

# “flUId streams”:

## Fountains that are keyboards with nozzle spray as keys that give rich tactile feedback and are more expressive and more fun than plastic keys

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For more information, Google search on “FUNtain” or “funtain”

### ABSTRACT

“flUId” is a system for fluid-based tactile user interfaces with an array of fluid streams that work like the keys on a keyboard, but that can also provide a much richer and more expressive form of input by virtue of the infinitely diverse ways in which each fluid jet can be pressed, hit, restricted, or otherwise manipulated by a user. Additionally, if desired, flUId can provide tactile feedback by dynamically modulating the pressure of the fluid spray, so that the keyboard is actually bi-directional (i.e. is both an input and an output device). A 104-jet version can be used as a fun and tactile “QWERTY...” style keyboard. More importantly, however, flUId can also be used for applications, such as musical instruments, where its more expressive multi-dimensional input capabilities can be put to full use. One such instrument, the “FUNtain”, is a hollow tubular object with a row of holes in it. It is played much like one would play a tin flute or recorder, by covering up the holes to restrict fluid flow. The FUNtain’s fluid-based “keys” embody features of a keyboard instrument (piano or organ) as well as features of the tin flute, to create a hybrid water-pipe organflute (“waterpipe florgan”) instrument. This gives rise to a fun new way of playing music by successively blocking water jets in a fountain, while sitting in a hot tub, or while frolicking in a pool, or lake. Other examples of fluid-user-interface systems that were invented, designed, and built by the author, to enable direct interaction with fluids, as input media, are also discussed. Some of the input devices will work with either air or water, to provide the benefits of richly expressive input and dynamic tactile feedback in settings where use of wet fluid is inappropriate. FUNtains that use no computer or electricity are also presented as wholly acoustic musical instruments. Some of these embody “back to basics” post-cyborg/undigital multimedia design elements such as fire, water, and air.

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### Categories and Subject Descriptors

I.4.0 [Image Processing and Computer Vision]: General; C.3 [Computer Systems Organization]: Special-Purpose and Applications-Based Systems—*signal processing systems*; J.5 [Computer Applications]: ARTS AND HUMANITIES—*Fine arts*

### General Terms

Design, Experimentation, Performance, Theory, Verification, Immersive

### Keywords

Fluid-user-interfaces, direct user interfaces, water-based immersive multimedia, computer mediated reality, FUNtain, poseidophone, funits (units of fun), frolic in the fountains.

## 1. INTRODUCTION

Part of my artistic practice has been in creating “undigital” interfaces, using fluid as an interactive, expressive, and tactile, medium for human-computer interaction [2][3].

In the pursuit of this work I have created a number of musical sculptures that use an array of fluid jets to function like keys on a piano, such that touching, pressing, hitting, or restricting the flow of each of the jets causes a note to be sounded, or another action to be taken.

### 1.1 The “florgan”: Combining the convenience of the organ/piano keyboard with the directness and expressiveness of the tin flute

To create my new input device, I used a tee fitting to supply fluid to a sound producing device on the output side of the tee. The straight-through path provides a supply of the fluid. See Fig. 1

With eight of these simple devices lined up in a row, I made a simple musical instrument that had eight notes, as shown in Fig. 2 The ability to directly interact with the fluid that is producing the sound was something I found to be very compelling. Unlike a piano, or organ, where the interaction is indirect (i.e. pressing a lever to cause a hammer to hit a string inside a box, or pressing a lever to cause a valve to be opened), there was a design element that I liked in touching fluid to move it through the system. There is also something very soothing and physical about touching fluid (water or compressed air) jets instead of plastic or wooden keys.



Figure 1: **Basic principle of operation for direct fluid user interface:** This user interface allows a person to engage the fluid directly, i.e. to manipulate the fluid that is then making the sound by way of touching it in various ways. Touching the jet of fluid forces it out through a whistle, flute, or organ pipe, while also allowing the user to feel the fluid on the hand and fingers. When not touching the jet, the fluid comes out the jet, causing the side discharge of the tee fitting to be in vacuum, by way of the Bernoulli principle of fluid flow. Thus the note is sounded when the fluid is touched, and the sound stops when the user takes his or her finger away from the output port.

Building on this concept, I made a large manifold (which I call a “fluid chest” to borrow and modify the term “wind chest” from pipe organs), and emerging from the manifold I soldered in nine “T” fittings. On the straight-through of each “T” I put a jet, and on the side of each one I put an output device to sound a note, in response to blockage of each corresponding jet.

An example of a fluid chest that I made using copper pipe fittings and waterpipe is shown in Fig. 3.

I made the manifold in the shape of a circle, with the straight-through of each “T” pointing upwards, perpendicular to the plane of the circle.

