MUSIC 250A / CS 377C
Human Computer Interaction Theory and Practice
Final Project

Sound Kitchen

Hiroko Shiraiwa Vivian Woo Rodrigo Segnini

Contents

1 Introduction

The wide range of behaviors of chemical reactions allows for the realization that they can be used to control musical processes. To explore this idea a number of substances were considered for its potential in producing interesting effects: hydrochloric acid, sulfuric acid, magnesium, and potassium chlorate, among others. However we quickly understood that the use of these substances in most performance situations would be risky, and therefore switched to household chemicals, which still offered a good range of possibilities, within a safer setting.

Discussions which we had often were if the natural process is appropriate for a musical structure, or if the process has enough controllability. Some of the natural processes which we experimented with were too slow for our musical ideas. Some process were so weak that we could not convert into the form of electric signal or mechanical force. The processes which survived the experimental stage, and which we used in the performance were relatively replicable, controllable and predictable so that we could use them for real time performance.

Our team was the combination of a chemical engineer (Vivian), an electronic engineer (Hiroko) and a composer (Rodrigo).

The following sections will describe our path from experiments to music. Section two covers the experiments and explanation of the reaction (chemistry). Section three describes the implementation of signal control and transmission (engineering). Section four is about mapping, composition and performance (music). Section five mentions conclusion and proposes future works.

2 Chemistry

2.1 Experiments

The initial idea was to use three mixtures: citric acid (orange juice), yeast, and acetic acid (vinegar) with sodium bicarbonate (baking soda).

The orange juice (along with copper and aluminum electrodes) was to be used as a battery which would provide a steady voltage signal to the AVR board. Yeast was thought to be a possible switch, which may be connected only when the yeast, water, and sugar mixture grows enough to overflow a small glass. The gas production from the reaction of vinegar and baking soda was thought to be strong enough to cause displacement to a film piezo sensor. Not all results were as ideal as originally imagined. The yeast mixture turned out to be too difficult to time and the gas production from the vinegar mixture was unable to cause any movement of the piezo sensor. The orange juice, however, functioned favorably.

Since orange juice seemed to be a reliable chemical, various other experiments were conducted to determine what parameters could be changed to cater to the needs of a possible musical composition. Experiments of changes in temperature, electrolyte (orange juice) volume, and electrode sizes were conducted. Such experiments did not provide any desirable effects. It was found, however, that with stirring, the voltage created by the orange juice battery would increase and therefore produced an easy and effective form of control.

Further research and experiments led to the final decisions of mixtures: orange juice, water, red wine, and vinegar with baking soda. As mentioned earlier, orange juice produces a steady voltage which may be altered by stirring the liquid. It was determined that water starting at approximately 63 degrees Celsius (145.4 degrees Fahrenheit) produces a steady increase in voltage as additional heat is applied to it with a heating element. Red wine, containing acid, contributed to the voltage change when added to water and also provided a dynamic visual effect for the performance. The reaction between vinegar and baking soda, although unsuccessful in moving the film piezo sensor, proved to produce extremely interesting sounds. For this reason, microphones were built to capture the sounds of this reaction. This signal was used directly as a part of the chemical music while all other substances used produced signals which were then used to control/manipulate a certain parameter in pd.

2.2 Reaction in a Nutshell

Citric Acid (Orange Juice)

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 hadron 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 (see Figure 1). This system induces a current, which is why a voltage can be created (see Figure 2).

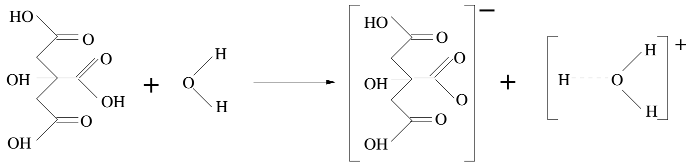


Figure 1: Citric acid gives up one hydrogen ion to a water molecule resulting in a negatively charged molecule (which is attracted to the aluminum strip) and one positively charged molecule (which is attracted to the copper strip)

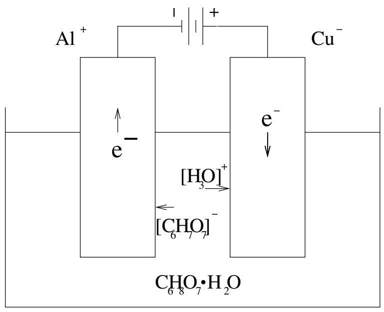


Figure 2: The orange juice battery system where orange juice is the electrolyte and a copper strip and an aluminum strip act as electrodes

