Sound Kitchen: Designing a Chemically Controlled Musical Performance

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ABSTRACT

This paper presents a novel use of a chemical experiments' framework as a control layer and sound source in a concert situation. Signal fluctuations from electrolytic batteries made out of household chemicals, and acoustic samples obtained from an acid/base reaction are used for musical purposes beyond the standard data sonification role. The batteries are controlled in handy ways such as warming, stirring and pouring that are also visually engaging. Audio mappings include synthetic and sampled sounds completing a recipe that concocts a live performance of computer music.

Keywords

Chemical music, Applied chemistry, Battery Controller.

1. INTRODUCTION

In data sonification[1], sound is the medium to display a process that generates data. While aesthetic principles may be used in the design of a sonification interface, the scope usually remains in the observation of data. The method and sounds selected have a limited role compared with the process at hand. In our project, sound is the goal itself, and the process from which it derives is designed to have a musical and visual outcome deliverable through a live performance. The wide range of chemical reactions allows for the realization that some can be appropriate for musical purposes. To explore this idea a number of household chemicals were considered for their potential in producing interesting visual and acoustic effects while providing signals used to drive a software sound engine.

1.1 Chemical Selection Criteria

A chemical process was defined as worthwhile pursuing if it had any combination of the following: controllability, availability, safety of use, visually engaging, wide and predictable dynamic range, or some degree of concordance between expectations about the process and the sound it controls/produces. Another concern was its matching to certain basic time gestures already considered part of the musical outcome: instantaneous changes, as well as slow build ups should be in the 'recipe'. After evaluating a number of elementary processes like acid/base reactions and electrolytic batteries, next came sorting through a list of potential 'ingredients' that would pass the criteria above. Thus colorful orange juice and red wine were chosen as acidic alternatives to the more powerful but transparent vinegar. Direct heating of water gained over the slower temperature build-up of yeast, water and sugar. The stirring of a liquid in a container remained as a must-do for the applicability of radial motion as a control for audio system playback rate. More hardcore chemicals were discarded, despite their potential for great effects, due to safety concerns.

1.2 System

Sound Kitchen uses three variations of a electrolytic battery: a stirring, a pouring and a thermally controlled battery. The three batteries generate voltage signals with variations in time, and are easy to manipulate in front of an audience. The voltage signals are captured and conditioned through a microcontroller and sent to a PC where they are mapped to musical parameters. The system also has four test tubes with acid and base. The fizzing sounds of an acid with base reaction are captured by microphones and used directly as sound source (Figure 1).

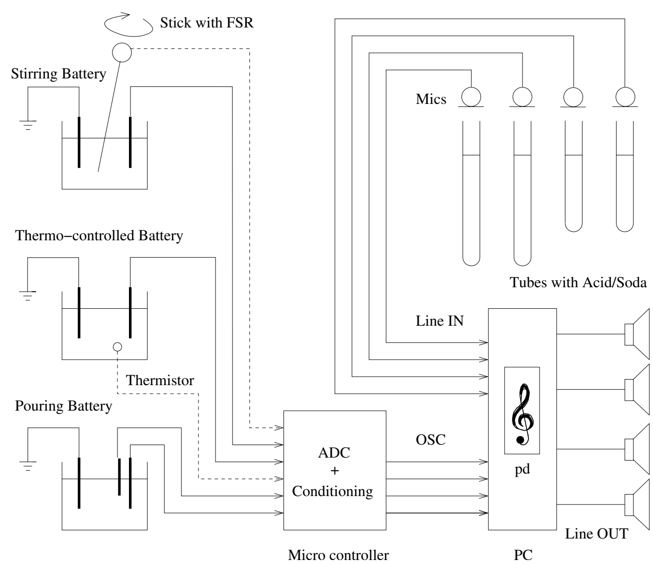

Figure 1: System overview

This work was done as a final project for the course "Music 250A: Human Computer Interaction Theory and Practice: Designing New Devices"[2] (instructor: Max Mathews and Bill Verplank) at CCRMA in Stanford University.