When supplied with fluid, the fluid comes out all of the nine jets. Because of the Bernoulli effect, this flow of water rushing past the side opening of the “T” draws a vacuum on it, preventing notes from sounding when the fluid jet is not touched.

When one or more of the jets are blocked (chords are played by blocking multiple air or water jets at the same time), the fluid is forced out the side of the “T” fitting into a sound producing system, causing the corresponding one or more notes to sound.

When one of the jets is blocked, more fluid flows out through the remaining jets, drawing the corresponding side discharges of the tee fittings into stronger vacuum, and thus preventing the other notes from sounding accidentally or by crosstalk. When chords are played, the effect is even stronger, and the unblocked jets spray even harder, pulling the remaining notes deeper into silence. Therefore there is no crosstalk, and, in fact, there is even negative crosstalk, between the notes. This results in excellent selectivity and a robustness that gives the instrument reliable operation in any orientation or in the face of various perturbations such as fluid pressure fluctuations (e.g. toilets being flushed elsewhere in a building while a garden-hose florgan is being played).

### 1.1.1 The waterpipe organflute

I built some instruments that use water jets spraying across pipes to generate standing waves in the pipes.



Figure 2: **A crude and simple musical instrument based on the principle illustrated in Fig. 1:** The result is an instrument that combines the simplicity of the piano keyboard (i.e. low notes on the left, high notes on the right, and a one-to-one correspondence between notes and “keys”) with the directness and expressiveness of instruments like the tin whistle or recorder.

Additionally, some of the other approaches I experimented with also included the use of real organ pipes, where I used the flow of water to modulate the sound output of the pipes. One of the simplest such instruments I built has just one rank of 16 pipes. A wind chest, connected to a blower, blows into all 16 of the pipes. Water also sprays into all of the pipes. The water interferes with their ability to produce sound, and thus modulates the intensity of the sound. Blocking the water flow to a particular pipe causes it to sound. See Fig. 4.

Therefore the organ pipe version of the instrument operates in reverse from the screechers, so the organ pipes go after the jets, not at the side of the “T” fittings on the fluid chest.

Moreover, the two modes of interaction can work simultaneously, with screechers on the side of the “T” and organ pipes after the jets, so blocking any given jet causes both to sound. A master control turns off all the screechers or all the organ pipes together, so that the instrument is like an organ with two stops (a FLUTE 8’ stop due to the organ pipes, and a SCREECHER stop due to the screechers. Additional stops are added by branching the fluid flow to additional ranks of organ pipes or to additional ranks of flow sounders (ranks of screechers, ranks of water motor gongs, ranks of standing-wave waterpipes, and so on).



Figure 3: **Fluid chest (flow chest):** A manifold carries a water supply to upward jets that point up, but are angled slightly inwards towards a bather/user standing in the center of the fountain. When one or more of the upwards facing fluid jets are blocked, fluid is diverted outwards to one or more output devices that can produce sound to generate individual musical notes or chords.



Figure 4: **The waterpipe organflute:** reverse modulation of a pipe organ with water flow. Increased water flow reduces the sound output of the organ pipe. The outer two pipes shown here are sounding at full volume, while the middle one is at minimum volume. Selective modulation of the organ pipes with water jets that can be touched by a user provides an immersive and direct experience.

## 2. FOUNTAIN JETS WORKING SIMULTANEOUSLY AS INPUT AND OUTPUT DEVICES: WATER JET MODULATION FOR TACTILE FEEDBACK AND THE COMPUTERIZED ORGANFLUTE WITH RESTRICTOMETRIC SENSING

I have built some of the organflutes so that they operate as computer Input/Output (I/O) devices as well as produce a MIDI output. (System architecture is depicted in Fig 5.)

Thus, like many modern church organs, and other instruments, the organflute can be interfaced to other devices. For example, I've connected it to a real church organ, and therefore used it as a fluid user-interface to the much larger instrument.

Fully computerized versions of the instrument consist of an array of restrictometers (devices that measure flow restriction) fitted to water jets. The purpose of the restrictometers is to measure the restriction of fluid flow, coming out of the jet. Ideally it would measure the height of water column, i.e. the height at which the hand is blocking the water. I have used a number of approaches ranging from computer vision, sonar, radar, lidar (Light Direction And Ranging), etc., to simple pressure transducers and flow meters (pressure sensors on the sideways diversion jets, or flow meters on the upwards aimed jets, or both).

Restrictometers sense the degree of restriction of a key-jet stream. To understand what a restrictometer is, think of the previously described flogan of fig 2 as simply having eight restrictometers, each of which output a pneumatic signal. More generally, restrictometers can output a pneumatic, hydraulic, or electrical signal, or a combination of these.

