BiA: a digital library for music and acoustics

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Abstract

This paper introduces BiA, an ongoing library of patches for musical acoustics. This research intends to establish an experimental approach that deals with musical acoustics theory. Pd presents as an affordable solution for students, especially compared to similar professional platforms. BiA is developed having in mind a specific audience: students who are unfamiliar with computer as a potential creative tool. Although the whole project focuses on musical acoustics, it is also expected that users start to manipulate Pd in a spontaneous way, as we feel that it presents a powerful tool for diffusion of experimental electroacoustic music in general.

Keywords

Pure Data, Computer Music, Musical Acoustics.

1 Introduction

Musical Acoustics is a course offered in almost every music undergraduate program. It is a field that includes some hard mathematical and physical concepts, which sometimes may result in resistance from students that are not acquainted with these skills in their everyday activities. In our experience, we have noticed some students have difficulties envisioning the topic conceptually. In this context, we have developed BiA[1] (*biblioteca de acústica* in Portuguese, which stands for acoustics library), a library of patches to support teaching activities.

The main objective of this research is to allow students to experience contents introduced in class. In that way, topics on acoustics and music theory could be audibly verified, making the process of comprehension easier. As stated by Andrey Savitsky, "(...) working with Pd becomes an exciting game: a game where the rules are created and changed on the spot by the player; a game where the process of playing may be much more thrilling than the outcome, while the outcome may be unpredictable and quite surprising." [11]. We believe that this strategy can enhance the learning process.

As a strategy to assist students in Brazil, BiA has been developed mainly in Portuguese[2] and applied to the context of experiences we have had at the *Universidade Estadual do Paraná* (Brazil). It is intended as supporting material to our classes, helping to establish a connection between theory and practice. There are other libraries developed in Pure Data with similar intentions to the one we are presenting. The most known initiative – and by far the most complete and advanced in content – is developed by Miller Puckette for his own acoustic course, taught at University of California, San Diego (UCSD) and freely available online[3]. The tools we present in this paper focus on complementary aspects of Puckette's work, especially on psychophysical and perceptual aspects of musical acoustics. Another initiative is the work of Alexandre Porres [8] towards a creative approach to the topic on *Dissonance Psychoacoustic Models*. Finally, the Pd tutorials themselves cover some particular topics in acoustics, such as Shepard Tones or Fourier analysis and resynthesis. BiA, on the other hand, focuses on a different target group and pedagogical content. It is mainly developed to intersect with the literature by [3], [5], [1], [13], and [9] – all in Portuguese. It also keeps in mind users that have never had contact with Pure Data. This is part of a dual strategy of teaching. On the one hand, the simplicity of control one might observe in these tools is a consequence of the contextual aspect of its application. Concerning this underlying aspect, our main objective is to allow students to intuitively operate these patches[4]. On the other hand, this is a strategy to familiarize users with Pure Data, allowing them to participate in advanced computer music courses. Lastly, BiA complements our classes in the sense of providing

1 BiA can be downloaded at: http://www.nucleomusicanova.com/BiA_pdcon16.zip

2 For the Pdcon16~, patches were translated to English.

3 http://msp.ucsd.edu/syllabi/170.13f/index.htm

4 Considering that our main public has never used Pd, we avoided using external MIDI controllers in order to decrease the complexity of patching and hardware configuration. Additionally, this strategy enables students to work on their assignments with their own computers, without requiring external gear.

a practical experience for the students based on the selected textbooks for the course.

2 Development and implementation

At the present development stage, BiA explores topics on microtonality, room acoustics, and psychoacoustics. Since the library is freely available on our research group's website, this section is dedicated to describe the elementary concepts involved in each case. For researchers interested in a 'how it works' perspective, models and equations can be found inside each patch. We recommend users to wear headphones, especially for patches related to psychoacoustics. The next tables present a brief description of BiA:

Microtonal Tools	**Objective**	**How it works**
Cents Analysis	Output interval in cents based on any given frequencies.	Students can choose any pair of frequencies and the output will be given in cents format.
Diatonic scales	Allow the perception between two diatonic melodic scales: Pythagoras and Zarlino.	Students can use the laptop/desktop keyboard as a controller in order to trigger each scale degree.
Temperament	Allow the perception between two melodic temperaments: Werckmeister and Rameau.	Students can use the laptop/desktop keyboard as a controller in order to trigger each scale degree.
Chord builder	Build microtonal chords.	Students can use the laptop/desktop keyboard as a controller in order to trigger each chord degree.

Table 1: Description of Microtonal tools.