2. HOUSEHOLD CHEMISTRY

2.1 Baking soda and vinegar

Combining 10 ml of vinegar (an acid) and 2g of baking soda (a base) results in an acid/base reaction with fizzing sounds inside a test tube. The products of all acid/base reactions are a salt, water, and carbon dioxide gas:

$$Acid + Base \longrightarrow salt + water + carbon\ dioxide\ gas$$

The specific reaction in this system is:

$$CH_3COOH + NaHCO_3 \longrightarrow NaC_2H_3O_2 + H_2CO_3$$

where CH_3COOH is acetic acid, $NaHCO_3$ is baking soda and $NaC_2H_3O_2$ is sodium acetate. This is followed by

$$H_2CO_3 \longrightarrow H_2O + CO_2$$

where CO_2 is a gas, dispersed as bubbles into the atmosphere. This part of the reaction causes a fizzing sound which is captured by microphones and processed as an acoustic signal.

2.2 Electrolytes in Batteries

A voltage can be created when two polarized electrodes, e.g. copper and aluminum strips, are inserted in an electrolytic substance. The negative ions in the electrolyte are attracted to the aluminum strip, while positively charged ones are attracted to the copper strip. Temperature increase/decrease and electrolyte volume are used to control the total charge of the system.

Citric Acid

Citric acid, a prominent component of orange juice is represented by the chemical formula $C_6H_8O_7 \cdot H_2O$. When the copper and aluminum (the electrodes) are submerged in the orange juice (the electrolyte), the hydronium ions (H_3O^+) of the orange juice are attracted to the copper electrode and the $C_6H_7O_7^-$ ions are attracted to the aluminum electrode (Figure 2). 40 ml of orange juice are used to charge the stirring battery.

Red Wine

Red wine may contain three acid derivatives: benzoic acid derivatives, cinnamic acid derivatives, or flavonoid derivatives (Figure 3). This substance works much like that of orange juice except that the $C_6H_7O_7^-$ is replaced by one of the acid derivatives of the wine. 400 ml of water and 100 ml of red wine are used to charge the pouring battery.

Temperature control

In this system protons (H^+) and hydroxide ions (OH^-) are the attaching elements. After heating around 60 degrees Celsius, the electrolytic properties of water become more intense, therefore more interesting as a slow paced control signal. Heat increases the agitation of the ions in the electrolyte thereby increasing the flow of the electrons (Figure 4). Our thermo-controlled battery uses a tea pot coil warmer to heat 250 ml of water.

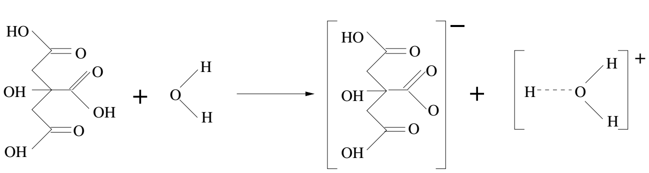

Figure 2: Citric acid gives up one hydrogen ion to a water molecule resulting in negatively and positively charged molecules

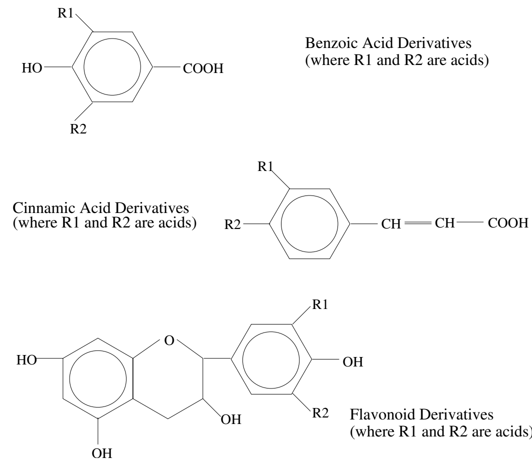

Figure 3: Three acid derivatives that occur in red wines - benzoic acid derivatives, cinnamic acid derivatives, and flavonoid derivatives