Usually the choice of system will depend on the instrument, and what is desired in terms of response, sensitivity, and overall artistic character. For restrictometers that have an electrical output, I have standardized on a cross-platform restrictometric signal that is either digital, or that is a voltage proportional to restriction, with zero volts for zero restriction, and some maximum voltage (usually either 0.05, 5, 10, or 12 volts) for full restriction. In some embodiments I have designed optical electroacoustic sensors that work in a way similar to the Hammond organs, but with water (exploiting its optical properties). Thus, although I have come up with many different kinds of sensing systems, they share a common frame of reference, which is the user interface.

The user interface that I found most satisfying was one in which no notes would sound until one or more jets were blocked. Blocking a jet sounds a note for as long as the jet is held down. I found that piano-like sounds were disturbing because I was aiming for a continuous fluid-like feeling, and it seemed to me that the sound should never die out (decay) until a user let the water begin flowing again (i.e. released the restriction of flow). Thus I used the organ, rather than the piano, as a metaphor for the translation going from restrictometric reading to sound output.

Thus, rather than sensing velocity, as with a piano (and then possibly applying aftertouch), I sense distance (displacement). In this way, note formation is continuous rather than consisting of an initial velocity value that is possibly later modified by aftertouch. I refer to my approach as “duringtouch” since it allows the amplitude (and/or other aspects such as timbre, etc.) to vary during as well as after the touching and moving up and down along the fluid jet.

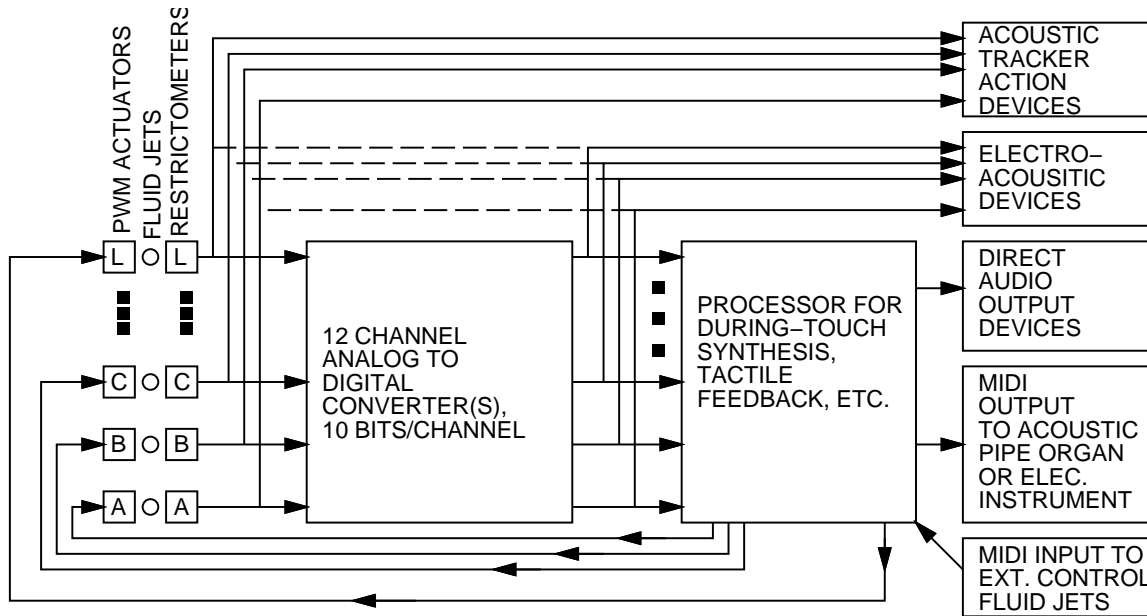


Figure 5: **Example of system architecture for a simple 12-note instrument:** Restrictometers control, by way of pneumatic, hydraulic, or electric signals, ACOUSTIC DEVICES. Additionally, a 12 CHANNEL ANALOG TO DIGITAL CONVERTER passes the restrictometric data to a sound synthesis PROCESSOR. The processor operates with what I call "during-touch". Rather than break the key press down into an initial note setup velocity to determine amplitude, and then modify (update) the amplitude by after-touch as in the MIDI standard, note amplitudes are continually updated by the height of fluid column of each jet. I find this to be more expressive and "fluid" (i.e. continuous). However, a MIDI output is available and can control note velocity and after-touch on a synthesizer, or can be supplied to a MIDI-operated pipe organ or calliope. Intermediate electrical signals are also available to electro-acoustic sound-producing devices. Tactile feedback is implemented through either 12 Pulse Width Modulated (PWM) fluid control solenoids, or by way of 12 separate PWM pumps that are also monitored to form their own restrictometers, thus causing the apparatus to function as both an input and an output device that both senses the blockage of the water jets, and actuates the water jets for purposes of creating tactile stimulus (the latter also being controllable by way of a MIDI input to the device).