Room Acoustics Tools	**Objective**	**How it works**
Stationary Wave Generator	Create sound stimulus to verify and reveal the different standing waves modes of a room.	Students can calculate and listen to different standing wave modes by providing room dimensions and temperature.
Schroeder diffuser	Display a visual model of a Schroeder Diffuser.	Users can calculate Schroeder diffuser dimensions and get a visual model of its construction according to three different prime numbers.

Table 2: Description of Room Acoustics tools.

Psychoacoustics Tools	**Objective**	**How it works**
Just Noticeable Difference	Verify the perception of changes in sound level based on the difference of amplitude between L-R channels.	Students can select waveform, frequency and panning. JND levels are displayed in decibels.
Virtual Pitch	Induce the perception of a fundamental pitch by playing upper partials.	Students can select a fundamental frequency and control the amplitude of each partial on a bank of sinusoidal oscillators. Presets of timbres are available.
Aural Harmonics	Verify the perception of aural	Students can select a fixed fundamental

	harmonics resulting from the difference between two frequencies.	frequency. A slider allows frequency changes on a second oscillator. The first three aural harmonics can be visualized in arrays and number boxes.
Stevens Effect	Verify the perception of changes in pitch based on different levels of sound amplitude.	Students can select a frequency and control its amplitude through a slider.
Pitch Perception	Verify the perception of pitch according to a sound grain's frequency and duration.	Through sliders, students can change frequency, duration, and amplitude. Different waveforms and envelopes are available.
Loudness	Verify the perception of changes in amplitude changes according to Fletcher & Munson's theory. Implemented accordingly to ISO 226:2003 specifications.	Students can select two ways to control amplitude: fixed or changeable according to perception curves. In changeable mode, sound amplitude is continuously adjusted to match perception curves.
Critical Bands	Verify the perception of dissonance between two different frequencies.	Students can control two sliders related to two superimposed frequencies. Differences of frequencies are displayed both in Hertz and percentage. Presets of different waveforms are available.
Auditory Masking	Verify the perception of a sound being hidden by another of different frequency and amplitude.	Students can control frequency and amplitude of two superimposed oscillators. Presets of different waveforms are available.

Table 3: Description of Psychoacoustics tools.

For pedagogical reasons, we have adopted a common graphic layout for all elements of the library. Controls were implemented using sliders, radio selectors and buttons. Results are plotted into number boxes or graphic arrays, depending on the context. Regarding the different operational systems and Pd distributions, a decision was made to only use the Pd Vanilla distribution, without external libraries. This choice facilitates the distribution of BiA among users non-familiarized with computers and specific installation procedures. The following paragraphs will discuss the library's content.

2.1 Microtonal tools

BiA has a section dedicated to the exploration of microtones, including historical and acoustic perspectives. The first patch *cents_analysis* presents to the user the concept of frequency intervals based on the microtonal resolution: based on any given two frequencies, the user can calculate microtonal intervals. The patch is based on the equation: $cents = (1200/\log 2)*\log(f2/f1)$, whereas $f2$ and $f1$ are two given frequencies [10].

The next patch presents melodic differences between German and French Baroque temperaments, more specifically Werckmeister's fifth temperament and Rameau's second temperament [4]. The aim is to introduce the world of temperament, especially to performance students, in order to encourage a discussion on performance practices and authenticity, topic discussed on graduate programs of music performance.

The third patch presents two melodic *diatonic scales* based on ancient tuning systems: Pythagoras and Zarlino [4]. The main goal is to engage with questions on how music from the Medieval times and Renaissance eras sounded like. There is also a pedagogical aim to link the content with well known counterpoint treatises, such as Johann Joseph Fux's *Gradus ad parnassum* published in 1725 and Knud Jeppesen's *The polyphonic vocal style of the Sixteenth century* from 1931.

Finally, the fourth patch *chord_builder* simulates microtonal polyphony, i.e. the user can construct and play any chord based on MIDI notes (middle C = 60) and with cents shifting. The idea is to work with a *tetrachord* in any tuning system available. This patch can also be used for psychoacoustics experiments.

2.2 Room acoustics tools

This section is composed of two patches for room acoustics measurements. The first one is a *Standing Wave* generator that allows students to simulate, hear, and experience the effects of standing waves in any "shoebox" room (with parallel walls, ground and roof), also taking temperature in consideration. Waves are generated in nine different frequencies and in three different room modes: *Axial*, *Tangential* and *Oblique*, giving a total of 63 different standing waves for each room.