Water

Much like the orange juice system, a current can be induced by using water as an electrolyte and copper and aluminum as electrodes (Figure 3). The ions in motion are the main difference in this system. Instead of H_3O^+ ions attaching to the copper electrode, protons (H^+) would be the attaching element. Meanwhile, hydroxide ions (OH^-) would replace the $C_6H_7O_7^-$ ion, which is from citric acid. The increased voltage with heating may be due to the fact that the addition of heat into the electrode increases the agitation of the ions in the electrolyte thereby increasing the flow of the electrons. The reason that a steady increase in voltage was only seen with water starting at 63 degrees Celsius has to do with the fact that water is a very special chemical with very unique qualities which is not within the scope of this report to discuss.

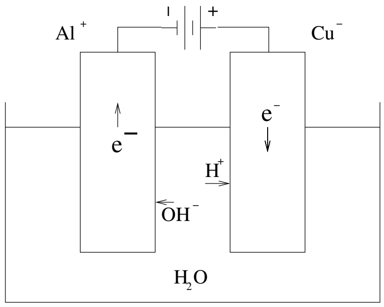


Figure 3: The water battery system where water is the electrolyte and a copper strip and an aluminum strip act as electrodes

Red Wine

Red wine, contains three acid derivatives: benzoic acid derivatives, cinnamic acid derivatives, or flavonoid derivatives (see Figure 4). This substance works much like that of orange juice except that the $C_6H_7O_7^-$ would be replaced by one of the acid derivatives of the wine.

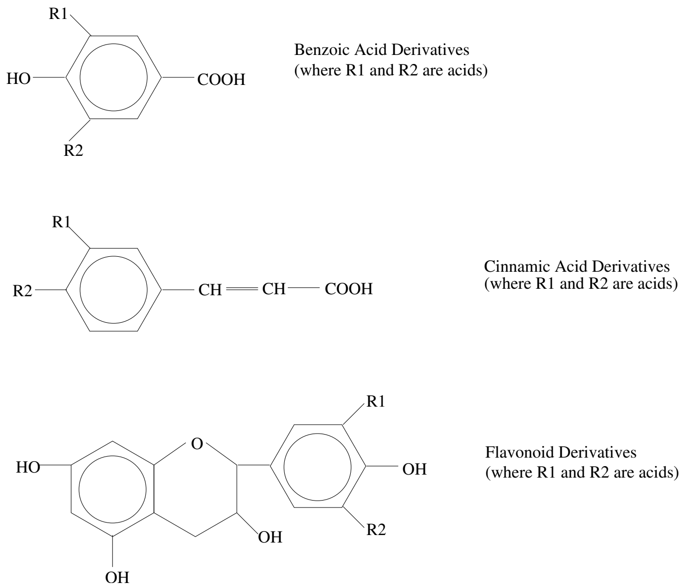


Figure 4: Three acid derivatives that occur in red wines - benzoic acid derivatives, cinnamic acid derivatives, and flavonoid derivatives

Acetic Acid and Sodium Bicarbonate (vinegar and baking soda)

Combining vinegar (an acid) and baking soda (a base) results in an acid/base reaction. The products of all acid/base reactions are a salt, water, and carbon dioxide gas:

$$\text{Acid} + \text{Base} \longrightarrow \text{salt} + \text{water} + \text{carbon dioxide gas}$$

The reaction in this specific system is:

$$\begin{array}{ccccccc} CH_3COOH & + & NaHCO_3 & \longrightarrow & NaC_2H_3O_2 & + & H_2CO_3 \\ \text{(acetic acid)} & & \text{(baking soda)} & & \text{(sodium acetate)} & & \end{array}$$

which is followed by

$$H_2CO_3 \longrightarrow H_2O + CO_2 \text{ (gas)}$$

This part of the reaction causes a fizzing sound which can be captured by microphones to provide a sense of how simple chemical reactions can produce some very unique and intriguing sounds.

3 Engineering

3.1 Overview

The ATMega163 controller was used to capture, control and transmit signals. AVRGCC was used for coding. The six input signals to ATMega163 were converted into four output signals after conditioning. These four output signals were sent to PC which was running Pd via Open Sound Control.

3.2 Signal Capture

Based on the experiments, we decided to use four test tubes and three batteries.

Tubes and Microphones

Four small microphones were used to capture the sounds of the reaction when mixing baking soda and vinegar in tubes. Signals were sent directly to four loud speakers via a mixer, 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 was carefully chosen not to damage the microphones with foamy acidic bubbles. The soldered parts of microphones were also coated with hot glue, to prevent rusting.