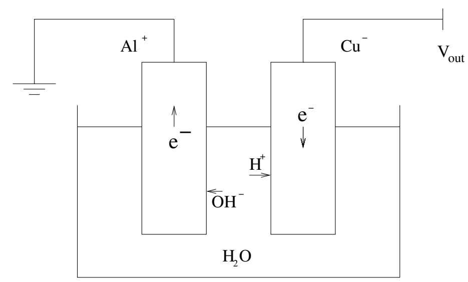

Figure 4: The water battery system where water is the electrolyte and a copper strip and an aluminum strip act as electrodes

3. ENGINEERING

An ATMega163 controller[3] is used to capture, condition and transmit signals from sensors in the chemical framework. AVRGCC is used for coding. Out of six input signals to the ATMega163, four output signals are sent to a PC after conditioning via the serial port using Open Sound Control (OSC) [4].

3.1 Tubes and Microphones

Four small microphones are used to capture the sounds of the reaction of acid and soda in the test tubes. Signals are sent directly to four loud speakers via a spatialization patch in Pd [5], e.g. the first tube to the front right speaker, the second to the front left, the third to the rear right, the fourth to the rear left. Before performance, the portion of vinegar and soda is carefully chosen not to damage the microphones with foamy acidic bubbles. The soldered parts of microphones are coated with hot glue, to prevent rust.

3.2 Batteries

Stirring Battery

The Stirring Battery exhibits a chaotic voltage flow when the electrolyte is stirred with a circular motion. For musical reasons, this is turned on and off in a controlled way. An FSR (Force Sensitive Resistor) attached to the stirring stick implements this switching functionality: raw voltage signal when the stick is held, or zeros when not held (Figure 5). Both signals from the FSR and the battery are sent to the micro-controller where the flow control switching takes place.

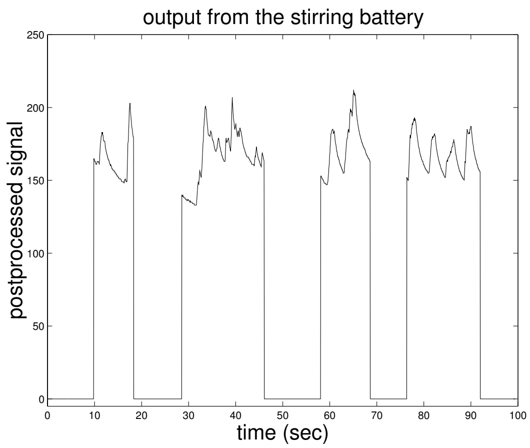

Figure 5: Example output from the Stirring Battery showing voluntary on and off switching at four instances. Note that fast transients occur during stirring.

Pouring Battery

The Pouring Battery has two stages during the performance: initially it is filled with plain water; then as some red wine is added, more ions charge the liquid, increasing the voltage output from the battery. By pouring the liquid into a different container, and back into to the battery container this voltage fluctuates (Figure 6). Two copper strips are set in the battery with different but coherent signal outputs. One of them is sent to a Non-Inverting amplifier, made with an Op-amp, as to provide more dynamic range to the signal.

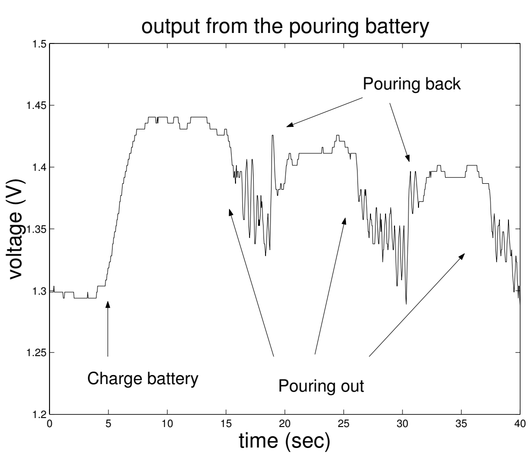

Figure 6: Example output from the pouring battery showing voltage fluctuations as wine is added and the electrolyte is poured in/out the battery container

Thermo-Controlled Battery

The Thermo-controlled Battery generates a voltage v_T which increases roughly proportional to the water temperature T within the approximate range of $60 < T < 100$ degrees Celsius. During the performance a coil heater, cold water and ice are used to control temperatures. A thermistor is also used to set a temperature threshold around the boiling point. Both signals from the thermistor and the battery v_T are sent to the micro-controller where the flow control takes place (Figure 7).

