Aquapella- Gestural Interactions with Liquid Turbulence as Musical Expression

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Figure 1: Aquapella interface with camera and laptop view.

Abstract

The Aquapella is a hand-held gestural instrument for exploring the unique relationship of liquid turbulence and musical expression. The device consists of eight conductive water-level sensors in a custom 3D printed container. As a musician moves the device, it generates a chaotic flow of water within the container and translates the motion into real-time midi signals for audio-visual interpretation. In our initial performances and tests with the Aquapella, we have focused on turning the flowing characteristics of the device into ambient and glitch soundscapes that move between noise and harmonics. We present the primary findings in developing the Aquapella including related works, description of the project development, and ideas for future iterations.

Keywords

Musical Expression, Water Instrument, Gestural Instrument

1 Introduction

The Aquapella is a hand-held gestural instrument for exploring the unique relationship of chaotic physics and digital art within musical performance. A musician holds the device in one or more hands, tilting and swirling the water in various ways. The internal sensors pick up and translate the turbulent flow of water into MIDI signals that produce a wide variety of sounds when connected to a digital audio workstation (DAW). The Aquapella's weighted feel, hand-held ergonomics, and immediacy provide a uniquely expressive computer interface that we are using for musical performance. The attached static camera observes the surface of the water with a circular light from above, enabling a tightly coupled visual component for live audio-visual display.

For a demonstration of the Aquapella's audio experiments in stereo as well as visualizations of the camera output please navigate to this short video: https://youtu.be/KEIr1re4Gls

A Github repository with all components, code, and housing are available at https://github.com/johnalettang/aquapella

The following provides an examination of related works, what makes the Aquapella unique, the development process, relevant findings, and future applications and possible iterations of our work.

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2 Related Works

While developing this device, we drew inspiration from prior research involving gestural NIME's that map motion, sensory dynamics, or malleable material to sound, often in a hand-held form. Additionally, we reviewed and were inspired by multiple NIME's that involve the use of water directly and indirectly, or that use gestures to manipulate live voice input. Finally, we elaborate on a few selected artworks and performances that have motivated our work with water and speak more to the aesthetic and psychological undertones of chaotic liquid propagation.

2.1 Hand-held Gestural devices

There is something particular about how human hands can map to musical expression, and there is no shortage of hand-held examples that forerun or prefigure the Aquapella. Within the NIME conference itself, we find direct examples of hand held instruments such as Eric Singer's classic Sonic Banana[18], the T-Stick[6, 10, 14], and Thales[17] that map the movement of a device in hand to sonic abstractions of various kinds. Orba[1] is a commercial example that we have spent time with. Other hand devices (outside of the traditional data glove) that correlate finger gestures to acoustic impressions, but are also informative, are David Wessel's Hands On[20], Pardue et. al's Hand-Controller[15] and Lane-Smith et. al's Hapstrument[9].

2.2 Gestural interfaces as Sculpture

Many acoustic instruments are more than just the sound they make. They have a presence and formal aesthetic akin to sculpture, and we take special appreciation of hand devices that convey an aesthetic through texture, weight, and material such as Han et. al's ParaSampling, which allows performers to hold an interface against a rotating magnetic head[5], and Tate et. al's Hand Turned Synthesis device that allows one to rotate a crank to make sound using basic electronics[19].

In many respects, the Aquapella looks like a futuristic tambourine, but it is mostly non-percussive and better geared for generating ambient backgrounds or "bending" signals. Playful devices such as the rummaging noise box example in Bower et. al's research[3] speak to the ludic background atmospherics we intend to create with the Aquapella.

2.3 Water based interfaces

Traditionally, water is an unusual medium for music making, especially in the NIME world where water and electronics go together like fingernails and chalkboard. However, there is some indirect precedence in the many liquid-based or underwater devices by Steve Mann that function like woodwinds but use water instead of air.[11]. Another example is the Symbaline[2], an active instrument comprised of several partly-filled wine glasses excited by electromagnetic coils. The Mocean[12] installation apparatus allows participants to swirl and move water in a tank and have that translated to sound from pipe organs. Tangible Sound[21] implemented an installation that modifies sound based on how a user's hand shapes the water flow from a faucet to a drain. More direct, but also abstract, references for our project are "The Argus Project" and Zack Poff's "Pond Station" where a natural body of water serves as a complex resonant space and is reframed as an instrument in itself[7, 16]. In our case, the body-of-water-as-instrument is hand held and portable, like an ocean in a bottle.