Batteries

Three types of batteries were prepared as shown in table 1. Basically signals were generated as voltages from the batteries. These voltages are sent to A/D port on the ATMega163.

Since a battery is a natural process, it never stops creating signals, or the dynamic range of signal is very limited. That is why optional control devices such as FSR, thermistor and Op-amps were used. Optional controls are described in the next section.

Table 1: Batteries: control and output

Battery type	Container dimension	Control	Optional control	Output signal
Orange juice	Small	Stir with a stick	FSR	Chaotic
Hot water	Medium	Warm and Cool down	Thermistor	Slow transient
		(with heater, cold water and ice)		
Water and Wine	Large	Add wine	Op-amp	Sudden increase
		Pour out and in		Periodic

3.3 Signal Control with Sensors and Amps

Using hardware, sensors and Op-amps, the raw signal from the battery was conditioned to provide more useful signals to handle musical expression.

Orange Juice Battery

The Orange juice battery generates a chaotic series of voltage when stirred. For musical expression, the signal needs to be turned on and off in a controlled way, e.g. send signal when the stick is grabbed, send zeros when not grabbed. An FSR was attached on the stirring stick to implement this function. Both signals are sent to the microcomputer, which does the flow control such as following. Typical output sequence is shown in Figure 6.

```
if( FSR_VALUE > THRESHOLD )
     send_signal(BATTERY_VALUE);
else
     send_signal(0);
```

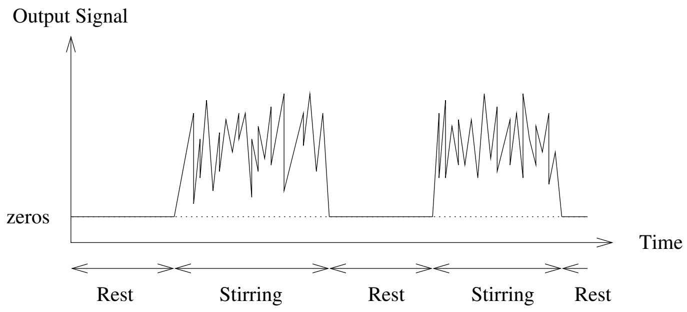


Figure 5: The signal from Orange Juice Battery with on / off

Hot Water Battery

The Hot water battery generates voltage v_T, which increases roughly proportional to the water temperature T within the range $63 < T < 100$ (Celcius degree). In the performance, we used a heater, cold water and ice to control temperatures. The thermistor was used to know the temperature status, such as before/after boiling and over/under temperature threshold. Both signals, v_T and thermistor values were sent to the microcomputer, which does the flow control as following to give a musical progression to the signal as shown in Figure 6.

```
if(Before_Boiling || Under_80degrees)
     send_signal(BATTERY_VALUE);
else(After_Boiling && Over_80degrees)
     send_signal(2*BATTERY_VALUE_at_80_degrees - BATTERY_VALUE);
```

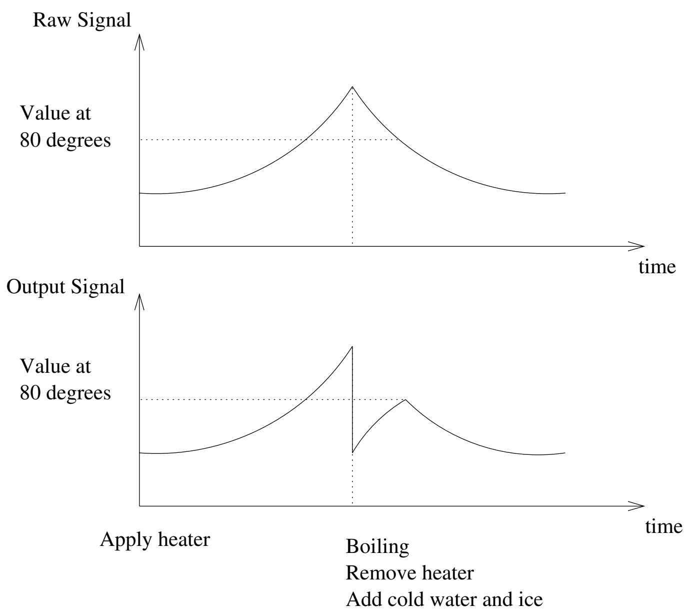


Figure 6: The signal from Hot Water Battery was conditioned for the musical progression

Water and Wine Battery

The Water and Wine Battery has two controls. One is, beginning with plain water, add some red wine in it. It will charge more ions in the liquid, increasing the voltage from the battery. The other is to pour the liquid into another container, and pouring back the liquid to the battery container. The typical output sequence is shown in Figure 7. Two copper strips were set in the battery to have two relevant signal outputs. One of them was sent to a Non-Inverting amplifier of gain three, which was made of an Op-amp, to provide more dynamic range to the signal.