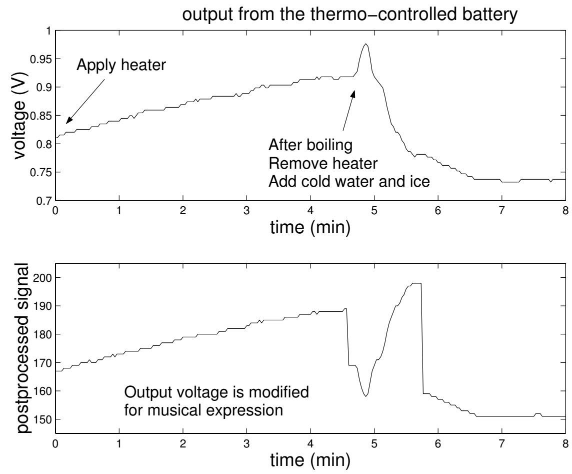

Figure 7: Signal from the thermo-controlled battery showing slow time transient during 8 minutes. Top : raw voltage output, Bottom : postprocessed signal

4. MUSIC AND PERFORMANCE ASPECTS

The metaphor used when composing music for this project was that of cooking. When preparing a dish, adding separate ingredients following a recipe results in a whole that is more than the sum of its parts. In our framework every chemical reaction contributes to the music as 'composed' on a score designed for live performance.

Since this composition is to be performed live, Pd was chosen as the sound engine where the incoming signals are translated into music.

4.1 Signal Mapping

Overall 4 input signals (signals 1 - 4) arrive into the Pd patch via the serial port using OSC. Additionally, 4 microphone signals (acoustic signals 1 - 4) are fed via the audio card and entered into Pd using 4 channels in the adc˜ object (analog-to-digital converter). The output of the whole patch is sent out through the audio card using 4 channels in the dac˜ object (digital-to-analog converter).

Signal 1: Multi-rate Sampler

Signal 1 is derived from the Stirring Battery and used to control the playback sample rate of two speech samples. While the stick is held, signals pass through, otherwise the input is shut down. When a signal is present, the Pd patch responds by fading in the voice samples, and depending on the motion achieved inside the container, the sample rate for playback varies. Based on tested behavior of this battery, whenever a critical motion speed is achieved inside the container, the signal value raises, otherwise it settles and decays. Because of the non-linearity of the chemical process, it is difficult to achieve the "sweet spot" where both voices are intelligible, otherwise sounding too slow and too fast, respectively. It is used after the climax in the composition.

Signal 2: BoiliBass

Signal 2 comes from the Thermo-Controlled Battery. It raises continuously until the boiling point is reached, at which point it shuts down. It controls a simple additive synthesis patch of two sounds with 4 partials each. The base frequency of one sound is equal to $f1 = x$, while that of the other is $f2 = x - (x/5)$, where x is the signal value. These two sounds produce a beating effect, which increases as both values diverge. This signal is used throughout the piece, providing its overall form (Figure 7, the bottom part) with the top value achieved at $\frac{2}{3}$ s of the duration of the piece, and the remainder $\frac{1}{3}$ showing a different behavior during cooling down.

Signal 3 + 4: Morning Bird & Meshscape

Signals 3 and 4 are derived from the Pouring Battery. It controls a patch producing 50 ms bursts of an additive synthesis array whose bandwidth, base frequency and preeminence of each partial's weight depend on various scaling of signals 3 and 4. It provides what is perceived as a background bird singing sound which tends to be stronger when the quantity and motion of electrolyte inside the battery is higher, that is, during pouring, with an immediate decay in presence (lower pitch height and intensity).