2.4 Water and Art

Water is a medium that speaks multiple languages between the drowning of floods and the calmness of floating. Besides signalling life, it signals human experience in many invisible dimensions. Our project takes inspiration from water based art works such as those by Anne Hamilton, Joshua Kit Clayton, and Christina Kubisch that have based art and performances on the presence or interaction with water. In "Songs of Ascension" by Meredith Monk at Anne Hamilton's tower on the Oliver Ranch, performers and audience members alike act on the long spiral staircase leading down to a pool of water, reflecting and reverberating within the tower all at once [13]. Kit Clayton's 2006 performance at ISEA saw the artist push his own face into a glass pool of water, recorded from below, as the video component of a live AV electronic performance [4]. In Christina Kubisch's "Marine Mix", participants walk and move in a large shallow pool of water in order to hear pre-recorded maritime sounds on headphones as an experiential mix [8]. While this paper presents the Aquapella in instrument form, our goal is to develop performative situations like the above that speak to larger ecological issues around water, but within similar artistic frameworks.

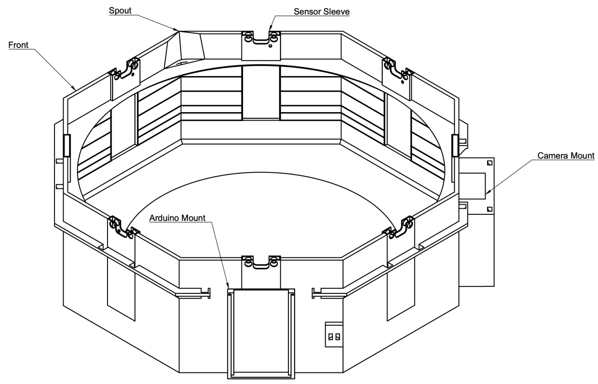

Figure 2: Mechanical drawing of the 3D Print of the Aquapella.

3 Project Description

Compared to works cited previously, the Aquapella is unique for its hand-held, fluid container experience. Sound is generated via controlling the height of the water at various points around the container's perimeter. Moving the container through a gesture generates chaotic force in the water, and tosses it against the walls. This turbulent flow, captured by sensing varying water levels, produces disparate and chaotic sounds through a digital audio workstation attached via USB.

3.1 Human Interaction

Playing the Aquapella is a tactile experience. Once the Aquapella is filled with water just below the sensors as seen in Figure 3 (a), the user can hold it with two hands on either side of the container and make gestures. These gestures are primarily broken down into three categories:

(1) **Tilting** - Tilting the Aquapella in any direction will cause the water to move towards the side of the container that is being tilted towards. This movement of water will cause the sensors on that side of the container to read a higher water level as scene in Figure 3 (b) and (c).
(2) **Swirling** - Swirling the Aquapella in a circular motion will cause the water to move in a circular motion inside of the container. This motion will cause the water to slide on the walls of the container through centripetal force and sequentially activate sensors in a clockwise or counter-clockwise manner.
(3) **Reverberating** - Reverberating the Aquapella is taking advantage of current momentum and motion of water to bounce water off the walls of the Aquapella. This motion could be seen as a rapid tilt or circular motion at just the right speed to keep natural flow of water moving.

While there could be a seemingly infinite amount of gestures possible with the Aquapella, we gravitated towards these three as we found they had the best results with our performances.

The Aquapella is designed with a splash guard, but it does not have a lid. You can't really shake it or produce wild splashing within it. This open-top format limits the device to some degree, but was a design trade-off. In this iteration, we prioritized the ability to see the water over a fully contained cavity that would allow wilder, more ecstatic, kinds of water motion.

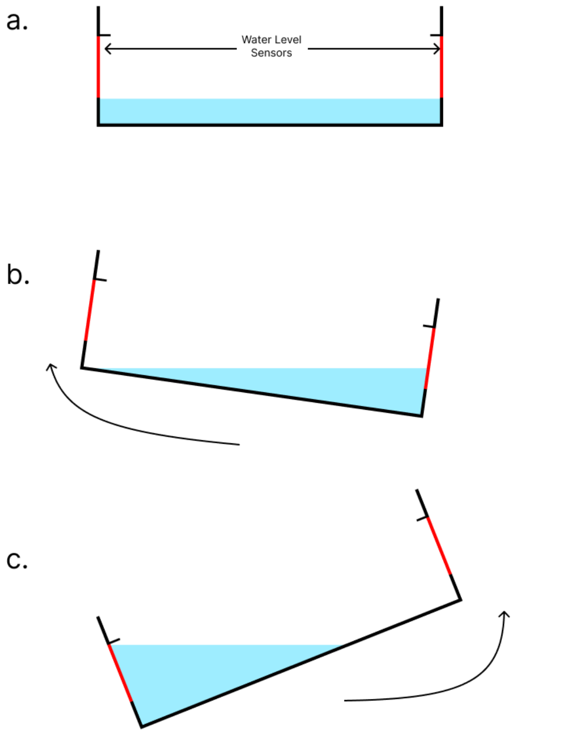

Figure 3: Horizontal Slice of the Aquapella to demonstrate lateral water movement.

a. Idle water while container is flat
b. Container tilted to the right and the water flows right
c. Container tilted far to the left while the water flows left reaching the top of the sensor.