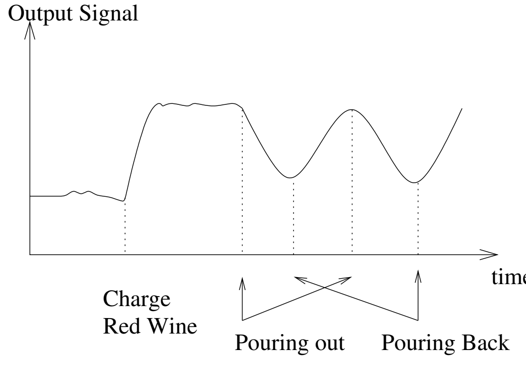


Figure 7: The typical signal from Water and Wine Battery

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.

After initially deciding which processes to include in our framework because of physical factors (its replicability under various circumstances, safety of performers and the public, etc), the reasons to keep some in the arsenal were diverse, but mainly responded to artistic considerations.

A process was defined worthwhile pursuing if it had a combination of any of the following:

- visually stimulant
- wide and predictable dynamic range
- some degree of concordance between what happens in the process and the sound it controls/produces

For these reasons, colorful orange juice and 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. And 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.

That the outcome of this composition is to be performed live was a crucial factor in the choice of a sound engine where to translate the incoming signals into musical sound. Pd (Pure Data) is a real-time graphical programming environment for live interactive computer music. Pd works on SGI machines, Microsoft Windows, Linux, and Max OSX.

Signal capture and conditioning was entirely off the composer's hands (see the Engineering section above), so the sound design portion was done independently and high-geared, although with some basic constraints that were agreed before starting. Among those constraints were the:

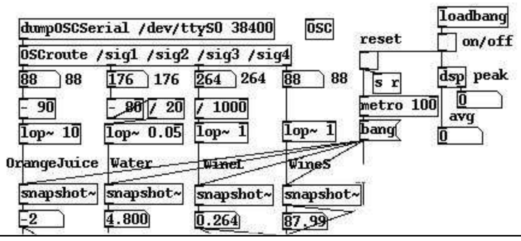
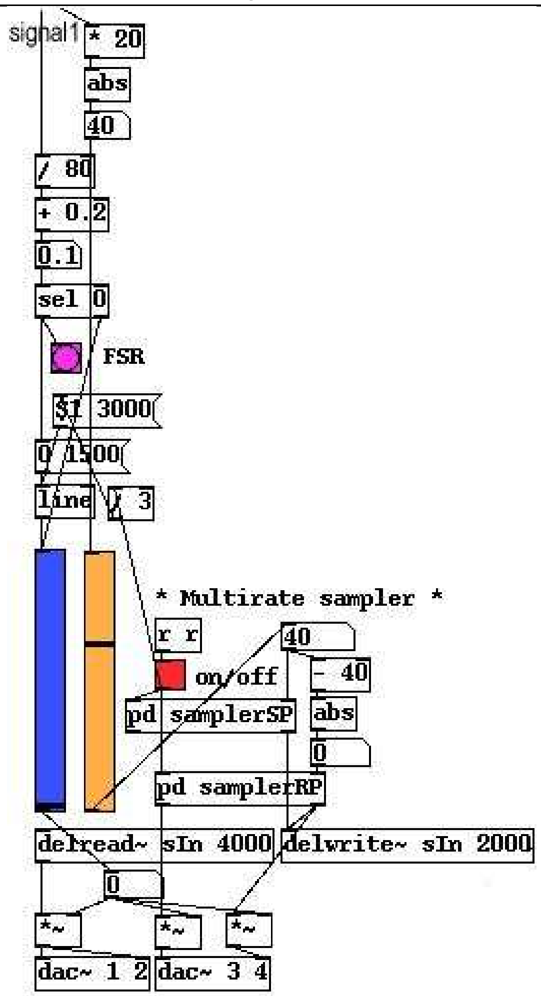
- number of incoming signals (after conditioning)
- tentative range based on preliminary research during the process definition stage
- physical size and other characteristics of each process as they would be used at the performance

This proved to be a successful approach in our team as it allowed for specialization to develop in each area. The chemical and electrical engineering effort was concentrated in assuring that every process was replicable, while the musical effort focused on generating (a range of) sound associations that would comply with our recipe definition.