In this way, a great deal more expression and subtlety can be created, for example, by slicing through or across the jet with the finger coming from the side, down low, versus coming down on the jet from above. Thus different ways of entering the jet result in different sounds — something you cannot do with a piano or organ keyboard.

The restrictometers are usually connected to a multi channel analog to digital converter and the degree of restriction on each jet is read out, and supplied to the computer. The computer then synthesizes the sound, and/or sends a command to another computer to synthesize sound.

Presently I have built a number of these instruments into swim rings, with the jets spread out around the ring, all pointing upwards. These instruments are fully self-contained, with restrictometers, computer, sound synthesis, batteries, water pump, and waterproof speaker. The entire instrument is often submersible.

### 2.0.2 *The human face of security: Playing in the fountains*

I took my organflute to Seattle to play in the hotel pool and hot tub, after my ACM CFP 2005 presentation (opening keynote on equeveillance). It drew a fairly large crowd, including one "suit" with an earpiece, who picked up the phone and called in several other "suits" with earpieces.

It turned out he was the director of security; I happened to meet him the next day with regards to another matter (a malfunctioning door lock on our storage and meeting room), and he named one of the songs that I was playing.

It turns out he was just there enjoying the music, along with the others, and not there to give me trouble.

A similar experience with security happened when I took my instrument to the big water fountain in front of the Seat-

tle Space Needle. A security guard came over, but not to tell me to get out of the fountain, just to listen to the music, and, surprisingly, he had no problem with it. Several women came over as well, took off their shoes, and got into the fountain to play the organflute. Soon others joined in, and before long, there was a large crowd of people in and around the fountain.

We played for a long time, and eventually there were some large crowds gathered around, blocking the road. Eventually the security guards explained that it was creating a problem with the blocking of traffic, so I shut down the instrument and left.

What surprised me was that the guards were very good about explaining why there was a problem, rather than just ordering me to leave without giving an explanation.

In many ways these two examples show that there can be a human side to the security forces, and to everyone, especially when our hearts are touched by music. It seems that music brings us together, in a happy or contemplative moment. See Fig. 6.

Additionally, on various occasions I have turned public fountains, water attractions, wading pools, and splash pads into immersive multimedia spaces. This served to challenge the tradition of music+performance as art, and focus more on the portable temporary multimedia sculptures being brought into the various places.

During a rainstorm, I put a temporary outdoor multimedia sculpture in a park, where I pumped water from a drain area into the sculpture. Despite the rain, various people came out from under the shelter where they had taken refuge from the storm. See Fig. 7.

Other public interventions included an impromptu setup at one of my daughter's swim lessons, where she gave a



