The T-Stick: From Musical Interface to Musical Instrument

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ABSTRACT

This paper describes the T-Stick, a new family of digital musical instruments. It presents the motivation behind the project, hardware and software design, and presents insights gained through collaboration with performers who have collectively practised and performed with the T-Stick for hundreds of hours, and with composers who have written pieces for the instrument in the context of McGill University's *Digital Orchestra* project. Each of the T-Sticks is based on the same general structure and sensing platform, but each also differs from its siblings in size, weight, timbre and range.

Keywords

gestural controller, digital musical instrument, families of instruments

1. INTRODUCTION

In addition to the challenges of the ubiquitous "mapping problem," Digital Musical Instruments (DMIs) often have a number of other limiting characteristics. Even the more robust are often fragile compared to traditional acoustic instruments, and almost always the designer/creator must be present at all demos, practise sessions, and performances. Of course, sometimes the designer *is* the performer, but it is notable that this does not encourage the construction of DMIs that are mature enough to "leave home." Also, DMIs are often unique, which makes for interesting demos, but how does one learn to play them? Surely the process of learning to play one new interface would help when learning a second, leading to some useful pedagogical generalizations (as in [13]), but what if the next DMI you picked up belonged to the same family as one you already knew how to play?

In this paper we present the T-Stick, a new DMI designed and built to explore and gain insight into some of these problems. Like many DMIs, the T-Stick aims to be an interface for "expressive" musical performance, engaging to new users, but rewarding to practice. The difference with the T-Stick, however, is that it is intended to be a *family* of instruments, each of which varies from the others while still conceptually belonging to a group. Some new interfaces seem to belong to a family (the *Squeezevoxen* [2], for example), yet often the members are essentially design iterations, with each one aiming to improve on the last, rather than coequal members of an ensemble or consort. Currently, two T-Sticks have been completed, and two more are planned to form an experimental quartet.

Two existing interfaces are similar in shape to the T-Stick: Ray Edgar's *Sweatstick* designed and built at STEIM [15] and Rags Tuttle's *Musicpole* [11]. This resemblance does not carry over to sensing-methods, mapping, performance-practice or design intention.

2. MOTIVATION

The Mapping Problem: Hunt et al., among others, pointed out that with DMIs, unlike acoustic instruments, mapping between gesture and sound parameters must be defined, and that this task is extremely difficult [4]. There is no doubt that the mapping largely defines the user interaction and experience, and can "make or break" a potentially interesting user interface. The mapping used for the T-Stick aims to use the familiarity of the physical world in the same way that instrument-like and instrument-inspired controllers are said to leverage pre-existing performer skill. The T-Stick does not deliberately mimic any existing instrument, but it does have a distinctive "feel" (weight, shape, and texture). Can we augment this with audible feedback? Can we use a logical approach to physical sensing of an object to create a kind of inherent integrality [5] in the sensor data output? Is it possible to implement mapping such that the controller itself is suggestive of the interaction possibilities and sound output? A long cylindrical object was chosen, and seemed to suggest certain gestures that would be consistent with excitation, modification, and damping of sound if the object were actually physically vibrating. Sensing these gestures required subtle touch sensing: pressure, area, pinching, damping, sweeping, striking, brushing would all be possible if the entire length of the gestural controller was able to sense multiple touches, and distinguish between the touch of a hand and that of a single finger.

What constitutes a family of instruments? Some cite spectral and temporal features of the sound as the most important metric [3], where others might consider only the user-interface (i. e. "keyboard instruments"). Choi focuses on mapping as the key, considering the collection of local relationships between movement-space and sound-control-space, and the collection of idiomatic gestures learned to navigate stable areas of these relationships, to be the determining factor [1]. There is not a consensus on this issue, however we are more concerned with performer and audience perception than with terminology, and experimentation is planned in which mapping, synthesis, and sensing are altered alone and in combination.

How does all this affect performance practice? Success would mean that a prospective performer could quickly and easily begin to make sense of the interface, using only their experience of the physical world. The next stage will be to see if performers can transfer their learned skill to the playing of another member of the T-Stick family.

