An alternative controller for a virtual bowed string instrument

Stefania Serafin
CCRMA
Stanford University
serafin@ccrma.stanford.edu

Richard Dudas
CNMAT
UC Berkeley Department of Music
dudas@cnmat.berkeley.edu

Introduction

One of the principal interests in building a virtual instrument model that works in real-time is the possibility of having interactive control of all its parameters. This means that the performer receives immediate audible feedback from his instrument so he can easily adjust and modify the sound produced while he is playing.

This interactivity makes sense only if one is provided with a tool powerful enough to control the many parameters of a complex instrument model.

Digitizing tablets, which have been developed primarily for the computer graphics field, have interesting applications to the control of sound synthesis, because they provide a substantial quantity of gestural data via a minimum amount of hardware.

Description of the tablet

The tablet we use is manufactured by Wacom Inc., which has produced several generations of graphical tablets, the most recent series of which is named "Intuos". Wacom's tablets come with a variety of tools — cordless and batteryless transducers. Each transducer is provided with its own identifier, so the tablet can be programmed in such a way so that two devices may be used simultaneously and independently. (Some earlier models allow only a single transducer to operate on the tablet at a given time.) The tablet communicates transducer information to the computer via one of the computer's serial ports. Tablet models designed specifically for the Macintosh can alternatively use an ADB (Apple Desktop Bus) connection.

By default, a transducer's location on the tablet can be used to control the position of the computer's on-screen cursor, in lieu of the mouse. Apart from the usual horizontal/vertical position of the transducer on the surface of the tablet, some tools, such as the stylus (analogous to a pen) are also sensitive to pressure and tilt angle. In the context of graphic design, these parameters enable the tablet to precisely capture the inflections of the user's hand movements, thereby allowing him to create natural-looking pen and brush strokes.

Because the stylus has this capability of conveying many subtle differences in hand gesture, the tablet is well suited to applications in musical control, as we will see in the next sections.

Use of the tablet in music

Taking the tablet out of its original graphic design context and putting it to use for musical goals came about in the early 1990s. Many musicians began using the tablets as two-dimensional musical controllers. The tablet was particularly well-suited to the spatial positioning of sound, because, unlike a mouse, the tablet allows absolute positioning of the cursor.