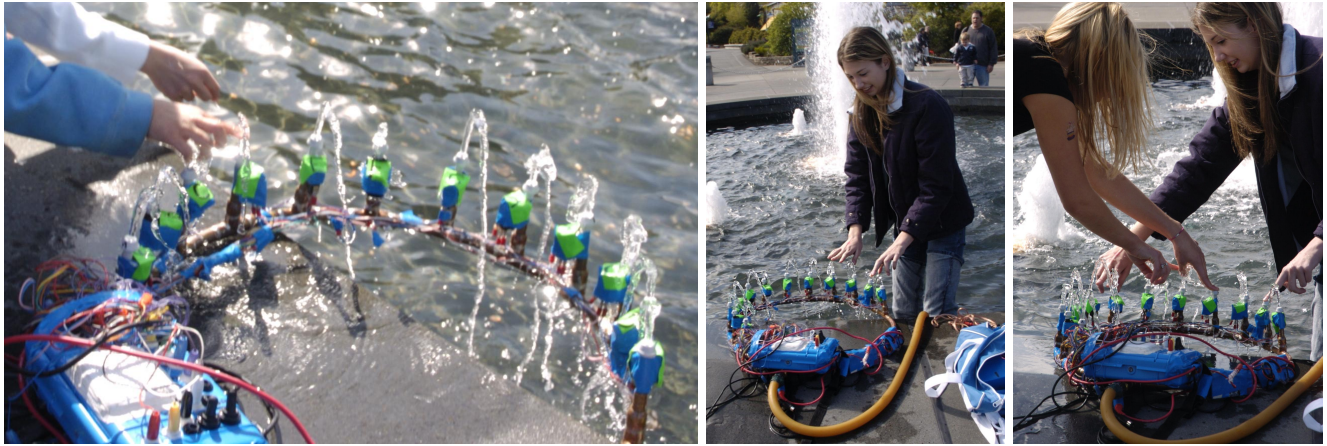


Figure 6: **The key to good music is to play in the water:** Playing in the fountain in front of the Seattle Space Needle, April 2005. The fully computerized organflute pumps water out of the fountain to use as its immersive multimedia input medium. In this small portable unit there are only 12 restrictometers (for 12 notes, A to E). Each restrictometer is connected to one of the 12 input on a completely waterproof 12 channel Analog to Digital (A to D) converter that I designed and built into a waterproof enclosure. I designed and built the restrictometers to operate on 1/10th of a volt. The ultra low voltage makes the entire unit fully submersible to a water depth of 1 meter.



Figure 7: **Singing in the rain:** Temporary outdoor interactive multimedia sculpture setup during a rain storm.



Figure 9: Interactive immersive multimedia sculptural installation at splash pad.





Figure 8: **Sculptural intervention during a break in swim lessons:** The interactive multimedia sculpture becomes one of the pool toys.

recital of some simple children’s music (Fig. 8), as well as setups at various splash pads (Fig. 9).

Interestingly, at one of the splash pads, the battery for the pump ran down, so participants in the immersive multimedia space began to hold the organflute supply hose up to the mouth of a fiberglass frog that was spraying water out of its mouth. Since the features on the splash pad were sequenced, this resulted in a fun game in which participants try to predict which water feature will come on next, and then run from one feature to another, carrying the organflute. As part of a song is played until the water runs out, the song is completed after moving to the next water source. See Fig. 10.

## 2.1 A waterpipe organflute sculpture

In order to make a sculptural form suggestive of a flute, I enclosed all of the restrictometers into a design element such as a nicely curved pipe. While the unit could be built into a straight pipe, I wanted to match the aesthetic elements of the water arc with that of the pipe. Thus largely for aesthetic reasons I usually aim the jets so they shoot upwards and come down in a nice arc, along a curved pipe. See Fig. 11

## 3. WATER JETS AS INTERACTIVE MEDIA

In some of my early electronic organflutes, I installed displays for visual feedback, in addition to the audio feedback. For I often had a flat panel display sealed safely behind a transparent opening in the waterproof enclosure, so that it would be visible while playing in the pool.

The simplest (i.e. diatonic 12 note versions) of the organflutes can be effectively used for typing, using the first 12 letters, as single notes, since they start on A. In most of the instruments I have the scale starting on A so it can be used to play a wide variety of songs that are written in a minor key (such as Summertime, House of the Rising Sun, The Ants Go Marching, etc.). To play, for example, a C major scale, one simply starts on the third jet over.

As a happy co-incident of starting with the natural minor Aeolian mode, the first note on the instrument corresponds to the first letter of the alphabet. The notes on the simplest of the instruments (the simple 12 note diatonic versions) are A, B, C, D, E, F, G, H(A), I(B), J(C), K(D), and L(E) as shown in Fig. 12.

Thus, to type in computer data, the first 12 letters of the



Figure 11: **Making the electronic organflute resemble its acoustic counterpart:** Here I have hidden the 12 restrictometers, a 12 channel analog to digital converter, and all of the computation and sound synthesis hardware inside an aesthetically pleasing housing that compliments the curved arcs that the water jets make. The picture shows the organflute being played over a hot tub, during an outdoor Mother’s Day performance, May 2005. This organflute pumps water out of the tub, and the water then lands back into the tub to be recirculated. A waterproof speaker inside the pipe makes the sound, so that the sound appears to come from the instrument, in the same way it does with an acoustic organflute.