3.2 Sensors

Since the height of the water level at various points along the container's walls is the control for the sound generation, choosing an appropriate sensor and ensuring its readings were accurate was a priority. The primary trade offs to contend with were form factor, price, accuracy, resolution, and speed. Water level sensors also vary in methods of measurement, and generally fall into one of three categories: capacitive sensing, optical sensing, and conductive sensing. To make the instrument hand-held and intuitive, we preferred a smaller sensor that could output readings in real-time (or as close as possible).

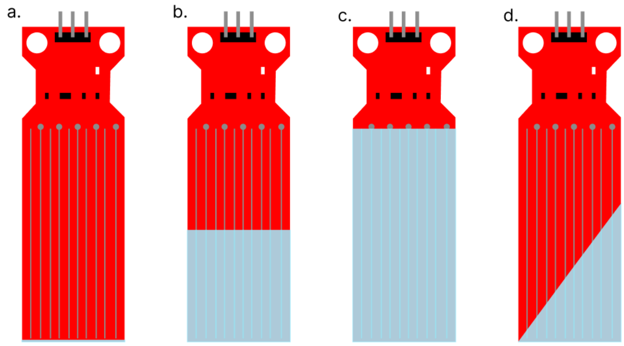

Figure 4: Visualization of water level sensors being submerged at different levels and ways.

a. Water level sensor with no water
b. Water level sensor half submerged
c. Water level sensor fully submerged
d. Water level sensor with an askew water level

In our tests of various water level sensors, we found the best commercial sensor for this iteration proved to be conductive sensors as seen in Figure 4. These sensors are affordable, compact, low-latency, and intuitive to use, and determine water levels by measuring the conductance between two nodes on a printed circuit board (PCB). Since water has a relatively high conductance, the more the sensor is submerged, the higher the measured value, allowing it to provide a relative indication of the water level. Nevertheless, the conductive sensors presented several challenges, including non-linear behavior, water adhesion, and drift.

Electronically, these commercial sensors work by inducing a small current between two electrodes submerged in water which biases a bipolar junction transistor (NPN BJT). When only a small amount of current is biased, the sensors are in active mode, exhibiting a fairly linear response. However, we observed that towards the top of the sensor, the voltage response becomes saturated, resulting in a non-linear response to the water level. While the transistor has an active mode with a linear voltage response, it also has a saturation mode where the voltage response is logarithmic. A visualization of this voltage response can be seen in Figure 5. In order to match a performers expectation of a direct reading from the sensor, we linearised and calibrated the sensors to map the bottom of the sensor to the top with MIDI values from 0 to 127 for a more intuitive response.

The water's adhesion – its behavior of clinging to the sensor surface – often left residue on the sensor, causing it to either report a false water level or to roll off too slow. We mitigated these false readings in two ways. First, as a part of the calibration curve, we added an initial threshold. As seen in Figure 5 the largest jump in sensed voltage is from water being below the sensor to barely touching it. By calibrating to this threshold small droplets of water sticking to the sensor don't make much of a difference if the water is not submerged at all. Second, to decrease overall water adhesion, the printed circuit boards were coated with silicone spray. This coating encouraged the water to slip off the sensor without impairing its ability to accurately measure the water level. Interestingly, compared to control as found in Figure 5, the silicone coating also increased the voltage response of the sensor, which made the sensors more effective.

Even with calibration and a silicone coating, these commercial sensors experienced drift and statistically inconsistent readings.

For instance, when the sensor was submerged at the same water level for a long time the output value would gradually decrease. We also found that these sensors seemed to exaggerate quick readings of water levels, turning a quick splash into an exaggerated spike in the sensor readings. While both of these made true consistency with the instrument impossible, we worked these known behaviors into how we developed the sound. Future versions of an Aquapella could utilize other, more customizable water level sensors to optimize the instrument.

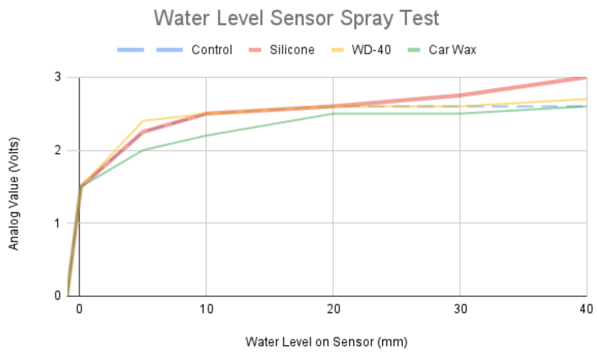

Figure 5: Measured logarithmic response of the water level sensor at various heights, showing how different sprayed materials affect the voltage response.

3.3 The Container

The Aquapella was originally imagined as a permanent installation where a user would splash the water around in a large aquarium. During a proof of concept design phase, we veered away from this instillation mode and towards a hand-held performative mode with more musical intention and variability.

