







and splashes independently from the fingers, thus creating a new user input space.

Fluid flow creates a large set of phenomena in response to finger motion. Surface tension, alone, leads to various kinds of waves, bubbles, splashes, atomizations and droplet mergers. All of these complex phenomena are controllable, and the human being at a young age gets a very keen sense of how they function, intuitively.

We created a separate detection scheme for bubbles and splashes using colour matching based on the hues associated with the reflections of waves and bubbles at various angles.

As a demonstration, we had the bubble interface control a polyphonic tone generator, and the result was a gamut of controllable sounds in sync with the visual turbulent splashes.

## 7. LIQUID PROJECTION SCREEN

Water in the vessel was able to make the projection display visible, given a small concentration of impurities in ordinary drinking water. With water alone, the projection is cast in a similar way as sunlight making visible rays of light permeating a deep lake.

It is also possible to use other materials as a projection screen. Oil, such as vegetable oil, floats on the water surface and adds a different scattering characteristic for viewing the projection.

## 8. WATERTOUCH AS A HYPERACOUSTIC MUSICAL INSTRUMENT

Inherent in the WaterTouch system is a high degree of idiosyncratic behavior that is specifically aquatic. Every time the surface is touched, ripples and waves are generated.

These disturbances, some turbulent and some laminar, create underwater sound, over a wide spectral range. A great deal of the frequency spectrum extends below the range of human hearing. Since many of these disturbances are controllable by fingers, we chose to embrace these sounds by capturing them and shifting them up to desired notes on a musical scale, where the degree of shift depended on the location of touch on the surface. In this way, our WaterTouch system, when used as a musical instrument, is a hyperacoustic instrument.

Unlike a hyperinstrument[5] in which position sensors, etc., add synthetic sounds to an acoustic instrument, hyperacoustic instruments use the acoustically-originated sound as their primary computer input/output and process that sound based on additional sensors or inputs [6].

To make this new hyperacoustic instrument as expressive as possible, we wished to bring the subsonic and ultrasonic sounds into the audible range. In a way similar to (but not the same as), superheterodyne radio reception, signals can be downshifted and upshifted by means of using an oscillator in the process of frequency-shifting and various forms of selective sound filtration. However, unlike what happens in a superheterodyne receiver, we prefer to scale frequencies logarithmically rather than linearly, in order to better match the frequency distribution of human perception. [7]

This digital signal processing is, in a general sense, a filtering operation, which may be highly nonlinear in certain situations. The frequency-shifter was implemented on a computer system having a broadband analog to digital converter, *i.e.* an A to D converter that responds all the way down to 0Hz (DC), and up to approx. 40kHz. Computer vision was performed on the same computer system, with the resulting multitouch ( $x, y$ ) coordinates controlling

multiple amplitudes and pitches, depending on the number of fingers inserted. One mode had a continuum of available pitches, while another mode constrained the pitches to a diatonic scale.

What we have done is brought the ultra-low frequencies (easily controllable by a user when touching the water [4]) into the audible range, in response to a real-time visual multitouch analysis of finger motion across the water surface.

## 9. CONCLUSIONS

We successfully implemented and demonstrated “Water-Touch”, a user-interface based on a Sensory Table (Water Table). The apparatus was equipped with sensors that resulted in a water-based touch screen that captured the randomness and idiosyncratic behavior of water waves, ripples, bubbles, and similar phenomena, in response to user input.

The use of total internal reflection, in a pool with an underwater camera, created a situation in which tracking became very simple. For example, fingers inserted into the water were immediately visible, completely disembodied, against a pure black background. This made the computer vision tracking extremely easy. Moreover, the simple algebraic projective geometry of the air-water boundary made it very easy to locate, in multiple dimensions, anything that penetrated the water’s surface.

## 10. FUTURE WORK

The use of a lake as a touch surface is being explored as part of a grander vision of turning an entire lake into the world’s largest musical instrument. Our hope is that this work helps with the creation of an Ontario Water Centre to help teach the world about the importance of clean lakes, rivers, and about water conservation (ongoing collaboration with the Ladies of the Lake, Georgina, Ontario, Canada).

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