This signal also controls an additive synthesis and frequency modulation patch. Volume is controlled by slow transient envelope taking up to 30 seconds to peak. The additive synthesis patch produces a mesh of 16 partials whose weight is scaled by three oscillators which also modulate the frequency of 3 other partials. The rhythm achieved with the liquid pouring influences the rate of oscillation, inducing higher sidebands that appear to match the movement of the performer.

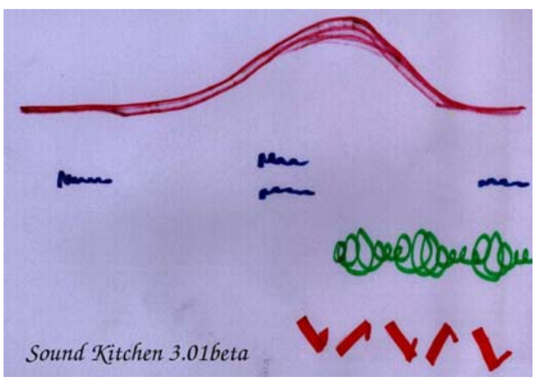

Figure 8: The score: its duration is 3 to 8 minutes depending on the start temperature of water. Drawings indicate location of group events in a timeline.

Acoustic Signals 1 - 4

The direct sound of baking soda diluted in vinegar inside test tubes of different sizes is sent across the room in a 4-channel spatialization setup controlled via a pd patch. This process has a short duration and defines the start point every time a scoop of baking soda is added to the tube. It appears along the beginning, reaching the climax, and at the end of the piece.

4.2 Score and Performance

The system was tested in December 2002 with a composition for which a simple score (Figure 8) was designed. The three authors participated as performers stirring juice, pouring water + wine in the batteries, baking soda to tubes, and otherwise, supervising that the whole system responded as expected throughout the performance. With practice, a single performer may be sufficient for the whole act.

As to not affect the impression that the visual performance is integrally bounded to the output sound, no manipulation of the Pd patch, nor the microcontroller board is required (except for a few start/stop instructions throughout the performance)

While this system was designed with an specific outcome in mind, there are few constraints for it to be used as a more general performance system. Most of the limitations are posed by the choice of audio synthesis and parameters in the design of the Pd patch, and the capture/conditioning stage in the microcontroller. This choices are completely arbitrary, and respond mostly to the initial compositional idea. A different user with Pd and avrgcc programming experience could modify this framework with a minimum effort, but that also brings the question of whether it would not be more effective to build a different one from scratch.

5. CONCLUSION AND FUTURE WORKS

The exploration of music creation with chemical reactions and manipulations is a novel topic in the field of computer music. Through simple chemical experimentations, analog circuitry, computer manipulation, and human control, a new way of creating music has been explored. Since making music using chemicals has not been vastly explored, there remains great potential for further improvement in this area. One method of improvement would be to implement some sort of real time automatic normalization of the chemical signals. Currently the system has to be tuned to prevailing conditions (ambient temperature, electrolyte mixture) before performance. Furthermore, it is possible to explore other chemicals, reactions, and control methods that can allow for other musically inspiring signals and performance situations. Finally, this project is truly a testament of the integration of diverse fields of study to create new music.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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[2] CCRMA, Music 250A home page: http://www-ccrma.stanford.edu/courses/250a/

[3] Atmel AVR home page: http://www.atmel.com/atmel/products/prod23.htm

[4] OSC is a protocol for communication among computers, sound synthesizers and other multimedia devices that is optimized for modern networking technology. OSC home page: http://cnmat.cnmat.berkeley.edu/OSC/

[5] Pd (Pure Data) is a real-time graphical programming environment for live interactive computer music. Pd works on SGI machines, Microsoft Windows, Linux, and Mac OSX. Pd home page: http://crca.ucsd.edu/ msp/software.html