IDMIL Engage report: SANDDE

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1 Introduction

The goal of this project was to explore enhancement of user interaction with the SANDDE software from Janro Imaging Labs by means of haptic feedback. SANDDE is a 3D painting and animation application which uses a 6-DOF input device to control a paint brush in a 3D workspace. Painted lines are rendered as textured paths in the workspace.[1]

This research took two main branches: the enhancement of input devices already used for SANDDE by means of attaching a vibrotactile actuator; and the addition of support for force feedback haptic devices to SANDDE. In this report we will describe what was implemented in each research branch and give a brief overview of comments from JIL employees as well as other members of the SANDDE researcher community.

2 Preliminary work

In initial discussions with JIL, it was decided that experimental work could be accelerated by integrating *libmapper* [3] support into SANDDE, a mapping and communications library developed at the IDMIL.[2] In fact, SANDDE already provides a flexible mapping interface that allows to arbitrarily connect input device signals to any control in SANDDE, including "wand" position and orientation as well as brush properties such as size and opacity. However, it was suggested that a network-oriented system such as *libmapper* could benefit the project, since it helped to decouple our respective software projects; for example, vibration and sound design could be performed in PureData [4], a visual language oriented towards audio computing.[3]

Therefore, JIL employees developed a SANDDE plugin module which exposed SANDDE's "agent" inputs and outputs as *libmapper* signals which could

[1] `http://sandde.com`
[2] `http://idmil.org/software/libmapper`
[3] `http://puredata.info`

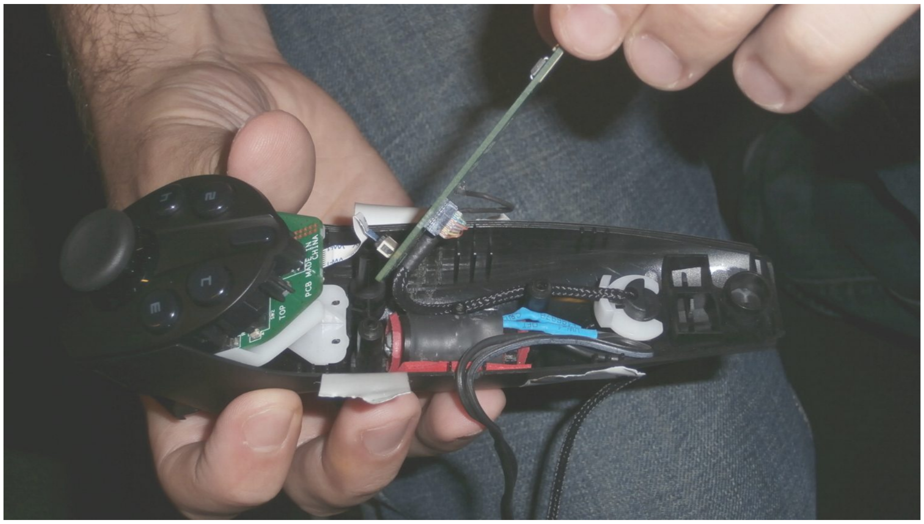

Figure 1: The Haptuator embedded within the handle of the Razor Hydra. (Photo by: Rebecca St. John, JIL, reproduced with permission.)

be connected to external processes and modified online via the *libmapper* GUI, allowing efficient experimentation with mapping choices.

The SANDDE mapping system allows to map both continuous signals, such as brush properties, as well actions, such as changing modes, to events from any input device. The *libmapper* plugin additionally exposes all brush properties, as well as any controller signals such as wand position and orientation, to the network as OSC streams. Thus any *libmapper*-compatible program can equivalently act as a SANDDE input device, influencing SANDDE brush properties, or, conversely, react to SANDDE's own input devices and brush states.

3 Vibrotactile feedback

The *Razor Hydra* is a low-cost, magnetic controller, originally designed for gaming, that features 4 discrete buttons and a continuous trigger. Its low cost and ease of use has led to its position as the *de facto* standard controller for new artist/animators working on SANDDE. For these reasons, we decided to focus exclusively on this device and augment it with vibrotactile feedback capabilities.

A commercially-available vibrating actuator (the *Haptuator* [6], Tactile Labs) was embedded into the device handle, taking advantage of the space available inside the controller, see Fig. 1. This actuator was chosen primarily for its cylindrical shape, which happened to fit perfectly into the body of the Hydra. Moreover, it is an actuator designed for haptics, having mechanical behaviour essentially similar to a loudspeaker, and this allowed us to use more complex signals for the tactile feedback than what would have been possible with a simple eccentric mass motor. It supports a frequency range at least between 10 and 500 Hz.