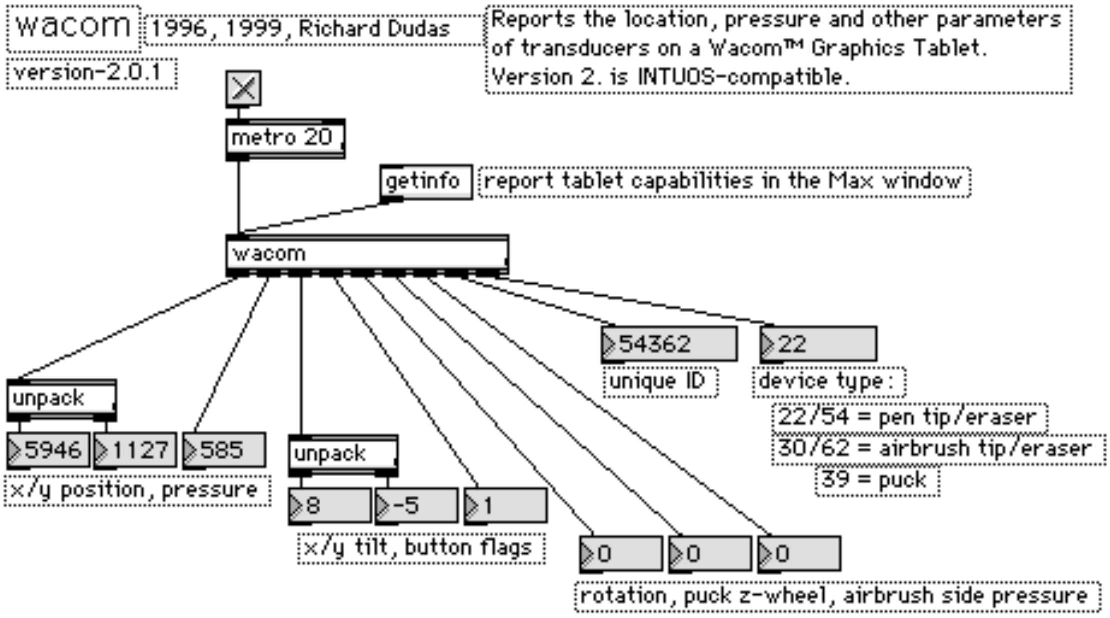

Fig. 1. The wacom external object as it appears in MAX

The creation of extensions — external code resources (or shared libraries) — to the musical programming environment, MAX, allowed the tablet to be used as a data input device for this program. Additionally, such extensions would be able to provide transducer information other that just the horizontal and vertical position which can be obtained by using the tablet as a mouse. The first such extension was made by Ronald J. Kuivila in 1992, and was used by a number of electronic musicians in the early 1990's. A more recent MAX external code resource, called *wacom*, was proposed by Atau Tanaka and developed by Richard Dudas at Bionic Media in Paris. This object has been recently updated to remain compatible with the latest series of tablets produced by Wacom, Inc. The *wacom* object as it appears in MAX is shown in figure 1.

The *wacom* object is able to detect and output not only the location of a transducer, but also which tool (transducer) is currently being used with the tablet, as well as the parameters corresponding to its position, pressure and inclination. A transducer may also have an eraser, one or more buttons and thumb wheels which provide additional control data.

A similar MAX external code resource for use with generic Macintosh graphic tablets was also created in 1996 by Shuichi Chino. The external, called *apd* (absolute pointing device), provides X, Y and Z position as well as side pressure and button information.

Additionally, M. Wright and others (see [7]) had also started using the tablet for the purpose of sound synthesis control, especially in the context of real-time additive synthesis.

Today graphic tablets are being more widely used by musicians for real-time electronic and computer music performances (see, for example, [6]). Many new synthesis environments such as James McCartney's SuperCollider are now coming equipped with tablet input capabilities. The tablet has been used for a large variety of musical purposes, including musical performances, improvisations, sound installations, film soundtracks and virtual reality sound effects for video games. The tablet is also ideal for pedagogical purposes in the electronic and computer music world. Since the stylus transducer is similar to a pen or pencil, it is immediately a familiar object and can be intuitively used to introduce students of all ages to the interactive world of "alternate controllers" or "virtual instruments".

Application to the control of a violin physical model

The violin

The violin evolved from early three-stringed instruments in China and India.

The "invention" of the violin as it is known today cannot be assigned specifically to any one person, although it is traditionally attributed to Gasparo Bertolotti (1542-1608). Today's violin has four strings made of steel, gut or nylon and tuned to G3, D4, A4 and E5.

Even if the exterior of the violin has a very symmetrical appearance, the instrument is actually internally highly asymmetric, which facilitates the propagation of its sound. A violin's resonance depends primarily on the choice of the wood from which it is made, on the thickness and tension of the soundboard, on the position of the soundpost and on the shape of the bridge. The quality of the bow used also plays an important role in the sound produced by the instrument. Another factor which contributes to the violin's sound and is often overlooked in the scientific domain is the violinist himself, who invariably adds his own personality to the violin.

The musician keeps the instrument in a small portion of his shoulder, in order to let it vibrate, and at the same time moves the bow delicately on the strings.

The movements of all good violinists are fluid, and equilibrated finely, as should be the continuity of the sound produced by the instrument.

All these characteristics should be preserved in building a model of a violin.

As soon as the model is considered to be satisfactory from a mathematical point of view, the problem of its control must then be dealt with if the virtual instrument is destined to be used for real-time performance.

At this point a question arises immediately: should we use a controller that looks exactly like a violin, or is it better to experiment with something new that underlines the qualities of the model while maintaining a certain distance from a real instrument?

The first solution is valid in the case we want to examine how far an instrument reproduced by computer can be similar to a real one, which implies that we are trying to reproduce a virtual instrument as closely to a real one as possible.

The advantage of choosing this kind of instrument relies on the assumption that the validity of the mathematical model of the instrument can be completely tested.

On the other hand, using a controller that behaves differently from a real instrument allows to capture some characteristics of the instrument itself, while keeping others "original".

Here we are interested on this second solution, since we want to explore the possibilities offered by the Wacom tablet, which has interesting characteristic that make it an alternative controller for our bowed string model.

A model for the bow

To reproduce the behavior of the bow in our violin-like instrument we use a stylus. Beginning violin students often learn the proper bow hold using a pen or pencil, since these both have the same shape as the bow but are lighter, and therefore easier to hold correctly. Translating the proper bow hold over to the graphical tablet's stylus is thus straightforward for performers.

We hold the stylus and move it on the surface of the tablet as if it were a bow moving across the strings of a violin, as illustrated in figure 2.