The first prototype of the Aquapella was built in a generic plastic food container. This rectangular container was easy to hold and transparent, which made it intuitive to interact with and fascinating to see under specific lighting conditions. For example, when lit from above, the clear plastic allowed the audience to see capillary wave patterns in the light refraction. The rectangular container made lateral movement of the water between the walls of the container easy, but performing smooth circular motions was a challenge.

In our next iteration, we used a shallow circular container that encouraged cyclical movement with the water (as seen in Figure 7). Ultimately, the short walls meant that this iteration didn't hold enough water in the container for the liquid to maintain any lingering momentum. Also, since the sensors reached the bottom of the container, the sensors lost a lot of reactivity and never read neutral. Lastly, the opaque red plastic of the container made the water more challenging to see and visually uninteresting.

We combined the best from previous designs into a custom, 3D printed, octagonal container. The design features a built-in housing for the water level sensors, set at a height that allows the sensors to sit above the resting water line while also accommodating enough space for the water volume to create reactions in the sensors. This enables the operator to engage in circular motions or tilt the water into a specific octant for a higher resolution of control. The flat walls of the container also made calibration of the sensors much easier.

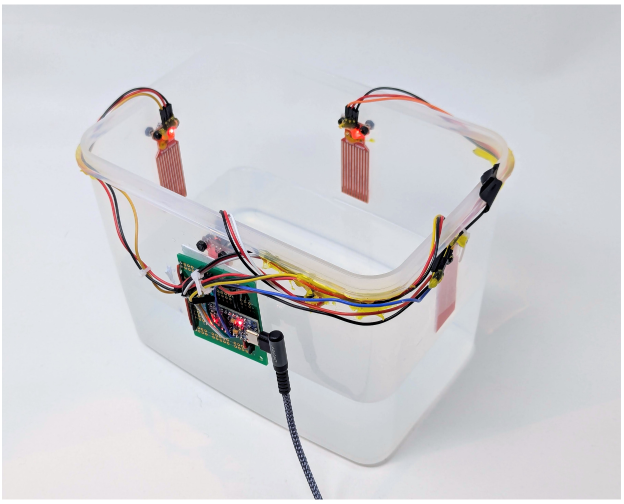

Figure 6: The first Aquapella prototype made from a clear, rectangular container.

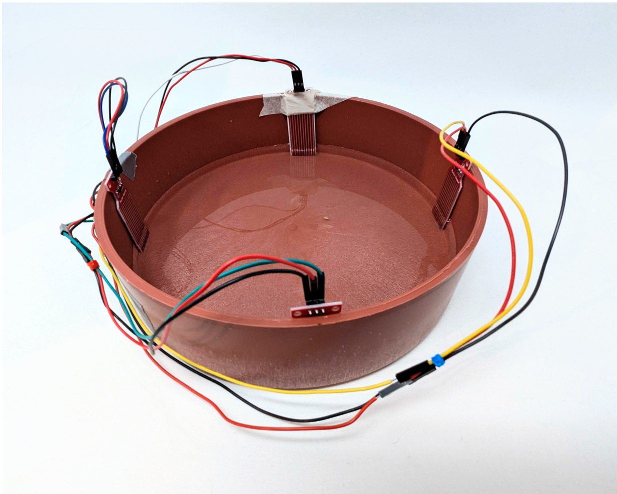

Figure 7: The shallow circular Aquapella prototype.

The octagonal form of the final container of the Aquapella enables the operator to engage in circular motions, or tilt the water into a specific octant for a higher resolution of control. The flat walls of the octagonal Aquapella allow water to "bounce" and reverberate around the container similar to the rectangular first iteration of the Aquapella.

3.4 Device Firmware

The Aquapella, in its current state, does not produce sound independently. Instead, it requires a microcontroller to interpret and calibrate sensor data, which is then sent as MIDI to an audio device as seen in Figure 10. We used an Arduino Pro Micro that supports up to eight analog inputs for sensor measurement and functions as a generic MIDI device, enabling communication with any DAW or MIDI-compatible program.

The Pro Micro supports eight channels of analog input, transforming the readings to align with a linearised calibration curve of MIDI values ranging from 0 to 127. This calibration, which

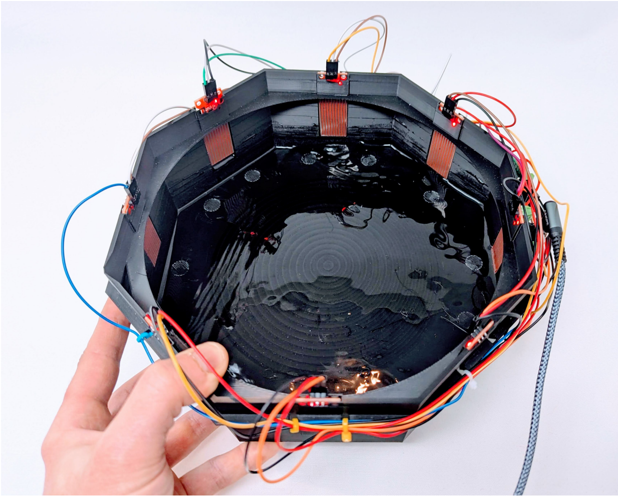

Figure 8: The final Aquapella container with eight sensors and water movement.