The actuator is driven using an amplified audio signal, synthesized in PureData, on the same computer running SANDDE. Thanks to the *libmapper* plugin, the brush's position and orientation and the state of the discrete and continuous buttons on the Hydra could be streamed directly from SANDDE to PureData. This gesture-related data was used as control parameters for the synthesis of the vibrotactile events.

The vibration effects we implemented aimed to give the user a sense of "presence" i.e. overcome the lack of feedback due to the fact that the SANDDE artist is drawing using an ungrounded controller. Two different types of interaction have been designed:

- **Spraycan Simulation**: One particular brush available in SANDDE reproduces the behaviour of a spraycan by randomly splattering bits of paint along the line being drawn. We decided to reproduce on the Hydra the physical vibrations coming from a real spraycan: using a contact microphone applied on a spraycan, the vibration produced when spraying paint was recorded.

  In PureData, the gesture data from SANDDE was used to control parameters of real-time filtering and amplitude modulation on the recording. Played through the actuator, this reproduced the vibration of a real spraycan which qualities changing in real-time according to user gestures. For example, the continuous trigger control present on the Hydra was mapped to the amplitude parameter, simulating a stronger vibration due to a bigger flux of paint from the spraycan nozzle.

- **Impulses**: The second effect we implemented is, in some sense, more abstract than the previous one, and is applicable to any brush available in SANDDE.

  Using the brush-position data, we performed an estimation of the brush velocity in PureData, and use this parameter to modulate the frequency of a pulse train sent to the actuator. The impulses were synthesized using a rectangular wave with a 1% duty cycle, and the frequency was directly mapped to the Hydra velocity.

These simple effects allowed us to give the Hydra user information about his interaction with the 3D canvas, making the controller react in a meaningful way according to his/her gestures.

We should note that some complications were found in noticing that the *Haptuator* could distort the Hydra's position sensing if stimulated by a high-frequency signal, presumably interfering with the electromagnetic sensing coils which are situation close to where the actuator was installed. This problem was mitigated by the use of a low-pass filter, which additionally had the benefit of reducing the audibility of the vibrations. In a permanent installation, it could perhaps be possible to alternate sensing and actuation signals to avoid this problem, or simply ensure that their distance is sufficient to avoid interference.

4 Force feedback

Two force feedback devices were selected for use with SANDDE, comprising a low- and a high-performance choice, so that these could be compared as representative of the range of possible qualities in force feedback devices.

The low-performance device selected was the Phantom Omni (SensAble), which has 6 degrees of freedom (DOF) sensing, and 3-DOF force capability. The high-performance device was the Freedom 6S (MPB Technologies), a 6-DOF force/torque serial mechanism. Both devices comprise serial arms with 6 axes of motion, and have a comparable size of workspace, and comparable motor strengths. They differ, however, in materials and sensing ability. The Freedom 6S is physically bulkier but has a sensing precision of about 0.002 mm, compared to 0.055 mm for the Omni.

A *libmapper*-enabled program for controlling the haptic device was developed using the *CHAI 3D* C++ library [1], which abstracts the device-specific API, allowing us to develop a force-feedback servoloop that works with any of several haptic devices, and includes support for our set of devices.[4]

Several haptic "effects" were developed for this software. While we emphasized effects that were specific to force feedback, such as friction, we also included, for comparison, several vibration-style effects that could be similarly implemented using a vibration motor only. The final list of effects was,

- Friction (Hayward-Armstrong friction [2]),
- Damping;
- Spring;
- White noise;
- Velocity-dependant noise;
- Poisson noise.

These effects were parameterized typically by a single parameter reflecting the strength of the effect, i.e. the maximum force of dynamic friction, the damping coefficient, the spring coefficient, etc. The spring anchor could be "triggered" by switching a parameter from 0 to 1. The Poisson noise effect had two parameters: the maximum amplitude of impulses, and the maximum time between impulses.

All effects were constantly calculated in the feedback loop, and therefore could be presented together by specifying non-zero strength for more than one effect. This allowed a degree of "mixing and matching" during mapping design. For instance, it was possible to combine the friction and velocity-dependant noise conditions for a "chalk-like" effect, or the spring and the damping to achieve a damped spring. Finally, some mapping choices were made and a selection of

[4] `http://chai3d.org`

these was turned into a demo application allowing quickly changing from one preset to another.

Two controls were mapped to brush parameters in SANDDE: the velocity of motion, and the continuous "squeeze" position of the brush trigger. For the latter, since the Freedom 6S does not feature a switch, the user instead held a Hydra handle in his left hand and initiated drawing with its trigger. The Phantom Omni does feature two binary switches, but these do not afford continuous control, so the Hydra was also used in that case as well.

