidance), while limiting movement of the bow (virtual fixtures) so that it cannot drift out of position.

4. Conclusions

We have developed and implemented a haptic model of bowing for the violin and viola. This model allows motion to be limited artificially in certain dimensions, which can be used to give the user feedback when the bow motion is incorrect. This approach helps the performer to focus on one specific problem, which can make the learning process more efficient. Thus the haptic device can provide some forms of feedback that teachers give manually.

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