New developments on the augmentation of a classical guitar: Addition of embedded sound synthesis and OSC communication over network

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The classical nylon string guitar is a versatile musical instrument that can generate a wide variety of timbres, but other characteristics such as the short sustain and the lack of sound intensity control after the attack are usually considered severe restrictions imposed by the physical structure of the instrument.

One of the approaches to solve these problems is the construction of augmented musical instruments (AMIs). Using sensors and actuators it is possible to generate gestural data that can be used to control specific software programed to address these issues using digital signal processing (DSP).

The *GuitarAMI* aims to use gestural data to control algorithms that overcome the restrictions described above [1]. GuitarAMI explores possibilities of modification of the commonly considered restrictive intrinsic characteristics of the acoustic guitar by using sensors that generate data trough effective and free gestures [2], controlling sound manipulation patches programmed in Pure Data [3]. The Pure Data patch modifies the sustain time by performing a Fast Fourier Transform (FFT) to analyze the audio signal and later re-synthesizes a sound that can be sustained indefinitely.

One of the major problems encountered during the use of previous GuitarAMI prototypes was the difficulty of system setup for performances. In the first prototypes the number of connections and cables increased the possibility of malfunctioning and made the instrument less robust. With the third prototype there was some improvement regarding setup time but the instrument still had not reached the robustness required for plug-and-play use by performers.

Figure 1: GuitarAMI new prototype, constructed using the ESP8260 WiFi microcontroller, ultrasonic sensor and accelerometer.

Embedding a single-board computer and an audio interface into the GuitarAMI base can simultaneously increase robustness and make the AMI more usable by the performer. We chose the *Raspberry Pi 3 model B* due to its unique qualities: As it is an open-source hardware platform we have a greater range of compatible boards and components. In addition, the Raspberrry Pi can run a wide range of operating systems including several Linux flavors, Android and even Windows 10. Finally, the Raspberry Pi has a wide and active user community, providing compatibility with other digital musical instrument (DMI) projects.

The latest GuitarAMI prototype uses a Raspberry Pi running the official Linux distribution entitled *Raspbian Jessie*, released in November 2016 [4]. This single-board computer is responsible for running the GuitarAMI embedded sound synthesis algorithms.

In GuitarAMI's older prototypes an Arduino was used to send gestural data over a serial-USB connection to a computer running a Pure Data patch that contains the processing, sound manipulation and synthesis algorithms. With the Raspberry Pi implementation the patch had to be reprogrammed for compatibility with PD Vanilla (version officially maintained by Miller Puckette).

Currently, communication using Open Sound Control (OSC) is fully implemented, allowing GuitarAMI to send already processed gestural data over network to any other device.

Along with the hardware implementation there was also the necessity of updating the GuitarAMI algorithm in order to address the problems reported in [5] such as timing, similarity between the synthesized and real sounds and volume control. In the improved GuitarAMI patch we used techniques commonly applied by the phase vocoder to accurately control the execution speed of a real time sound buffered into two different arrays. This process should be performed with minimal latency possible so that it can be used in real-time performances.

The algorithm design uses the performance model presented by Young and Lexer in [6], where gesture and audio analysis are parameters subordinates to creative decision making, i.e. the processes depends on performer's decisions in real time. The interface design and in a later mapping for use in AMIs must take this model into account.

Pure Data *rfft∼* and *irfft∼* objects are responsible for these operations and they use the block and overlapping settings configured for the subpatch. These settings can be changed to provide the best relationship between frequency and time resolution. As expected, signals are handled as pairs containing real and imaginary part.

With the use of Raspberry Pi it was possible to embed a microprocessor powerful enough to perform synthesis and manipulation sound processes already present in previous GuitarAMI prototypes. We performed experiments with two audio interface possibilities and implemented the standard MIDI protocol, allowing communication between GuitarAMI and any hardware or software capable of sending or receiving MIDI data.

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