Some mapping configurations demonstrated were:

- Damping combined with noise, whose amplitude was mapped to velocity;
- The squeeze position mapped to noise amplitude;
- The squeeze position mapped to Poisson time and amplitude;
- Simultaneous mapping of spring and damper effects;
- A spring whose strength was controlled by the squeeze position.

It was intended that in the future some of these mappings could be selected for specific SANDDE brushes, or specific effects mapped more meaningfully to SANDDE brush parameters; for example, the noise could be mapped to the granularity of the spray can, while friction could be mapped to opacity or brush size. Over time, an artist could begin to recognize the distinct feel of particular brushes.

5 Community feedback

The work we accomplished was presented during one of the regular "SANDDE Research Group" meetings; researchers from a number of universities, all working on SANDDE-related projects, had the possibility to experiment with the haptic feedback. This moment was important to this project since we ourselves were not as familiar with usage of the SANDDE software as other researchers and artists. We were eager to have someone using SANDDE on a daily basis give us his/her impressions about the force and tactile effects.

For what concerns the vibrotactile feedback, users remarked that the feedback in both conditions improved their overall sensation about the interaction with the 3D canvas. According to their comments, the vibration feedback managed to convey a sense of presence and physical interaction that made the experience more real, offering at the same time a greater degree of control.

Some users in particular noticed that the velocity-based "Impulses" effect produced the sensation of a physical grid embedded into the 3D canvas which they positively evaluated as being helpful for finding their bearings during the interaction. This suggests perhaps that a 3D grid effect could be explicitly designed, and may help users orient themselves in the space.

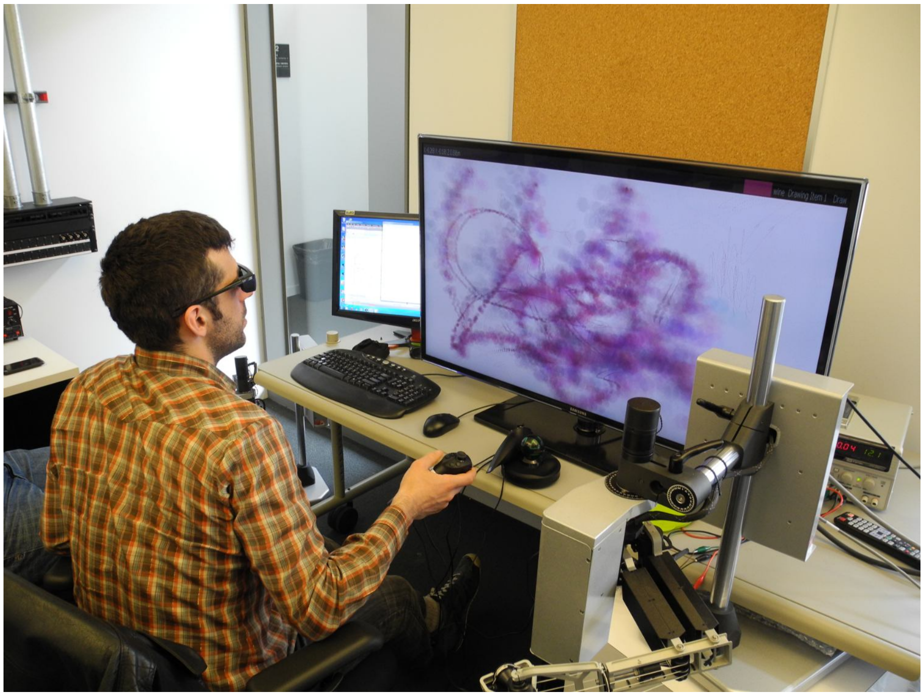

Figure 2: David Seitz interacting with SANDDE using the enhanced Hydra at CIRMMT. The Freedom 6S is present in the right-hand side of the photo.

For force feedback, the Freedom 6S device was used to demonstrate the conditions. People enjoyed using the kinematic controller, and seemed to understand intuitively the connection between their movement and the haptic effects.

The demonstration spawned a few ideas in observers, such as an idea for using spring-like constraints to provide a 3D surface on which to paint, or dynamically moving a “paper”-like surface along with the wand position and orientation in order to provide 2D-like resistance in a 3D environment. These ideas could be tried in a future iteration of the project, since they would require some development.

The general feeling from JIL and researchers was a desire to have SANDDE artists use it for a more extended period of time in order to better evaluate the conditions and also to construct more appropriate mappings to typical softare usage patterns. Such a session was organized, and is described in the next section.