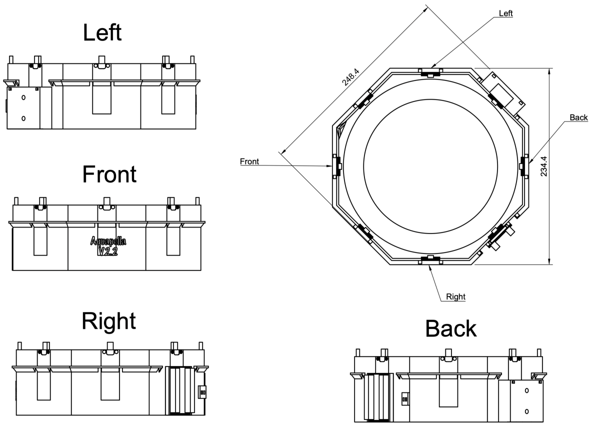

Figure 9: Mechanical drawing of the Aquapella showing all sides of the Aquapella.

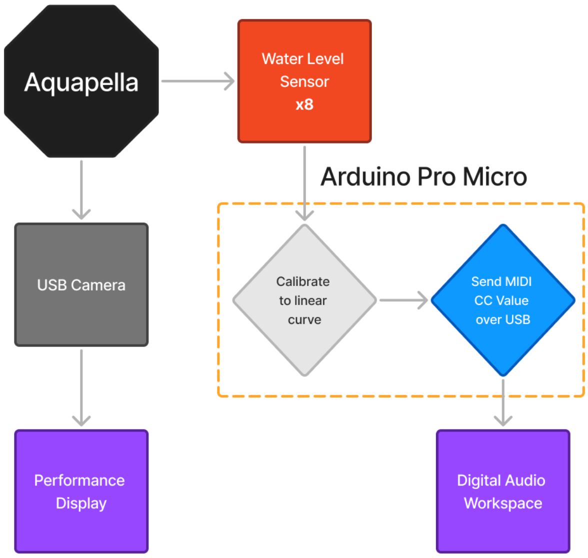

Figure 10: Functional block diagram of the Aquapella system featuring water level sensors, microcontroller, and USB camera.

is hard-coded into the microcontroller, ensures consistent and normalized readings across all eight sensors. The calibrated data is transmitted via MIDI as Continuous Controller (CC) values whenever its respective sensor reads a change. This is similar to how a MIDI fader device only transmits when it moves positions. CC MIDI was chosen for its flexibility, allowing users to map Aquapella's MIDI data to control parameters such as amplitude, EQ, ambisonics, modulation, or any other MIDI-controllable feature in a DAW.

In the Aquapella's current state, the MIDI channels and values sent by the Aquapella are fixed in the microcontroller's code and cannot be changed without reprogramming. However, in the future, we plan to implement a system to configure MIDI mappings from an interface on the Aquapella to make it more adaptable to a variety of performance setups.

3.5 Audio Experiments

As a gestural interface for a computer rather than a stand-alone sound-producing instrument, the Aquapella offers numerous ways to map its movements into sound. While there is still more to do, we conducted extensive experiments to determine aesthetic mappings that harmonized the chaotic, natural motion of water with imagined acoustic outputs. We found that flowing and ambient sounds paired best with the Aquapella's character, leading us to focus on ambient, noise, and glitch aesthetics that meander around moments of harmony. For this phase of development, we focused our experiments on Max/MSP, Pure Data, Strudel, and Ableton Live, producing sounds in both stereo and quadrophonic setups.

3.5.1 Spatialization. One natural behavior of the Aquapella is the tilting and swirling of water within the container. The initial approach mapped the device's tilt directly to sound location within a room. For example, tilting west positioned the sound on the west side of the room, and tilting north moved it northward. Since the device lacks elevation detection, spatial mappings were confined to a 2D plane. This mapping was done by each sensor having a "weight" that pulled an ambisonic source in its direction proportionally to its water level. This successfully created dynamic effects where sounds "reverberated" across the room, mimicking the water bouncing off the container's walls.

In other experiments involving spatialization, the sounds were rotated in space while using tilt to control additional parameters. For instance, in looping experiments, multichannel Max objects were employed to pan sound across a quadraphonic setup, using gestures to modulate dynamics, synthesis, and voice parameters while the panning occurred in the background. While the panning was not directly controlled by the user of the Aquapella, it added an immersive element to the sound.