Largely, design and construction of the T-Stick is aimed at producing an interface that performers can take away with them, connect with no supervision, and then practise or perform for many hours a day without the device wearing out or breaking.

3. CONSTRUCTING THE T-STICK

3.1 Hardware

Structurally, the T-Sticks are built using sections of ABS plumbing pipe, with a 5-centimetre diameter, and varying in length depending on the member of the T-Stick family (the original prototype is 1.2m long). The pipes are cut in half length-wise in order to place sensors, circuitry, and wiring inside, with sensors affixed to the inside and outside of this base. The structural part of the interface is intended to provide a robust platform that protects the sensors from damage or wear: it is strong and a shrink-tubing cover makes it mostly water-proof. Covering the sensors and circuitry also makes the controller less intimidating to performers who are not technically-savvy, since the only technology apparent is a USB plug and a single power-status LED. If repairs need to be made, it is simple to slice and remove the shrink-tubing cover.

An adjustable steel spike of 0.5 metres in length was installed in the first T-Stick model, enabling the controller to be rested on the floor at a comfortable height and performed in a posture somewhat similar to that of a 'cellist (figure 1). When retracted, the spike slides smoothly into a rubber sheath inside the controller, preventing it from rattling or touching sensors or circuit-boards. Since it adds considerable weight to the controller, the spike is also easily removable if the performer does not wish to play in this way.

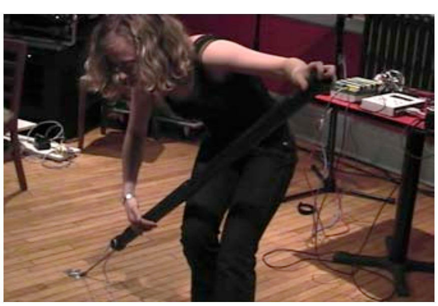

Figure 1: Xenia Pestova playing the T-Stick in "cello" position during a concert.

3.1.1 *Sensors*

The T-Stick makes use of a variety of sensors to transduce performer gestures. One half of the pipe (divided length-wise) is covered with numerous discrete capacitive touch sensors (48 in the first prototype and 32 in the second) formed with 1/2" copper tape electrodes and Quantum Research Group QProx QT161 charge-transfer sensor ICs. Together, these sensors form a low-resolution, completely multi-touch position sensor spanning the length of the controller (figure 2). Since the field sensitivity of the QT161 ICs must be set using external capacitors, and varies with the size, shape, and thickness of the key electrodes, experiments were performed using a T-Stick mock-up to find the right capacitance, and the field sensitivity was set so that a touch would be detected approximately one millimetre above the surface of the copper tape electrodes. The QT161s are run using 20MHz crystal oscillators rather than the standard 10MHz in order to increase the responsiveness of the controller.

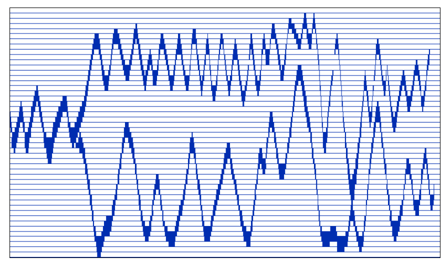

Figure 2: Graph in Max/MSP showing multi-touch data over time: two hands brushing the controller.

The circuit boards at each end of the controller each include an STmicro LIS3L02AS4 3-axis accelerometer. One of the axes is left unconnected on one accelerometer, since it is duplicated by the other sensor.

Two home-made paper-based pressure sensors (designed and built by Rodolphe Koehly [6]) were fixed to the other half of the pipe, with enough space between them, and at each end of the controller, for a hand to comfortably grasp the pipe. The pressure sensors are covered with several thin layers of closed-cell foam to provide proprioceptive feedback from what are essentially isometric sensors.

Lastly, a simple piezoelectric crystal is used as a contact microphone to sense acoustic jarring, bending, and twisting of the pipe. It is fixed with epoxy adhesive to the inside of the front surface of the controller (that containing the capacitive touch sensors).

