New developments in the O-bow

Abstract
A bow controller is presented, for the performance of string-like synthesized music. While several related controllers have appeared before, all have had various drawbacks that have prevented widespread adoption despite the many possible uses. The original has been developed into a new prototype that is presented here for the first time. The improvements and their implications for the use of the bow will be discussed.

Keywords
Music controller, string instrument, music synthesis, human-computer interaction, tangible interface

Introduction
The string instrument family has some of the most intricate and refined human-machine interfaces, permitting a very wide range of musical expression. It is natural to wish to emulate this interface electronically in the same way that electronic keyboards are used to emulate acoustic keyboard interfaces. This can introduce new artistic possibilities: new sound behaviours, interface variations, as well as new practical possibilities: reduced size, flexibility, reduced acoustic feedback. String playing is recognized to be very difficult requiring years practice. Should electronic emulations necessarily be so difficult, or can they permit an easier route, without compromising much an the range of expression possible?
Previous examples of bow controllers have not been able to emulate the bow interface with sufficient precision and practically to lead to widespread adoption. They all require specially instrumented bows either optically prepared or fitted with electronics or binding mechanical linkages [2,3,4,5]. Also an important aspect of string playing is vibrato and fingerboard work, and it is not clear how these can be integrated into an electronic interface that is not very difficult to play.

The O-Bow [1] is a musical bow controller consisting of a sensor unit with a saddle shaped guide in which a bow is stroked. A mouse-type optical sensor positioned under the saddle measures the movement of the bow via an aperture. A wide variety of bow types can be used including unmodified acoustic string instrument bows. The saddle also permits some rotation of the bow in a horizontal plane while bowing. The angle of bowing can be found from measurements and used to control vibrato intensity. This allows vibrato and bowing to be integrated in one hand gesture, which proves to be natural and effective in practice. The other hand is left free for note and pitch slide control using a keyboard controller or other device, and avoids direct vibrato. The mechanical linking of vibrato and bowing works well from a human interface perspective because these controls are naturally correlated in musical phrasing.

The variety of simple bows that can be used, the integration of vibrato control, and the simplicity of the sensing mechanism make the O-bow attractive in comparison with existing designs. No down force sensing is incorporated, although this would be possible. In an acoustic string instrument down force has to be controlled carefully to maintain a good quality tone, which makes control much harder. If the importance of this parameter is reduced in the electronic emulation then control can be simplified while maintaining a high expressive capability.

![Figure 1. O-bow shown with holder and bow in place.](image)

Despite the promising results achieved with the first prototype, there were many shortcomings. The sensor was unable to reliably track realistic string playing. The case form factor had only been crudely developed, exacerbating the control and tracking problems. Also little thought had been given to the different ways the O-Bow could be used and how this impacts on the overall design.
New Developments
The main areas of recent development are as follows:

- The sensor electronics and firmware has been completely redeveloped (The original used adapted mouse electronics). Several sensors were tested to find one with the highest speed sensing, lowest measurement noise and the widest sweet spot for bow position relative to the sensor. The firmware in the host microprocessor was optimized to output measurement values over USB with low jitter. The measurement smoothness and response are critical to being able to produce convincing bowed sound control. Small amounts of noise disrupt the perception of this. The Kontakt script contains adaptive filters that dynamically vary in order to provide the best balance of smoothness and response at any time. The sensor electronics is able to approximately measure the distance of the bow above the saddle in addition to horizontal movement. This is used to detect the contact state, and the rate of change of bow distance above the saddle, both useful for new synthesis features described below.

- The synthesis software was originally prototyped using Max/MSP [6] by and is now implemented using the Kontakt [7] script language. This allows larger numbers of samples to handled more effectively and flexibly. In particular free string release sounds are produced when the bow is lifted quickly from the saddle, using the sensing method mentioned above. Kontakt allows the synthesizer to be easily incorporated as a plugin in any Digital Audio Workstation environment, allowing multi-track workflow and editing of raw bow performances. Some features have been added that affect the overall behavior of the synthesizer, besides those in the prototype, including a speed warping control. This is similar to velocity mapping for keyboard instruments, determining how gain varies with speed, and allowing the feel of playing to be easily altered. The feel can also be altered when a recorded performance is played back, as part of the overall mixing and editing process.

- The shape of the bow saddle has been carefully designed with Computer Aided Design software to allow positive engagement and horizontal rotation over a range of angles without skidding or significant lift of the bow away from the sensor. This helps maintain the bow in an optimum position for tracking. For prototyping a copper tube is used, as this is soft enough for the saddle to be formed by pressing with shapes that have been CNC’d using the CAD design. Copper also permits the thin walls required by the optical arrangement.
- Design of case shape: A cylindrical form factor allows free orientation by rotation in microphone-style holder. Using a standard microphone holder allows it to be adapted to a variety of stands and suction clamps.

**Conclusion**

The improved O-bow has addressed the limitations of the original: The tracking is now smooth and responsive for a wide range of surfaces, and can follow rapid string playing. The mechanical feel is positive and engaging, and the form factor allows it to be used in a wide range of configurations. The synthesis now supports bow release sounds, which greatly adds to the realism.

Future work will focus on further developing the synthesis for high quality string sample sets, and consolidating the various options for synthesis and the bow response. Also methods will be investigated for reproducing the casing using aluminum casting and extrusion techniques, to simplify production. Looking further ahead, down force sensing can be incorporated, leading to a variety of control modes from beginner to expert. Linking new control parameters progressively into the synthesis engine makes the instrument more difficult to play but potentially also more expressive. Providing a graduation of difficulty could help the learning process, and even provide a path to acoustic string instruments.

The O-bow has attracted interest from a wide range of people including professional live musicians, studio producers, amateur musicians, educators, disabled musicians. Plans are in place to further develop this device so that it can be made available soon to as many people as possible.

**References**


[6] [http://cycling74.com/](http://cycling74.com/)