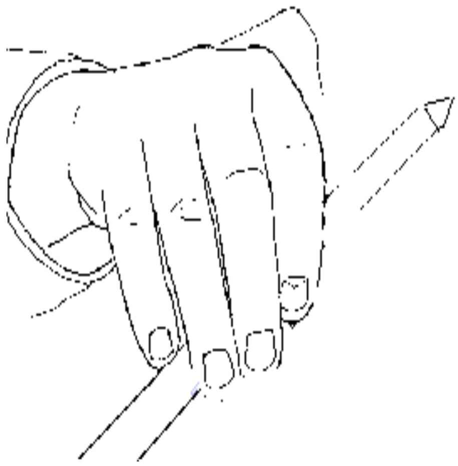

Fig. 2: The performer holds the stylus (pen) in the same way a violinist holds a bow.

By tracking the position of the pen along the horizontal axis of the tablet, we can calculate its corresponding velocity, and use this to represent the velocity of the bow on a real instrument.

In the same way, tracking the position in the vertical axis, we map this parameter to the bow position regarding the string: the bottom part of the tablet corresponds to the bridge, while the upper part corresponds to the nut.

Moreover, since the pen is pressure sensitive, it is straightforward to map this parameter directly to the bow force exerted by the player on the strings. Thus, all of the relevant output parameters coming from the stylus can be easily mapped to the violin model's control inputs by scaling the parameter values linearly.

One of the most interesting properties of a bow is its ability (in the hands of a skilled performer) to create a wide variety of articulations. Attacks can be very light or rather strong, while a bow stroke can be very short or take the entire length of the bow, moving very quickly or incredibly slowly. Dynamics are also a result of the performer's bow technique; accents, changes in velocity and amplitude can make a musical composition come alive.

All these differences in expressivity depend on relationships between the movements of the musician and the way he uses his body to communicate energy to the instrument.

For example, in a fast attack the violinist moves his arm in a decisive way, creating a high velocity and short burst of pressure against the string.

On the contrary, in order to obtain a *pianissimo,* the violinist has to hold the bow very lightly with his fingers, and move it softly and slowly on the strings. The resulting sound also depends highly on the way the violinist holds the bow: some bow strokes require the bow to be kept firmly by all the fingers, while others require the musician to exert a light bow pressure, sometimes even just slightly brushing the string with the bow hair in order to create whispering sonorities.

One of the main advantages of using the pen transducer is that it can be used similarly to the way a violinist uses his bow. Using the pen we are able to reproduce the playing techniques commonly performed by violinists; the relationship between both the performer's bow movements and the resulting sound is maintained.

Bow strokes

We will now examine some of the most common bow strokes, to see how the model produces them.

In the following bowing descriptions we use the word *pen* instead of *bow*, since we are referring to the model, although the movements would be the same for either.

Détaché

The pen produces sound by keeping contact with the tablet; the changes of the pen's "bowing" direction are almost imperceptible.

Legato

This is similar to the détaché. The difference is that more than one note (pitch) is played while the pen is moving on the same direction of the tablet.

Martellato / Martelé

This is a rather energetic bow stroke, obtained by moving the pen quickly along a small portion of the tablet. Despite the origins of this stroke's name ("hammered"), the pen does not strike the tablet from above, but rather begins and remains on the tablet's surface.

Staccato

This consists on a series of martellato notes where different notes are played in the same direction.

Balzato / Spiccato

This bow stroke is a kind of martellato where the pen rebounds off the tablet at each note, as if it were "jumping" on the tablet.

When a bow bounces on a violin string, the string itself (due to its elasticity) reacts to the force produced and provides some energy to the bow, helping it bounce again.

Unfortunately this effect is lost when using the tablet, since it is a rigid surface. As a result, the performer does not get the same type of kinesthetic feedback from the tablet as he would when using a real instrument.

Flying staccato

This stroke is a variation on the common staccato (above), in which the pen leaves the tablet from one note to the other. As with staccato, the pen does not change direction from one note to another.

Ricochet / Jeté / Saltando

The pen is allowed to fall and freely rebound against the tablet.

As with the spiccato, the tablet's rigid surface does not yield to deformation as would a string. The energy provided by the string assists the bow's rebounding motion, and is felt by the violinist. The pen and the tablet do not provide the performer the same elastic feedback.

Tremolo

This stroke's name derives from the fact that the movements of the pen are so short and fast that it seems as if it were trembling. It is basically a highly accelerated variation of détaché (above).

The way the performer's movements relate to the bow-stroke and the resulting sound is summarized in table 1. Note that f_b, v_b and p_b represent bow force, bow velocity and bow position respectively.

Until now we have only described bow strokes which relate to movements along the tablet's horizontal axis. If we observe the movements of a violinist, we notice that it is necessary to change the inclination of the right hand to switch from one of the four strings to another.

