The Self-resonating Feedback Cello: Interfacing gestural and generative processes in improvised performance

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ABSTRACT

The Feedback Cello is a new electroacoustic actuated instrument in which feedback can be induced independently on each string. Built from retro-fitted acoustic cellos, the signals from electromagnetic pickups sitting under each string are passed to a speaker built into the back of the instrument and to transducers clamped in varying places across the instrument body. Placement of acoustic and mechanical actuators on the resonant body of the cello mean that this simple analogue feedback system is capable of a wide range of complex self-resonating behaviours. This paper describes the motivations for building these instruments as both a physical extension to live coding practice and an electroacoustic augmentation of cello. The design and physical construction is outlined, and modes of performance described with reference to the first six months of performances and installations. Future developments and planned investigations are outlined.

Author Keywords

Actuated Musical Instruments, Hybrid Instruments, Active Acoustics, Dynamical Systems, Live Coding

ACM Classification

H.5.5 [Information Interfaces and Presentation] Sound and Music Computing – Systems; C.0 [Computer System Organisation] General – Hardware/Software

1. INTRODUCTION

The Feedback Cello project is a collaboration between Halldór Úlfarsson, Alice Eldridge and Chris Kiefer. Úlfarsson is an artist and designer who has been developing a cello-like feedback instrument – the halldorophone – over the last decade; Eldridge is an improvising cellist who works with adaptive dynamical systems in electroacoustic performance; and Kiefer is a computer-musician who works with gestural controllers and dynamical systems. Following the design of the halldorophone, the self-resonating behaviour of the Feedback Cello is induced by acoustic and vibrational actuation: the signals from pickups under each string are sent to a speaker built into the back of the instrument, and a vibrational transducer fixed on the front. The complex response of the resonating acoustic body of the cello creates wide timbral variation, and individual gain control on each pickup affords rich interaction. In performance, the instrument can be approached from a variety of angles; it can be played as an augmented cello using traditional bow and finger control, with additional gain control using foot pedals; it can be played through manipulation of external live-coded digital signal processing which alter the characteristics of the feedback loop; or it can play autonomously using adaptive DSP processes in installation settings.

The Feedback Cello can be positioned at the nexus of contemporary acoustic, gestural practices and digital, generative practices: as an electroacoustic feedback instrument, the cello brings analogue, generative processes into the extended string tradition; as a resonant signal generator and modulator, it provides a lively gestural interface to digital music and live-coding. The design, construction and experimental use of the instrument serve as a practice-based exploration of the similarities and differences between as well as a new synthesis of gestural and generative improvisation practices which are traditionally associated with acoustic and software instruments respectively.

The project is ongoing and purposefully advances in iterative cycles of instrument design and performance practice development. Within this project these two practices are so closely interlinked that they are arguably facets of a wider artistic practice exploring methods for situated, open-ended experimental instrument design. We begin to document this ongoing process in this paper. Whilst the instruments themselves are evolving to fit our very personal performance interests, it is our intention to open-source any reusable design patterns as they emerge and to contribute to a growing community of musician-makers interested in feedback resonator instruments.

2. RELATED WORK

The use of feedback to enrich timbre or enliven electroacoustic or digital systems has a long history in art and experimental musics. A staple of American experimentalists in the 1950s, simple sinusoidal electroacoustic feed-back was explored by David Tudor [11], Alvin Lucier and others. More complex, dynamic and adaptive 'architectural' feedback systems were explored by the next generation, epitomised by the self-stabilising circuitry of Nick Collin's *Pea Soup* (1974 -76; 2002). The beguiling balance of adaptation and autonomy of such systems was championed poetically by Augustino Di Scipio [3] who has inspired another generation of artists and performers, designing and describing adaptive DSP processes in terms of second-order cybernetic principles of adaptation and coupling [12].

NIME'17, May 15-19, 2017, Aalborg University Copenhagen, Denmark.