Sensor outputs are wired to an Atmel ATMEGA16 microcontroller for sampling, data formatting, and USB communication of the sensor data with a laptop computer [8]. The microcontroller also controls the multiplexers on each capacitive-sensor circuit board.

Finally, the two sides of the ABS pipe are placed together, and the entire structure is covered with shrink tubing, providing both increased strength and protection against wear-and-tear on the copper strips.

3.2 Software

A framework for Max/MSP software design was developed based on the "abstracted mapping layers" proposed in [16] and [4] (figure 4). A more complete discussion of mapping issues and a specification of the implemented solutions is

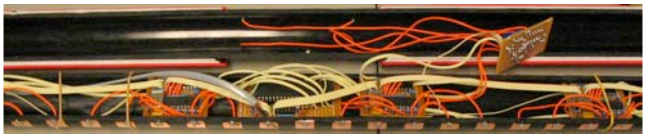

Figure 3: A view of the circuitry inside the original T-Stick prototype.

available [7]. It is easiest to explain the software developed for the T-Stick in the context of this framework:

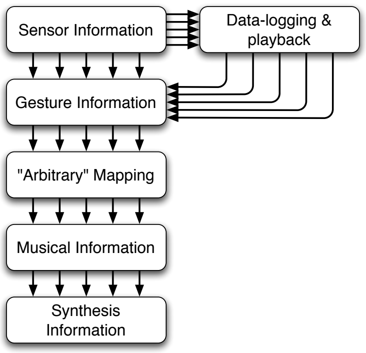

Figure 4: The software framework used for the T-Sticks and other McGill Digital Orchestra DMI's.

Sensor Information: This layer simply acquires data from the connected device and performs simple signal-processing operations such as scaling and smoothing to remove jitter. Since the digital signals from the capacitive sensors arrive via USB time-multiplexed in six 8-bit bytes, it is necessary to unpack them into the individual sensor outputs and route them appropriately. Every third capacitive key on each half of the controller is addressed simultaneously by the micro-controller, and is read as a single byte.

Gesture Information: This layer corresponds to "body-centred data" in [9] and is derived from the sensor data provided by the sensor layer. As an example: the sensor layer outputs the demultiplexed capacitive sensing data, which takes the form of a list of 48 digital values (0 or 1). The gesture layer uses this information to calculate higher level features, and outputs the centre, width, and velocity of each "area" touched (a series of consecutive capacitive sensors which have detected touch). This data indicates the movement of the performer's hands, rather than the state of the sensing platform, and is also used to sense gripping, brushing, and damping gestures.

Arbitrary Mapping: This layer is where the character of the musical interaction is determined. Mapping inputs to outputs in this layer is essentially arbitrary in that the data itself does not contain information about what it should do. Mapping at this level could be seen as a matter of personal taste or bias, however in the case of the T-Stick a commitment exists to make the mapping reflect a kind of physically-informed interaction model, in which a user should be able to quickly construct a personal model of "how it works" – a task which is not trivial [4]. It should be noted that mapping abstracted gesture- and music-layers, rather than the sensing and synthesis parameters, intrinsically adopts a *many-to-many* mapping strategy [4] [16]

Musical Information: This mapping layer makes abstracted, higher-level musical parameters available as mappable controls. Rather than dealing with frequencies, envelopes, modulation indexes, this layer takes more abstract musical parameters as input, such as pitch, timbre, and dynamics.

Synthesis Information: The last layer is responsible for actually generating audio. Its inputs are specific to the synthesis method used, and may be highly technical. For the T-Stick, sound-synthesis has taken many forms during development, including control of the *Sculpture* software synthesizer [12] but more recently using custom-built granular and modal software synthesizers.

Data-logging & playback: This area of the patch is not a mapping layer, but rather a means to record the gestures of a performer and then replay them through the other layers for refining and adapting the mapping. This allows "off-line" editing of the patch when the performer is not present.

4. PERFORMER COLLABORATION

Much of the T-Sticks' development took place in collaboration with performers in the context of two organised sessions: a seminar taught at McGill, and as part of a larger project entitled the *McGill Digital Orchestra Project* [10]. Many design decisions were made in consultation with performers, such as decisions on the lengths of pipe to use, the spacing of capacitive sensors, the foam thickness over the pressure sensors, fret height, the location of fret markers, and the length and location of the pressure sensors.