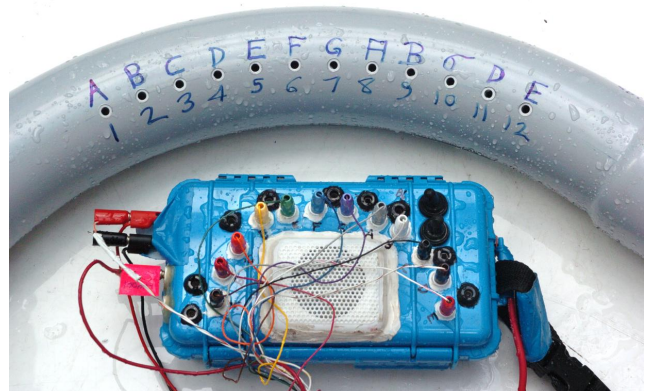


Figure 12: Going beyond the “anti-electric” aesthetic, and the use of the posidophone as a general purpose input device: Organflute pictured together with a completely waterproof (immersible) multimedia computer. The computer has a waterproof speaker, as well as serial or wireless output to other computers and networks. The new symbols such as the “A/H” (squared-off letter “A”) depict that high “A” functions as “H” when typing or other non-musical usages, etc.. The high “B” is also drawn to also look like the letter “I”. The “C/J” combination is drawn as a “sigma-like” character, etc.. An immersible (underwater) patch bay can be used to select the key that the instrument plays in. Note the sharps and flats are black jacks in the patch bay, whereas whole notes are white jacks. The numbering system, A=1, B=2, C=3, etc., follows the standard (i.e. R.E.T.M.A.) colors for wire, i.e. A=brown wire and brown plug, B=red, C=orange, etc..



Figure 10: Once when the battery for the pump ran down, participants began to supply the organflute with water power, holding the input hose up to various water features, such as the mouth of a giant fiberglass frog that squirts water out its mouth from time to time. Since the water features go on and off, the participants chased the water sources around, to keep playing.

alphabet are just individual notes, and after that, chords are used to denote the letters M-Z, numbers, control characters, and other symbols such as escape, backslash, tilde, etc..

Capital letters may be entered by hitting a jet harder than normal.

Larger organflutes usually have 61 jets (5 octave chromatic scale) which covers most of the letters, numbers, and other symbols nicely.

In this kind of application, a flat panel makes sense. However, I prefer to transmit wirelessly to another computer, using its display, and preserve the non-electrical aesthetic of the organflute itself.

In addition to the sound that emerges from the instrument, there is also other feedback. For example, the tactile feedback of the water jets is an important design element, that can also be modulated interactively so that the jets can be made to feel differently on the flesh, by way of computer modulation, in response to changes in internal state of the system.

Additionally I often have a certain number of “system status jets” that function as a display, much like Koert van Mensvoort’s datafountain (a fountain that is used as a display device to show stock values as height of water column). Others have also used fountains as displays (e.g. the fountains in front of the Bellagio hotel, designed by Mark Fuller of WET Designs, function as a display and “dance” in time with music). Often, however, I like to be able to combine data display with the ability to set the data quantity, so that I can insert a finger into a system status jet and pull it up or down, and when I take my finger away, the jet will remain where I last set it.

I found that such *interactive* system status jets can function like the stops on a pipe organ. A row of jet stops can be lifted or dropped with a finger, and stay where they are set.

Thus there can be two kinds of jets on a larger instrument:

- **note jets** that function like momentary pushbutton switches (except that each one typically has 16 bit precision rather than just the binary on/off action of a switch) in the sense that they “spring back up again” when you stop blocking them; and
- **parameter jets** that function like sliders, in the sense that they stay put when you let go of them (they stay set to the height where you last had your finger in the water at).

Each jet, whether a note jet (momentary jet) or a parameter jet, will often have 10 to 16 bits of precision, so that organ stops can be pulled partially out, unlike a church organ in



Figure 13: **Put on your surf shorts to surf the web: Splashing through cyberspace...** A “SPLASH PAGE” is made from a 144-note linear organflute turned upside-down and illuminated with a data projector. The system detects the location of where the hand is inserted into the “waterfall” of the splash page, so that an immersive interactive multimedia experience is possible. The green arrow under the left palm is the cursor. The curved portion of copper pipe to the left is a 61-note organflute located to the left of the splash page. It is a free-standing sculpture connected to the same water supply and computer systems as the splashpage.

which stops are typically only binary (1 bit precision). This provides added flexibility in creating mixture stops.

## 4. SPLASH PAGES

I’ve built some larger 61 note organflutes that led to larger units, 88 notes and beyond. When there are sufficiently many jets the device becomes an essentially continuous input device in both water column height and in position.

Fig. 13 depicts a 144 jet instrument, turned upside-down, with a data projector animating onto the water, under control of the multimedia computer. In this case, the restrictometric sensing can be augmented with optical sensing [3] to measure water column height very accurately, and thus, with enough jets, a two dimensional or three dimensional splash space results.

### 4.1 From splash pages to splash screens

The vertical splash page of the upside-down organflute gave rise to other explorations such as creation of a splash page that is an array of jets.

I was inspired by pinscreens (Fig. 14), to make, instead, of pinscreens, splashscreens. A number of public performances (Fig. 15) used the splashscreen.





Figure 14: **Invention of the splashscreen, inspired by the pinscreen:** Left hand print on the metal rods of the well-known pinscreen invention. Middle and right images: A new invention of my own, inspired by the pinscreen. I call it the “splashscreen”.