Since the tablet is able to detect the inclination of the pen, this "tilt" parameter can be mapped to the string currently played.

The pen's inclination ranges from –60 to 60 degrees. We are interested only in the values between 20 and 60 degrees, that represents approximately the range of the angle between the bow and the surface of the violin.

A value of 60 degrees corresponds to the bow playing an E string, while a value of 20 corresponds to the bow playing a G string.

Movement	Parameters	Bow stroke
The bow is always in contact with the string moving back and forth. The left hand changes notes only when the right hand changes direction.	Small variations of vb and fb, pb in between the bridge and the fingerboard	Detaché
The performer changes the fingers (left hand) while the bow continues moving in the same direction.	Small variations of vb and fb	Legato
The performer lets the bow "jump" back and forth against the strings	Fb impressed regularly once in each direction.	Balzato / Spiccato
The bow is allowed to bounce against the strings, until it comes to a rest.	No initial fb or vb impressed by the performer.	Ricochet / Jeté
The bow moves back and forth, stopping once in each direction, leaving space between the notes.	Strong attack (high fb and vb) then the player follows the bow	Staccato

The position of the bow while playing the four strings is shown in figure 3.

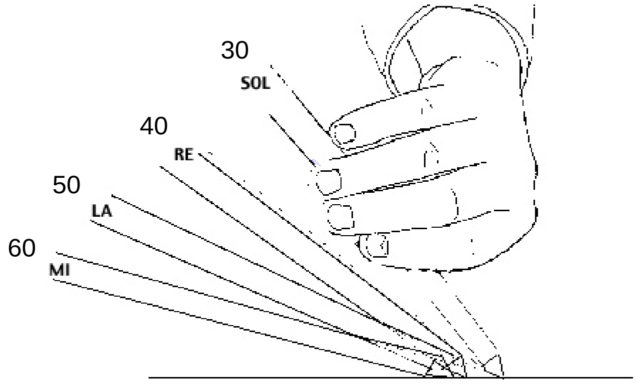

Fig. 3. Different angles that correspond to the strings the pen is "playing"on the tablet.

Another parameter that has not been discussed until now is the position of the pen along the tablet's vertical axis. In the model this parameter corresponds to the position of the bow along the length of the string.

By changing this value we can play over the fingerboard or near the bridge. Naturally, the amplitude and timbre of a note are strongly related to the position of the bow along the length of the string.

A model for the left hand

We take advantage of the fact that the tablet is able to detect two transducers simultaneously in order to also control the "left hand" of our violin model, which is mainly responsible for pitch changes, vibrato and glissando.

We have experimented, and continue to experiment with different tools, such as the puck and pen.

The pen has the advantage that it can sense pressure and tilt angle; pressure could be used to indicate the playing of a natural harmonic on the string and tilt could provide the slight back and forth motion necessary to perform vibrato.

Since we consider the tablet’s vertical axis to represent the length of the string, and that the four strings are virtually placed from left to right, we could simulate a glissando via a continuous movement of the "fingering" pen along the vertical axis; a movement along the horizontal axis thus represents a change of string.

An inconvenient of these transducers is the fact that, supposing that the tablet represents the fingerboard, the direct contact of the performer with the instrument is lost: while in a violin the left hand of the musician moves on the strings, in the case of the tablet this is not possible.

To solve this problem, in [4] is proposed to add to the tablet sensors that can measure position and force, which allow to maintain the same degrees of freedom as in a violin.

Combining the two hands

Coordinating two hands at the same time is not as simple as it would initially appear. Those who have studied violin (or any other musical instrument for that matter) will know that it takes quite a long time to learn how to control and move the fingers of both hands independently yet simultaneously.

The model, for example, must be able to recognize that when the inclination of the right-hand tool corresponds, let’s say, to a G string, while the left-hand tool is moving on a E string, the resulting sound must be the one of an empty G string.

Changes of pitch take place just when the left and right-hand devices are both acting on the same string.

The Wacom tablet does not currently allow the use of more than two transducers at once, so we are obliged to use one for the bow and another for the left hand. It would be interesting to be able to add transducers for each finger of the left hand, in order to produce chords or simply play the instrument comfortably with the use of all fingers, as with a real instrument.

Final considerations

In this paper we have proposed a controller for a bowed string instruments, the Wacom tablet. The tablet has the advantage of having become a common accessory especially in the field of computer graphics. The fact that the gestures of the violinist can be captured and reproduced with fidelity makes it an interesting choice as a controller for a virtual bowed string instrument.

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