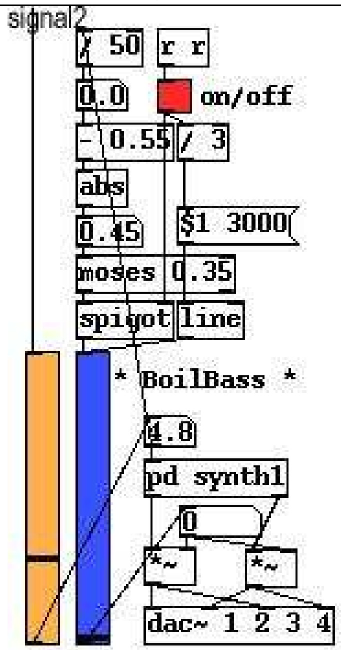
Overall 4 input signals arrived into the Pd patch via the serial port using OSC (Open Sound Control). Additionally, 4 microphone signals were fed via the audio card and entered into Pd using 4 channels in the adc object (analog-to-digital converter). The output of the patch was sent entirely via the audio card using 4 channels in the dac object (digital-to-analog converter).

The whole patch and a detailed view of its subpatches is included in the appendix. The remaining of this chapter will focus on a description of the sounds' handling and production by every stage in the signal flow.

4.1 Pd Patches

<table>
<tr><th>PATCH</th><th>DESCRIPTION</th></tr>
<tr><td>Input stage</td><td></td></tr>
<tr><td>
</td><td>4 signals come in, are scaled, downsampled with low pass filters and snapshot objects. There are switch controls for audio on/off and for all the other subpatches to switch off without switching off the audio which is used by the microphone signals patch.
There is also a dsp usage meter usually peaking 80% during performance.</td></tr>
<tr><td>Signal 1</td><td>Multi-Rate Sampler</td></tr>
<tr><td>
</td><td>This signal is derived from stirring the orange juice. There is also an FSR used as a switch on the handle which gates the signal into the system. While the handle is held, signals pass through, otherwise the input is shut down.
Same signal controls volume and sample rate for playback (sample - see appendix) with different scalings for each.
Based on tested behavior of the orange juice process, whenever a critical motion speed is achieved inside the container, the signal value raises, otherwise it settles and decays.
When a signal is present, this patch responds by fading in 2 different voice samples, and depending on the motion achieved inside the container, the sample rate for playback varies.
Because of the non-linearity of the chemical process, there is a difficult to achieve 'sweet spot' around the middle of the right-most slider where both voices are intelligible, otherwise sounding to slow or to fast.
Used after the climax in the composition.</td></tr>
</table>

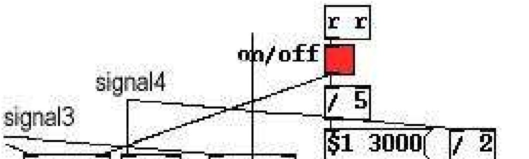
<table>
<tr><th>PATCH</th><th>DESCRIPTION</th></tr>
<tr><td>Signal 2</td><td>BoiliBass</td></tr>
<tr><td>



</td><td>

Signal2 comes from measuring the temperature of water being heated. It raises continuously until the boiling point is reached, at which point it shuts down.
The same signal controls a simple additive synthesis patch (synth1 - see appendix) with 2 by 4 partials whose base frequency is equal to $f1 = x$ and $f2 = x - x/5$, therefore at the range this patch is designed to work, there is an increasing beating effect in sound as both values get apart.
This signal is used throughout the piece, giving it a single sawtooth form where the top value is achieved 2/3s of the duration of the piece , with the remainder 1/3 with a different behavior during cooling down.

</td></tr>
<tr><td>Signal 3+4</td><td>Morning Bird</td></tr>
<tr><td>



</td><td>

In this patch sound is produced as 50 ms bursts of an additive synthesis array whose bandwidth, base frequency and preeminence of each partial's weight controlled by various scaling of signals 3 and 4.
Signals 3 and 4 derive from the pouring of wine in and out from a beaker rigged with our measurement instruments. The big square with raising columns shows the weight of a random number distribution as if they were partials displayed in the frequency domain.
In our rehearsals this signal behaved most random among all the process. Not being clearly linked to any salient visual feature of the framework, it provided what was perceived as a background bird singing sound.
It tends to be stronger when the motion inside the wine is higher, that is, during pouring, with an immediate decay in presence (lower pitch height, intensity).