Figure 15: **Public performance with splashscreen.**

## 5. GETTING BACK TO BASICS: EARTH, WIND, WATER, AND FIRE

Finally, after much experimentation with immersive multimedia as a form of computation, I am currently working on an embodiment of the musical water fountain sculpture that does not use electricity or computers. Fig. 16 illustrates an acoustic waterpipe organflute having eight notes on a diatonic natural minor (aeolian mode) scale: A, B, C, ... a. Only four of the eight notes are shown: the first three (A, B, and C), and the last note (a). The fluid chest carries water to water jets, from which emerge water, except when and where blocked by the user. Alternatively, flow on one or more of the jets may be partially restricted by the user, to vary the amount of water squirting out through the side discharges of the tee fittings.

Each side discharge directs water at the inlet of a pump. To maintain the purity of the “back to basics” theme (“elements” like fire, water, and air), a hydraulic pump can be used. In this way there is no need for the instrument to use, or have any connection to, electricity. Using a more primal element such as water, to power the pumps, rather than electricity, allows the user of the immersive multimedia experience to be “further from a computer than anywhere else on earth” and enter into a post-cyborg frame of mind.

The side discharge is not sealed directly to the inlet of pump, but, rather, there is an air gap between the side discharge and the inlet of a pump. Each pump is a pump that can run wet or dry. When water is squirted into its inlet, it

pumps the water into a steam boiler. For each note, there is a miniature steam boiler to supply steam to a sound making device, which, in this case, is a steam calliope pipe. In this example there are 8 boilers, 4 of which are shown in the drawing. The sound-making device is a pipe from a steam calliope, steam organ, steam whistle, or the like. Each of the 8 boilers are heated by a flame from a heat source. This brings together the design “elements” of water, wind, and fire.

The purpose of the pump is to overcome the pressure  $P_b$  in the boiler. Thus pump outlet pressure  $P_o$  should be greater than pressure  $P_b$  in the boiler. However, if pump inlet pressure  $P_i$  can be made higher than pressure  $P_b$  in the boiler, then the pump and air gap are not necessary. In this case, water is squirted directly into the boiler. A typical scenario might be to use calliope pipes that take very low pressure, such as 2 inches (approx. 51mm) of water column, so that the water squirted out of the side discharge of the tee fitting has sufficient pressure to sustain a note without the need for the pump and the air gap.

Otherwise if the boiler pressure is too high, notes cannot be sustained. A one-way valve can be used, instead of the pump and air gap, if notes of short duration are acceptable.

When a jet is blocked or partially blocked, water is squirted into the pump to feed the boiler to cause the sound. The water is converted into steam in the process, resulting in a nice visual effect, as well as the sound.

If desired, a hybrid acoustic/electronic instrument can be made in which steam is produced, while at the same time