3.5.2 Octet. The Octet experiment highlights the Aquapella's capabilities by assigning each sensor to control the amplitude of a synthesizer. Gesturing the Aquapella changes the water level of all sensors and transforms the synthesizers into a flowing octet controlled by water. When leveraging the water's cyclical and reverberating motion, this mapping creates dynamic effects with any sound source.

The shape of the Octet causes some idiosyncrasies. At rest, the water level of the Aquapella sits flat just below the sensors , as in Figure 3(a). However, when tilting around the container and moving the water slowly, the octagonal form along with the water depth forces three sensors to be hit with water at the same time. This effectively means that the Aquapella's octet is formed from a series of trios whose volume flowed with the turbulence of water.

An initial instinct of how to map the pitches of the octet was to choose eight notes in a scale (repeating the tonic at the octave), one for each sensor. However, this led to the "trios" of the octet only being whole steps or half steps apart making an unpleasantly dissonant cord. In a more successful mapping, we assigned pitches within a circle of thirds, fourths, and fifths which spaced out each sequential sensor/note with at least a third. This mapping allowed for relatively easy programming while also producing pleasing ambient chords.

We found that the most successful outcome of the octet, however, was when water was swirled in a cyclical pattern quickly around the container. This created a flowing circle of notes that would be extremely reactive to the speed of the circular gesture.

3.5.3 Spaceship. This sound experiment mainly features two sounds. The first is a rhythmic chirping sound that changes it's location in an ambisonic spatialization based on the tilt of the Aquapella. The chirping was chosen because of how clearly defined the sound is when panned across the room or over headphones. The second sound is a theremin-like synthesizer that changes frequency based on water level across all sensors. This generally means that the more the water is moved around across the sensors, the higher the frequency of the theremin sound. When combined, these sounds create a soundscape that is reminiscent of being in an otherworldly spaceship.

3.5.4 Ocean Wind. Ocean Wind is a soundscape featuring white and pink noise that is transformed with different envelopes to emulate the sound of an ocean shore. All eight water level sensors are used to directly control a filter affecting the loudest of the emulated "ocean wave" adding a low pass filter that makes the user feel as though they have been submerged in the wave. When this sound is explored quickly, the white noise emulates more of a quick gust of wind blowing past the user.

In the background of this soundscape are many quieter sources of white noise that are constantly oscillating and randomly change based on the input of the Aquapella. While these sounds are not directly controlled by the Aquapella, they are in a constant motion that will always sound different while interacting with the Aquapella.

3.5.5 Patterns and Euclidean Rhythms. While the Aquapella isn't struck like a drum, its tilt and movement lend themselves to unique interactions that could manipulate percussive sounds. Experiments with controlling Euclidean rhythms, altering sample scrubbing speeds and locations, and generating metronome patterns, achieved varying degrees of success.

We attempted to implement peak detection that would give timing and velocity to a splash against any of the sensors. The idea being that rhythmic sounds could be driven by dynamic splashing water movements in the container. However, with the sensor's inconsistencies leading to extremely inconsistent peak measurements, this experiment proved to be unsuccessful in this iteration of the Aquapella.

Our best example in generating a rhythmic sound from the Aquapella featured two percussive sounds with the same rhythm. The Aquapella would shift the phase of one of these sounds leading to a completely different final output of rhythm. The circular shape of the Aquapella lends to an intuitive mapping of a cyclical concept such as phase shifting.

3.5.6 Voice loopers and Autotune. We also used the Aquapella's tilt and motion to modulate vocal and spatial audio. A performer records their voice either in real-time or through stored buffers and moves the device to manipulate pitch, shift, and modulation through gestures. In one setup, a MIDI foot pedal controlled eight recorded loops, rotating them around the room using Max's multichannel objects. Another experiment combined Pure Data with a microphone and MIDI foot pedal to create heavily autotuned vocal modulations tied to the Aquapella's movements.

3.6 The Camera

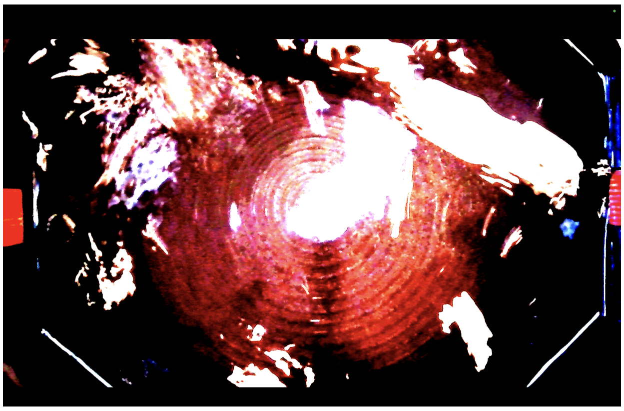

Figure 11: Aquapella camera view with contrast filter.

We built a detachable USB camera mount in the device in order to experiment with a tightly coupled audio-visual experience. As the camera is statically fixed to the device, it features the water's movement, not the container's. This USB camera also features a ring light around the lens that projects a glowing circular orb on the water's surface. From the webcam's perspective (see Figure 11), the ball of light is disrupted with any change to the water's surface, and when the water is tilted around the inside of the Aquapella, the ball of light seems to move with the direction of tilt.