</td></tr>
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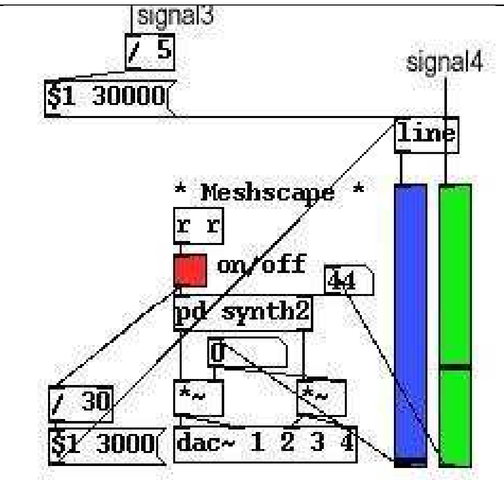
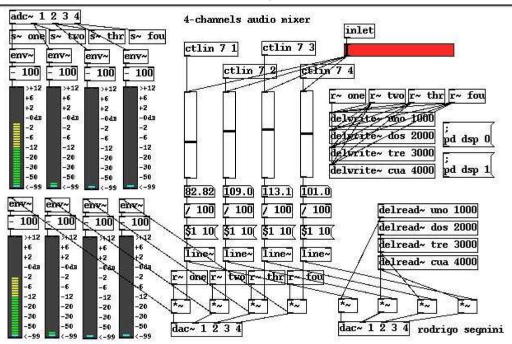
<table>
<tr><th>PATCH</th><th>DESCRIPTION</th></tr>
<tr><td>Signal 3+4</td><td>Meshcape</td></tr>
<tr><td>
</td><td>The same signals as above control this stage containing an additive synthesis and frequency modulation patch (synth2 - see appendix).
Volume is controlled by slow variations taking up to 30 seconds to peak related to the behavior of signal3. 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 wine pouring influences the rate of oscillation, inducing higher sidebands that appear to match the movement of the performer.</td></tr>
<tr><td>Additional Signals 1−4</td><td>Microphone Signals</td></tr>
<tr><td>
</td><td>The direct sound of baking soda diluted in vinegar inside test tubes of different sizes feeds this patch, which basically sends a delayed version of the original sound across the room in a 4-channel setup.
This process appeared along the beginning, reaching the climax, and at the end. Can be used several times without human intervention.</td></tr>
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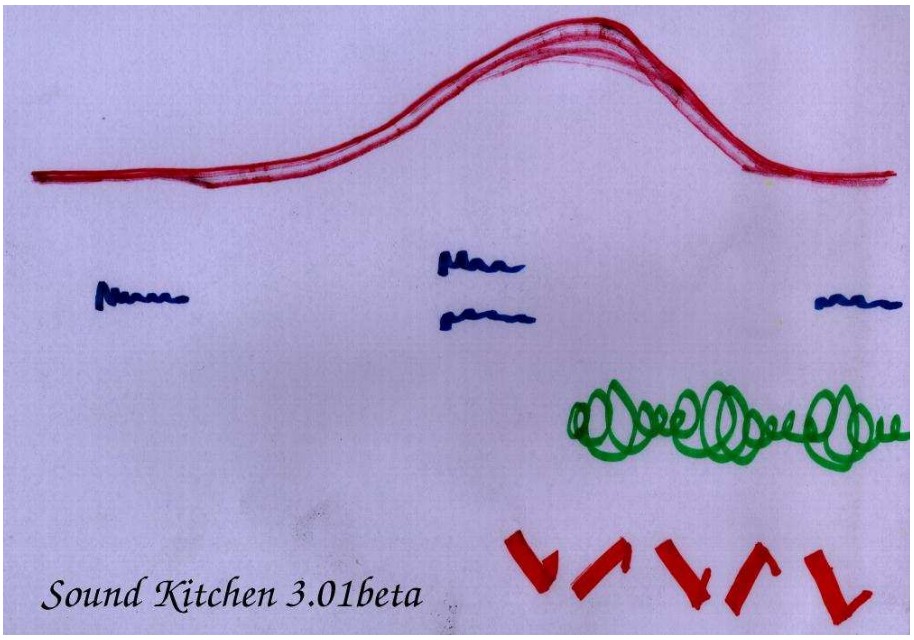

Figure 8: The score: The length is 3 to 8 minutes depending on the start temperature of water

4.2 Score

The score which was used in the performance is shown in Figure 8.