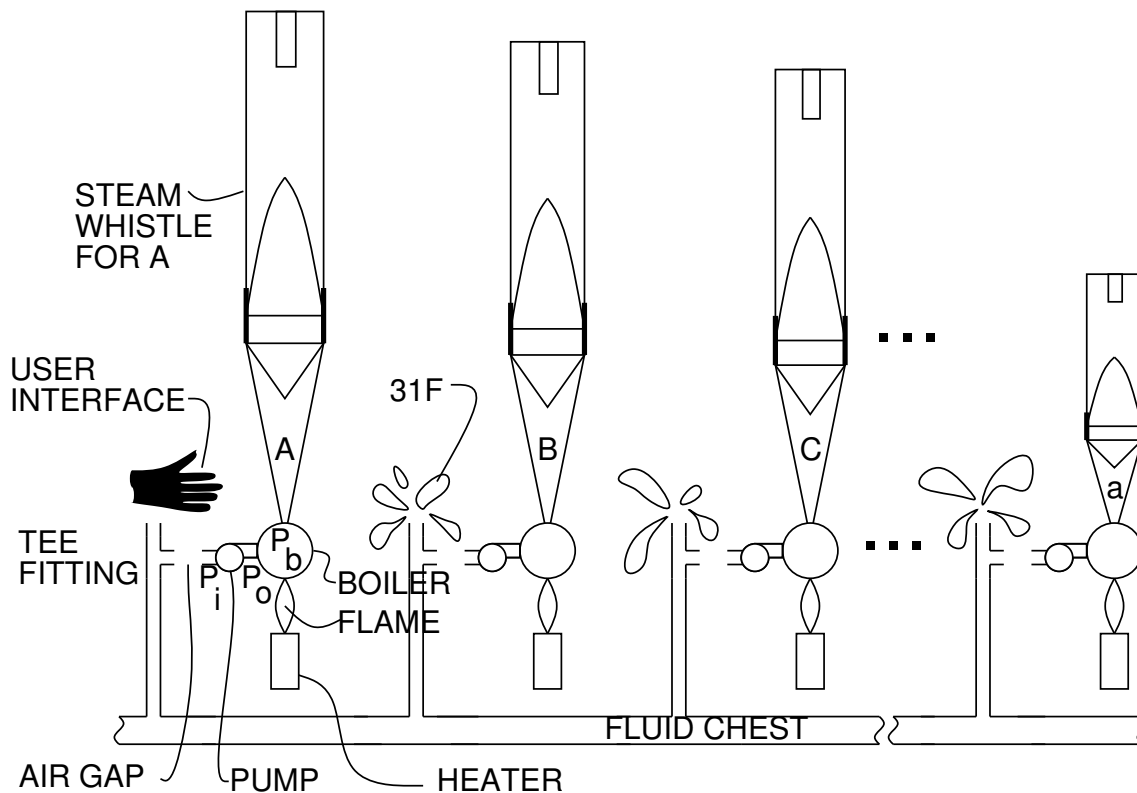


Figure 16: **Steaming Audio**: Combining the user-interface (input modality) of the tin flute with the output modality of the steam calliope.

triggering a note. Steam atomizers or boilers, etc., can also be used as sensors. For example, notes can be triggered on the presence of steam, by way of optical, conductivity, or other sensors.

An ultrasonic atomizer can also be used to directly sense the position of the user's hand above each note, providing a more rich sound experience based on the hand position in the water is determined by the ultrasonic wave, using the ultrasonic heater as both a sender and receiver of sonar.

Sonar devices may also be installed in the jets to make a hybrid electronic/acoustic instrument, and various sensory combinations.

A functional (working) research prototype is shown in Fig 17

## 6. RELATED WORK

The ancient Romans and Greeks had so-called "water organs" such as the "hydraulis"[1] but the term "water organ" did not mean that water was used directly in making the sound or the user-interface. Rather, the hydraulis was simply an air organ that was powered by water. The hydraulis was the world's first keyboard instrument, and was, in fact the predecessor of the modern church organ. Water power was used to obtain air under pressure. To the extent that waterfalls are often now used to produce the electricity that runs the air compressors and blowers in modern pipe organs, a modern pipe organ is a water organ in the sense that a waterfall such as Niagara Falls turns a turbine that produces the "hydro" to run the blower fan. The term "hydro" is slang for electricity, and we often speak of the "hydro meter" when we refer to our electricity bill, and to the electricity we use to power modern pipe organs.

Although some of the instruments that I have proposed in this paper are indeed water-powered, this paper has focused mainly on using the water as a direct user-interface, rather than just a source of power.

Peter Richards, 1986 Artist in Residence at the San Francisco Exploratorium, created a Wave Organ that similarly used water power to push air through organ pipes[4]. The wave-organ has no user-interface.

Other fountain installations consist of fountain jets that can be aimed by users but do not use direct interaction with the jets as a user input.

Fountains have often been used as output devices. Koert van Mensvoort's data fountain [5] is one such example. Fountains are often used as information displays, sometimes in sync. with music (e.g. the fountains in front of the Bellagio hotel). What is novel about the FUNtain is the use of fountains as both input and output devices.

## 7. CONCLUSIONS AND SUMMARY

I have presented examples of wet-user-interfaces for immersive multimedia. The organflute, for example, uses water as both an input and an output device. As an output device it is related to the datafountain (or the fountains in front of the Bellagio hotel, etc.), but also as an input device, it adds a new aspect to multimedia art, namely that of immersive multimedia. This new immersive quality follows from the fact that (1) it uses fountain jets as input/output rather than just output/display (2) it involves direct interaction (immersive multimedia) with the water as the interactive medium.

When turned upside down, another input device, the splash-page, results, as a two-dimensional sheet of water from the



Figure 17: **Steaming Audio:** Combining the user-interface (input modality) of the tin flute with the output modality of the steam calliope. Restricting the flow of fluid coming out of the jets of this FUNtain causes the water to be diverted into the production of steam. This musical water sculpture combines the down-to-earth design elements of fire, water, and air.

one-dimensional array. Moreover, a three-dimensional volumetric fluid user interface, the “splashscreen” contextualized water jets in the tradition inspired by the pinscreen. Additionally, other fluidic user interface metaphors were presented, including the use of valves to control multimedia devices. Additionally, some fully acoustic embodiments of the fluid-user-interfaces were presented. These use no computers or electricity, and yet still provide an immersive multimedia experience that goes “back to basics”, namely fire, water, and air. Fluid user interfaces were found to create a diverse range of immersive multimedia experiences that were enjoyed by a wide range of individuals and groups.

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