Various string instruments have been developed in recent years in which sound can be induced without striking or bowing, using electromagnets to excite the strings, as in the Feedback Resonance Guitar [10] or the Magnetic Resonator Piano (MRP) [8]. Mechanical excitation has also been explored, either via a vibrational transducer on the bridge, as in the Feedback Lapsteel [6] or the body of the instrument directly as in the Overtone fiddle [9]. The Feedback Cello extends this approach and uses mounted tactile transducers together with a speaker built into the back of the instrument. It is part of a wider community of feedback actuated instruments being developed by contemporary experimental performers and instrument makers both within and beyond academia. For example it has been programmed alongside Andrew McPherson's MRP as well as Till Boverman's minimal Half-closed Loop [2] and Thrainn Hjalmarsson's Thranophone #2[1]. Half-closed loop is comprised of a string inside a brass tube which is fitted with a transducer pick-up, the signal is heavily processed and sent back to actuators fitted onto a hardwood board on which it rests, creating an only-just controllable complex system. The Thranophone #2 is a feedback tuba; a microphone inside the performer's mouth is sent to a speaker mounted in the tuba bell, effectively coupling and amplifying the resonant chambers of the Tuba and the performer's mouth cavity, which acts as a filter. Together these instruments developing traditional acoustic performance practices in new directions; although demanding equal if not more advanced technical skill, the performer's relationship with the instrument is evolving to become one of negotiation, rather than control.

3. DESIGN AND CONSTRUCTION

The basic design is inspired by the halldorophone of Halldór Úlfarsson. As shown in Figure 1, vibrations of the strings are picked up by electromagnetic pickups, amplified and sent to a speaker built into the back of the instrument – and optionally a transducer braced against the front of the cello – which excites the body, bridge and hence strings of the instrument.

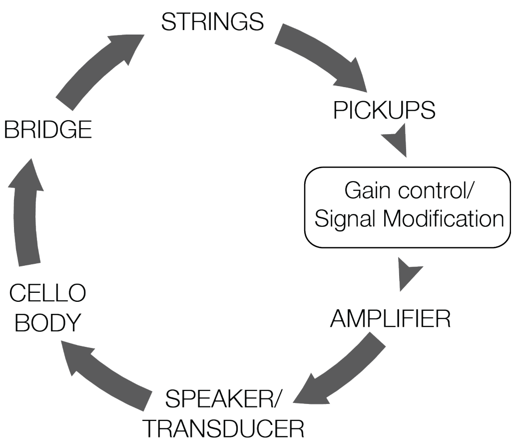

Figure 1: Schematic of electro-acoustic-mechanical signal pathway in the Feedback Cello

3.1 Design and Fitting of Pickups

An electromagnetic pickup is fitted under each string, housed in a bespoke 3D printed mount (see Figure 3). These CycFi[2] pickups have a built in pre-amp and a flat response, creating a clear tone with steel core cello strings. The pickup mount is designed to clamp onto the end of the fingerboard, allowing rotational and height adjustment of each pickup. This is important as the feedback tones produced are very sensitive to positioning, with changes of a few milllimeters affecting which harmonic dominates.

3.2 Actuators

Feedback is induced via mechanical and acoustic processes: a vibrational transducer is fitted on the front of the instrument; a speaker is built into the back of the instrument. Transducers are clamped with plywood braces to allow variation and fine tuning of positioning as this has a big impact on dynamical response of the system and resultant sound.

Speakers are fitted into holes cut in the lower half of the back cello body (Figure 7). To guard against tearing the bodies, and to maximise vibrational conduction between the curved cello body and flat speaker, collars were cut from spruce on a CNC machine and hand sanded to fit the three-dimensional curvature of the cellos. Collars were glued (using Titebond III) to the surfaces of the cellos and 50W 8Ω Monacor SP 50-X speaker bolted on, using a plywood reinforcement internally to house the bolts. A hole was drilled in the collar for the speaker cable, to prevent vibration against the body during performance.

Figure 4: A 50W speaker is built into the back of the cello body, mounted on a spruce collar to maximise vibrational conductance.

3.3 External Connections/ Gain control

The instrument has individual gain control for each pickup, so four 'output' channels. To date we have explored two options for gain control: through an analogue mixer and pedals, or via a digital audio interface into SuperCollider for digital and programmatic control. The combined pickup signal is then further amplified in a 50W 2x2 channel Sony car stereo amplifier, before being sent to the speaker and transducer. Either set-up creates an opportunity to add additional audio signals to the mix (see section 4.4). The car amplifier is selected because of its portability - both physically and in operating at 12V.