The second patch attempts to solve the problem detected on the first one: to improve the room frequency response. By given parameters, it generates data to create a *Schroeder's Diffuser*. The main goal is to improve internal room acoustics. In addition, users can review how to build a sound diffuser.

2.3 Psychoacoustic tools

In this section we present eight patches related to psychoacoustic properties. The first one explores the concept of *Just Noticeable Difference* [15], [3], [9] and allows students to explore differences of sound level between left and right channels. The intention is to experiment with the perception of amplitude changes. It is possible to define a waveform as sine, triangle, saw tooth or square. They can also test different frequencies in the scale between 100Hz and 1kHz. The patch displays the difference in decibels between left and right channels and amplitude.

Virtual Pitch, the psychoacoustic effect of perceiving a fundamental frequency either if it is not present [6], [9], [3], was implemented through a patch that allows students to control the volume of each partial component of timbre. It was implemented through a bank of oscillators generating a set of predefined timbres accessible through a radio selector. Students can change the fundamental's frequency and explore different configurations of amplitude for each partial, decreasing or increasing its presence.

The effect of *Aural Harmonics* [14], [3], [9] generates a set of harmonics that are not present in the original signal, which results from the difference between two sinusoidal frequencies. The patch allows students to select a fixed frequency and continuously increase a second one through a slider. According to the combination of frequencies, number boxes and graphic arrays plot the relative position of the three salient harmonics.

The patch that presents the *Stevens Effect* describes the perceived variation of pitch to a fixed frequency as its amplitude increases. Students can explore this effect by selecting frequencies mentioned in [12] and [3] to audibly perceive the frequency deviation.

The patch that explores the *Perception of Pitch* [7], [3], [9] generates constantly timed grains as sound stimulus. These grains can be associated to different waveforms and envelope curves. It allows students to combine frequency, amplitude and duration of the sound stimulus. Students can try different combinations in order to audibly verify that higher frequencies are perceived in smaller time grains, as well as waveforms that result in more complex spectral distributions are also easier to perceive.

The patch that explores the concept of *Loudness* [3], [9] allows students to audibly verify two different approaches to sound level perception. The first one presents fixed amplitude, independently of frequency changes. The second one applies Fletcher and Munson's [2] curves on sound level perception, compensating the reduced ability of human beings to perceive frequencies near to the threshold of hearing. Curves were implemented based on ISO 226:2003[5] specifications that updated Fletcher and Munson's studies. Concerning those ISO 226 specifications only considers frequencies in the range of 20Hz to 12.5kHz, the patch features a slider to control frequencies restricted to this range. To better illustrate this phenomenon, each time students select a new amplitude level a graphic array displays the corresponding ISO 226 values. This array is also the buffer we use to control amplitude in order to match loudness curves. Students can change parameters 'on the fly', allowing them to compare differences between the amplitude and their variation through frequencies.

The psychoacoustic effect of *Critical Bands* or the perceived dissonance between two close frequencies [15], [9], [3] was implemented through a patch that allows users to change two sliders, each one associated to an individual frequency. The patch reveals that critical bands are better described as percentage than as

5 Available in: *http://www.iso.org/iso/catalogue_detail.htm?csnumber=34222*. Last access in August 13th, 2016.

absolute difference in Hertz.

Auditory Masking is the inability to perceive a first sound due to the presence of a second one, both distinct in frequency and amplitude values [14], [3], [9]. The implemented patch allows students to set up through radio selectors a first pair of frequency and amplitude. Afterwards, they can control a second pair of frequency and amplitude through sliders, having as goal to mask the first one, making it unperceived. Other waveforms with more complex spectral configurations are available for experimentation.

3 Final considerations

As a flexible and free software, Pure Data allows us to implement and easily distribute this library. This project goes in direction to decrease the gap between socioeconomic situation and learning possibilities. This is an important aspect to our research since most of our users are low-income students. Within this context, development of BiA's main intention to support pedagogical activities. With this in mind, we developed a library of patches to support our course in musical acoustics. The general community is welcome to download our material and to join the creation of new tools with our research groups: *Grupo de Pesquisa Núcleo Música Nova* (CNPq/UNESPAR) and *Grupo de Pesquisa em Criação Musical, Gesto e Processos de Interação Artística* (UFPR). For future development, we intend to: 1) increase the number of patches within the mentioned topics; 2) develop tools for the acoustics and design of musical instruments; 3) develop tools for analysis and acousmatic composition; 4) expand the application of this library to support high-school teaching activities as a tool to illustrate aspects of physics.

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