6 Mappings developed in collaboration with JIL

After the research group meeting, an evaluation and mapping session was organized with David Seitz, a JIL artist, which took place on Sept. 21 at CIRMMT. As a SANDDE expert user, David provided interesting observations and also collaborated to develop some mappings for each of our hardware choices that integrated well with his working style. This session, of which a photo may be found in Fig. 2, turned out to be fruitful, since, interestingly, his preferences as a practised user of the software sometimes differed from our initial expectations.

For the vibrotactile condition, another configuration was found in which the spraycan effect was used during painting, while the pulse train effect was used in Nudge mode, a feature of the software that allows to manipulate lines after they are painted. In this case the feedback transmitted not only gestural information, but also communicated modal information to the user. By varying the pulse train frequency with velocity during nudging, an interesting sensation of "bending effort" seemed to be achieved, giving the impression of exerting force on a spring. Moreover, the peculiar sound produced by the actuator while playing the train of pulses was immediately associated to the "cracking" one would expect from exerting forces on a stiff but flexible object. Coordinated with the visual feedback of Nudge mode, this seemed particularly successful: all those present agreed that it increased the sense of physicality in the manipulation gesture.

We note that this observation seems related to previous work on displaying "pseudo-kinesthetic" sensation through vibrotactile stimulation. For example, in [5], friction and shape information are displayed using vibration.

In force feedback conditions, an observation by David was that when damping and friction effects were enabled, it was possible to leave the controller in a static position and let go, without it moving. He found this to be an improvement because it saved energy and allowed him to relax compared to trying to maintain the position of an ungrounded pen.

At his request, we also exposed the haptic device's angular roll as a mapping parameter, which he was accustomed to using to control line width or density when using the pen-based electromagnetic sensor. The roll angle therefore provided an extra continuous modulation parameter that we additionally played with mapping to damping and other effects; we did not attempt any torque effects on the roll angle, however the device would have been capable of such and may be tried in future sessions.

He enjoyed using damping at low velocity, as he felt that it helped with positioning accuracy for small movements. We designed a configuration where damping decreased with velocity, since he wanted to achieve completely free motion during higher-velocity moments. This was very different from our initial idea that damping could be associated with thicker or harder lines, for example. Instead, we applied a subtle white noise to induce vibration when the brush was painting, to indicate the software's mode.

Therefore an interesting distinction was learned on the roles of vibrotactile and force feedback during drawing—force feedback can encourage accuracy and enable otherwise difficult gestures by physically restricting jittery hand motions and providing constraints, while vibrations worked well for indicating mode and could additionally be used to increase a sense of physicality in manipulation gestures without actually restricting motion.

Unfortunately, in this one-day session, we did not have time to thoroughly explore every possible mapping, and were forced to skip some effects such as the spring. We also did not have time to experiment with the Phantom Omni for comparison purposes, although David expressed a liking for its smaller desktop footprint.

7 Conclusion

We consider the project successful since we were able to demonstrate to a manufacturer of 3D interactive software some benefits of haptic feedback, and in the process some good observations were made in the mapping and design of feedback effects for visual arts.

During development of vibration effects, it became clear to us that several effects were also interesting purely as audio feedback. It was encouraging to realize that perhaps some similar benefits could be had at much lower cost by implementing a range of sonification mappings. In that context, it would be beneficial to investigate what kinds of information are best transmitted haptically or as sound, or whether some redundancy may lead to fusion of the two, fundamentally providing a richer sense of immersion in the software than either alone. Informally, this seemed to be the case in our mapping of the Nudge mode between visual, audio, and haptic feedback channels, since the motor vibration was clearly audible in this condition.

One other possible application that we did not have a chance to test, due to limitations in the signals exposed by the SANDDE software, was the use of haptics for notifying the user about his/her interaction with user-interface elements in SANDDE. For example, we had wished to enhance interaction with the menu that appears in the workspace, which we found somewhat difficult to navigate using free-hand gestures since it requires precise pointing. We felt that this could be improved by giving non-visual indications of the edges of menu items, for instance using vibrational cues, or by using "cursor snapping" force effects. Although it would require modification to SANDDE, future work could produce such interactions in collaboration with JIL programmers, and JIL has expressed interest in getting information from us on what GUI events might be useful to expose as signals for this purpose.

Finally, a useful way to continue this work, apart from implementing more and more haptic feedback effects, would be to design a set of effect mappings to brush properties and software modes that could remain static for users over a long period of time. In our short demonstrations and sessions we were able to find some encouraging configurations, but ultimately we are curious whether long exposure to feedback mappings during regular use of the software might establish an internalized sense of expectation in the user; if the association of haptic information can be deeply embedded in the user's experience of the software, they may begin to "know" that a particular brush *feels* a certain way. Since the haptic feedback may carry a rich amount of information about that brush's behaviour, we wonder whether users may then feel that something is lacking if it is subsequently removed.

8 Acknowledgements

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