This provides an interesting synaesthetic dimension that emphasizes the connection between visualized water motion and sound. Our plan is to potentially use two or three Aquapellas together for a stereo or triadic wide-view display in performance settings. We may also add physical objects in the water such as beads or glitter to create analogue VJ'ing capabilities. Additionally, we plan to collaborate with VJ's who can use the MIDI signal to modulate the visuals in parallel to sonic activity.

4 Discussion and Future Work

There are a few points of discussion we'd like to highlight regarding the Aquapella that focus on the use of liquid turbulence in

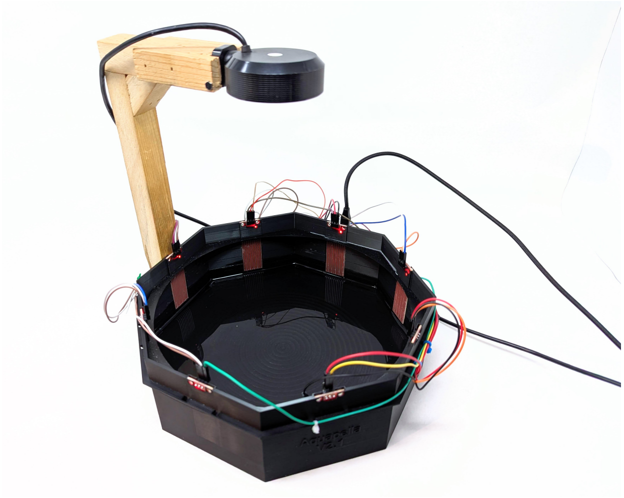

Figure 12: Image of the Aquapella with attached camera. While the Aquapella is made out of a black plastic, the camera mount is made out of wood. The camera itself has its own USB cable separate to the microcontroller.

sound making, the combination of physical and computational media, gestural audio interfaces based on water, and performance.

4.1 Liquid Turbulence and Sound

The Aquapella demonstrates a novel way to interact with fluid dynamics through sound, offering a tactile yet flowing medium of engagement. Unlike fully contained and controlled hydraulic systems, the Aquapella embraces the inherent unpredictability of water while monitoring it in detail. This balance between control and chaos makes the device uniquely interactive, capturing the erratic nature of water and translating it into a form that can be intuitively understood and experienced through sound.

4.2 Combination of Physical and Computational Media

The Aquapella exemplifies the synergy between physical and computational interactions. Physical interactions are inherently engaging, but challenging to quantify and interpret in real time. Computational interactions offer vast possibilities, but often lack a tangible, kinaesthetic quality. By merging these two media, the Aquapella augments interaction with the physical world while grounding the experience in the digital realm. This fusion enhances both the intuitive understanding of fluid dynamics and the creative potential of digital sound design.

4.3 Liquids as a Gestural Audio Interface

The novelty of this research lies in using water as a gestural interface where the device's direct motion leads to indirect and dynamic acoustic outcomes. Nearly identical inputs generate unique outputs due to the chaotic nature of the water. Furthermore, the Aquapella's gestures are contextually dependent and driven by flow. The momentum of water carries over from one gesture to the next, creating sustained effects. This residual momentum introduces an "aftertouch"-like quality, where the physical properties of water extend and transform the sonic output in nuanced ways.

Interestingly, we found that most people who used the Aquapella for the first time had an intuitive understanding of the capabilities of the device. While this needs more research, it suggests that people have a natural understanding of how to interact with water in a container and different ways that water is moved through gesturing with the container. This is perhaps because people interact with containers of fluid on a daily basis and turning one into an instrument is a natural extension of that interaction.

4.4 Performance with the Aquapella

Performing with the Aquapella has some challenges due to its inherent inconsistency. Distinguishing between inconsistencies caused by the water's chaotic nature and those resulting from calibration issues proved difficult. This variability can make precise musical performance challenging, particularly for artists seeking consistent outputs. However, embracing the fluid and unpredictable nature of the Aquapella opens up endless creative possibilities. For performers, the sensation of feeling the water's weight shift within the container, while simultaneously hearing the corresponding sound move through the room, is uniquely satisfying.

The Aquapella also offers immense audio-visual potential. The mounted camera provides a visual representation of the water's movement, allowing the audience to share in the fascination of elemental dynamics and observe how gestures shape the chaotic fluid into expressive soundscapes.

4.5 Future Work

In future work, we want to explore custom sensors, use in education, various container shapes, feedback systems, new peak detection, chemical changes, and future performance concepts.