The performers also worked very hard helping to establish notation standards and a vocabulary of gestures idiomatic to the interface. They lost no time in discovering and making use of new playing techniques: subtle twisting of the gestural controller (which deforms the piezoelectric sensor intended for sensing velocity of bumps and hits) has now become a "standard" part of T-Stick performance practise and pedagogy.

4.1 Performances

To date, the T-Stick has been performed publicly four times in concert and numerous times in formal and informal demonstrations. Most recently, on November 19th 2006, percussionist Fernando Rocha performed a ten-minute piece written for the T-Stick in a lecture-recital (figure 5). Rocha also discussed his experience with the T-Stick in [14].

Three short pieces have been written for the DMI by student composers, two by D. Andrew Stewart and one by Aaron Lindh. Both worked with the performers to develop standards for notating music for the T-Stick. The Digital Orchestra Project (mentioned above) will culminate in performances of new works during the 2008 MusiMarch Festival in Montréal, in at least one of which the T-Sticks will form part of the ensemble.

5. DISCUSSION: DON'T FRET

The first T-Stick featured small fret-like protrusions, between the positions of capacitive sensors, to allow tactile navigation of the sensing surface. Some frets were marked for quick visual navigation, similar to the way harps use red

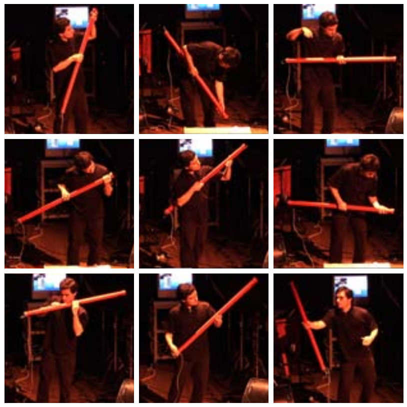

Figure 5: Fernando Rocha performing the T-Stick in concert. Note the different playing technique compared to figure 1.

and blue strings for the pitch-classes C and F. Many different materials were tested to find the right feel through the shrink-tubing cover, allowing easy tactile navigation without preventing the use of smooth brushing gestures.

The second T-Stick does not feature these frets, however, as it was deemed that their presence encouraged users to perceive the capacitive-sensing surface as 48 discrete touch sensors rather than a low-resolution multi-touch position sensor. As discrete touch sensors, each capacitive sensor is not very well suited to musical control, especially as they lack independent velocity sensing - as a single multi-touch sensor, however, mapping and performance becomes much more interesting and potentially expressive. Without the frets, the location of the copper strips is hidden from the user by the covering of shrink-tubing.

It is hoped that removing the knowledge of sensor positions will benefit future mapping implementations, as well as encourage the performers to concentrate on the object (the interface) or the resultant sound, rather than the sensors. It may seem like a small issue, but considering that the motivation for building the T-Stick was to use intrinsically integral sensor data (by attaching many sensors to one simple object), using the 48 capacitive sensors separably is essentially opposite to the design intentions.

An interesting dilemma arises: can the present performers learn to forget their habit of viewing the multi-touch sensor as a sort of slow, non-velocity-sensitive keyboard, or are fresh performers required for studying interaction metaphor and the T-Stick?

6. FUTURE DIRECTION

Although the T-Sticks are gaining maturity in that they have been played for hundreds of hours in the lab, practise room, and on the concert stage, there are many changes and improvements to be made. On the purely technical front, iterative improvements to sampling rates, data throughput and position-sensing resolution will likely improve the performer-experience greatly, without dramatically affecting the techniques they use. More profoundly, the future completion of the entire quartet of T-Sticks promises insight into the portability of skill between members of the family. How great a change can we make to one T-Stick before "breaking" the perception of family resemblance? Is it enough to change one characteristic (i.e. size, shape, sensing, sound)? The challenge becomes mapping and giving voices to the members of the T-Stick family in such a way that they are complementary musical instruments rather than redundant copies with superficial differences.

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