5 Conclusion and Future Works

The exploration of music creation with chemical reactions and manipulations is a very unique and unusual topic in the field of computer music. Through simple chemical experimentations, analog circuitry, computer manipulation, and human control, an entirely new way of creating music has been demonstrated. Furthermore, this project has shown that the interaction between human and computers can be used to capture and convert the often unpredictable nature of chemical behavior into a relatively replicable musical performance.

Since making music with 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 that are fed into the PD patch during performance such that nobody needs to be physically normalizing the signals at the computer during performance. Furthermore, it is likely possible to explore other chemicals or methods of manipulation that can allow for more stable and consistent signal.

Finally, this project is truly a testament of the integration of diverse fields of study to create new music.

A Complete Pd Patches

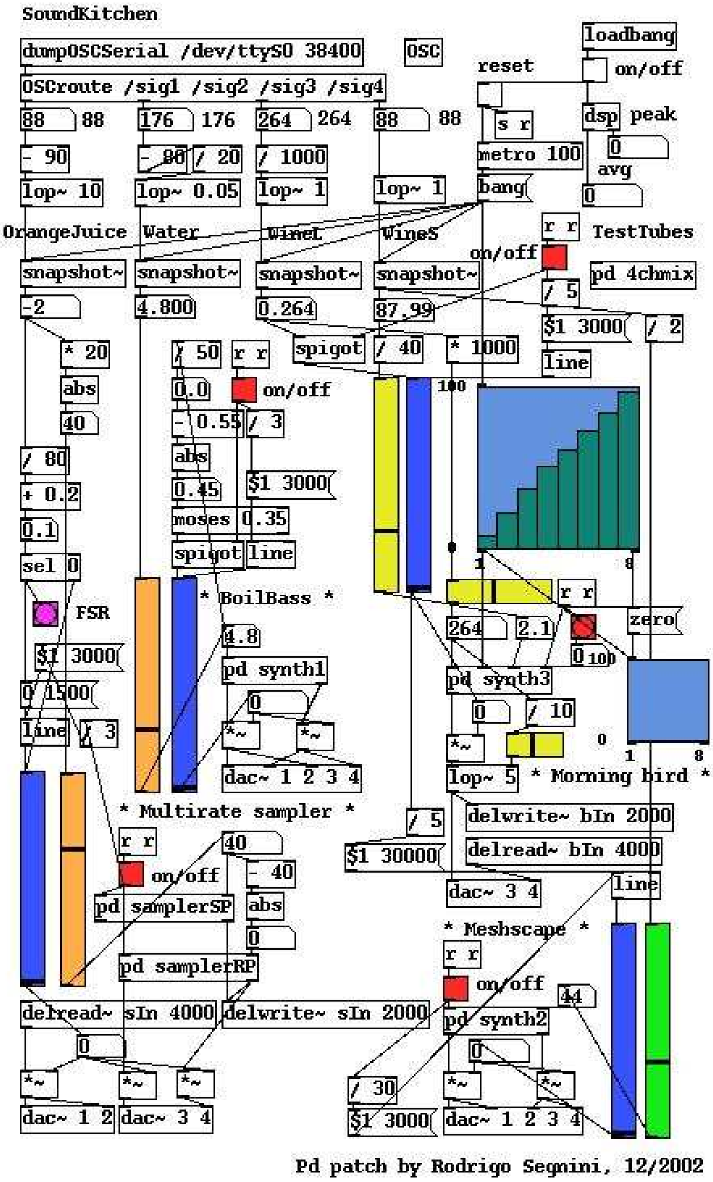

Figure 9: Main Pd Patch

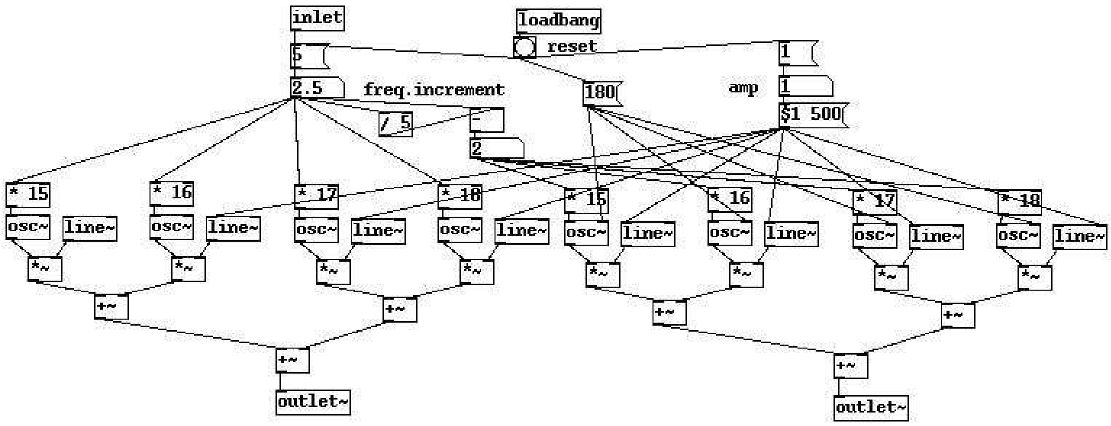

Figure 10: Synth1

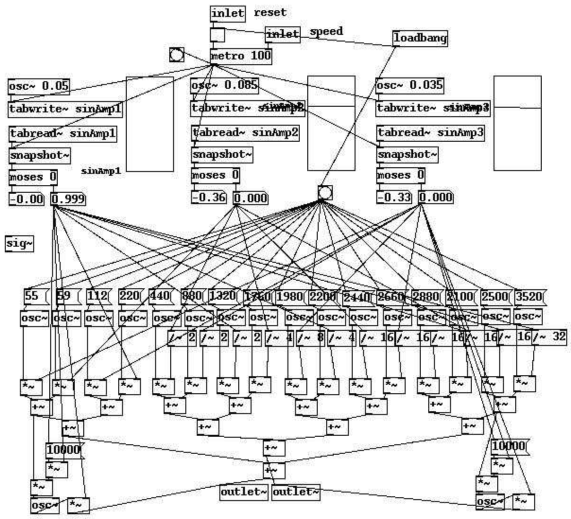

Figure 11: Synth2

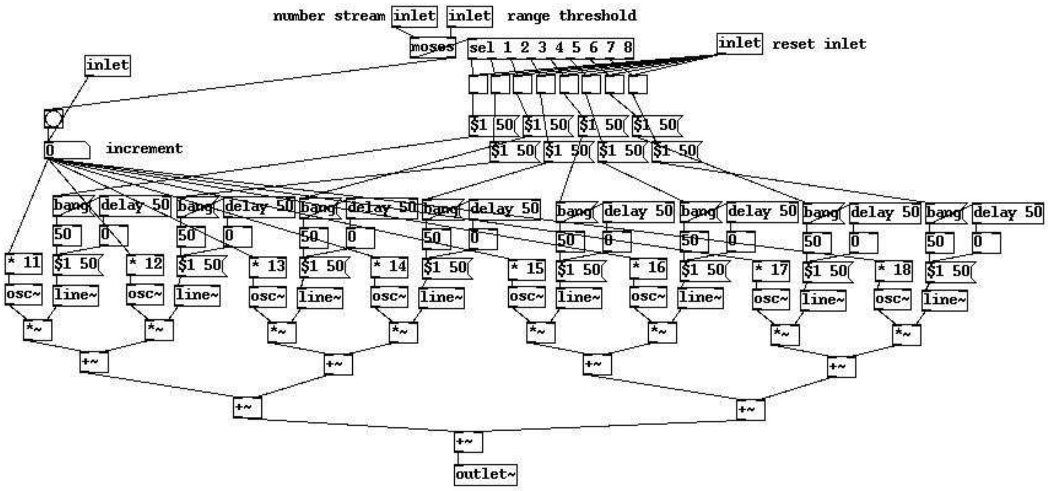

Figure 12: Synth 3

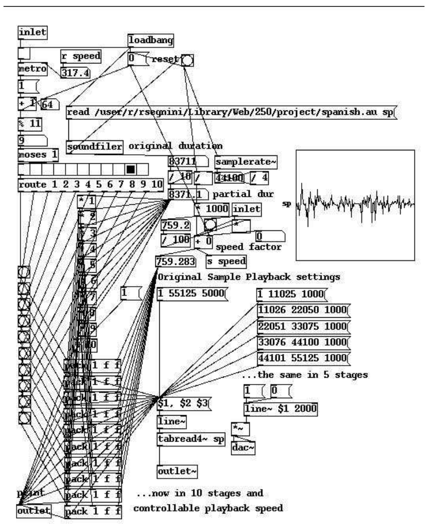

Figure 13: Sampler