4.5.1 Custom Sensors. The commercial sensors, while sufficient for the current system, present a limitation in terms of accuracy, durability, and adaptability. We believe we can custom build more robust and accurate sensors that are tailored to the Aquapella's needs. Custom sensors offer greater precision, longer lifespan, and flexible form factors, opening up possibilities for further iterative changes and enhancements to the device. While our current sensors are based on conductance, we are interested in exploring capacitive sensors where integrated circuits could be used with exposed wire in the water, copper plates that measure water level from the outside, or conductive 3D printed filament. Capacitive sensors would likely prove to be less finicky and require less calibration than the conductive sensors we are currently using

4.5.2 Container Shapes. The shape of the container significantly influences the personality of the instrument and its gestural interactions. Future iterations could explore a variety of container shapes to expand the range of possible gestures and sounds. For example, long containers like tubes or gutters could function as low-frequency oscillators (LFOs), while fully enclosed spherical containers could enable dynamic performances, such as holding and moving the device while dancing. Pendulum-mounted containers could add another layer of motion-based sound manipulation. A collection of diverse container shapes could also create versatile and visually captivating performance setups.

4.5.3 Feedback Systems. Incorporating auditory and visual feedback into the Aquapella could greatly enhance its interactivity and aesthetics. For instance, an underwater speaker could produce waves of sound within the water, creating a feedback loop where the instrument responds to its own output. Similarly, integrating LEDs that change based on sensor readings or visual inputs from the camera could add a dynamic glitch aesthetic to the visuals. These feedback systems could deepen the performer's connection with the instrument and provide audiences with a more immersive experience.

4.5.4 Peak Detection. We have implemented a peak detection feature in the Aquapella's hardware that sends MIDI note-on and note-off commands based on detected peaks in the sensor readings. This allows the Aquapella to function as a traditional MIDI instrument, capable of interfacing with other electronic MIDI instruments.

When a sensor detects a significant peak, the Pro Micro sends a note-on command with the peak value as the velocity. Once the sensor reading falls below a certain threshold, a note-off command is sent. This enables the Aquapella to work with MIDI instruments and samplers that have their own ADSR envelopes.

While this mode abstracts the flowing nature of water, it allows for more traditional MIDI interactions. However, we aim to refine this functionality as the current peak detection algorithm does not feel very responsive. We believe that improving the algorithmic detection of peaks and allowing the Aquapella to change MIDI notes without reprogramming the device will enhance its performance.

4.5.5 Chemical Changes. Experimenting with liquids other than water or chemically altering the liquid mid-performance could introduce new dimensions of interaction and sound generation. Adding salt could increase conductivity, cornstarch could change viscosity, and colored oils could add visual richness. These changes could be dynamically reflected in the instrument's output, allowing performers to explore a broader range of auditory and visual effects.

4.5.6 Future Performance Concepts. The Aquapella lends itself to exploring water in various social, aesthetic, and physical contexts. We imagine future performances with the instrument to explore psychological or political themes around water. For instance, one interest of ours is something known as the Diving Reflex which describes a series of physiological changes that occur when an air-breathing vertebrate holds its breath underwater. As an example, when a person submerges their face in water, their heart rate slows down immediately. We are also interested in developing compositions that address water rights and conservation.

4.5.7 Education. While designed as a performance instrument, the Aquapella also has educational applications. Its interactive nature could serve as a tool for teaching physics concepts such as acoustics, resonance, and wave dynamics. By engaging with these principles through sound and movement, students could develop a more intuitive understanding of complex physical phenomena.

4.5.8 User Study. At this time, no formal evaluation has been conducted with the Aquapella. We have only conducted informal user studies to help gauge the general usability of the device. In the future, we plan to conduct a more formal study with a variety of musicians and user groups to assess the expressiveness and capabilities of the Aquapella in a variety of hands and scenarios.

5 Conclusion

The development of the Aquapella, a water-inspired gestural device for musical expression, showcases the innovative intersection of chaotic physics and digital art in musical performances. This novel instrument harnesses liquid turbulence to generate dynamic soundscapes, offering a unique perspective on the interplay between liquid motion and sound. By leveraging computational technology to report the real-time state of a liquid to a digital audio workstation, the Aquapella creates opportunities for exploring this relationship in ways that were previously difficult or less-direct.

While more conventional methods exist for capturing gestures and translating them into sound, the Aquapella provides a distinct, tangible, and kinaesthetic experience. It bridges the physical and auditory worlds, allowing users to manipulate and interact with both in a deeply kinaesthetic way.

Future applications of the Aquapella lie in innovative performances that study the complex relationship between gesture, turbulence, and music. These explorations could further uncover the potential of this instrument as both an artistic and educational tool. Additionally, experimenting in custom sensors, container shapes, feedback systems, and chemical changes could significantly enhance the Aquapella's capabilities, making it a versatile and powerful instrument for a wide range of creative applications.

6 Ethical Standards

All research presented in this paper is the result of ideation and iteration of our own without any funding. We have used no animals or human participants in this research. We have done our best to cite all known inspirations for this work as well as any prior software used.

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