[1] http://thrainnhjalmarsson.info/thranophones/

[2] http://www.cycfi.com/

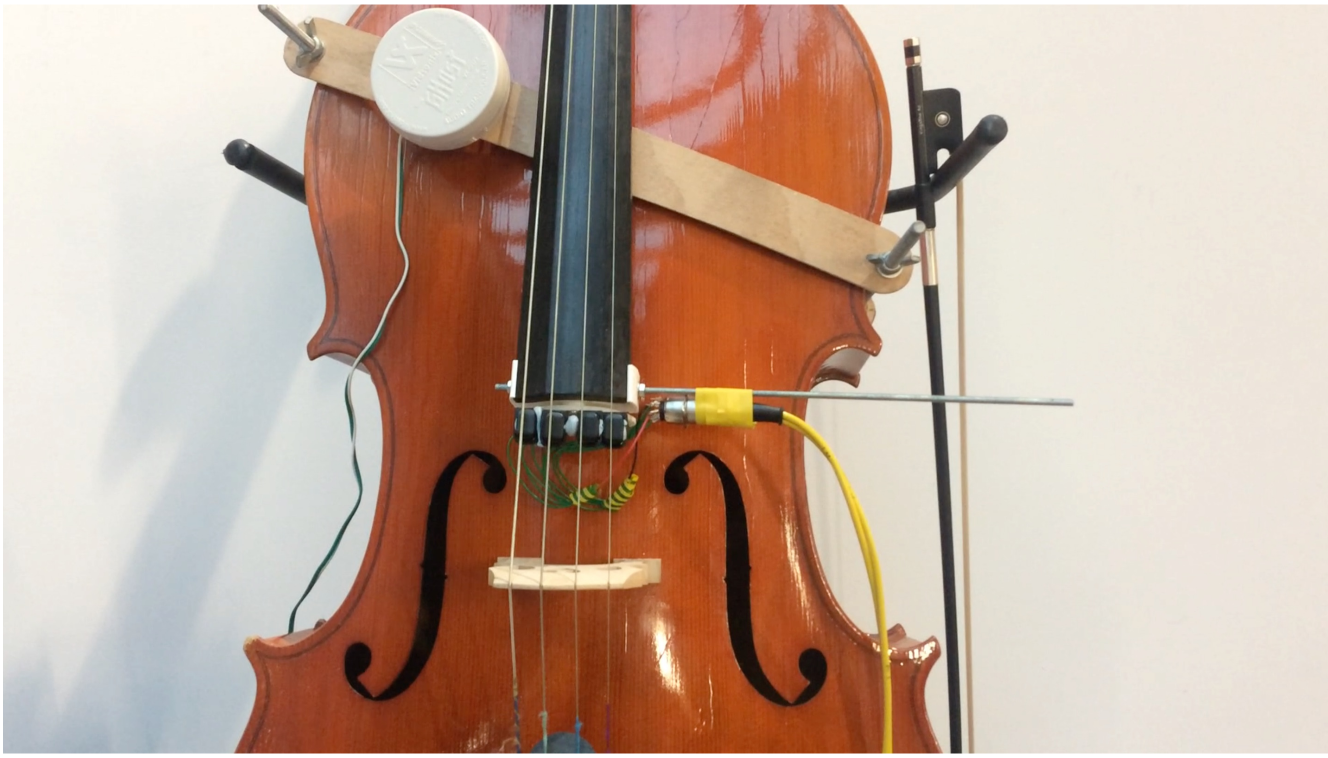

Figure 2: The four pickups are held in a 3D printed mount which attaches to the end of the finger board. A transducer is braced on the upper front body

Figure 3: Close up of the pickup mount which allows vertical and rotational adjustments. The blue tack in this prototype prevents oscillations in the plastic arms of the individual mounts which can themselves become the dominating frequencies if undamped.

4. PERFORMANCE MODES

The Feedback Cello affords a range of possible modes of interaction – gestural, digital and combinations of the two. The system as a whole – strings, resonating cello body, pick ups, speaker – can be best understood as a dynamical system where the dominant feedback tone is one of a number of possible attractors. The state space – and therefore acoustic behaviour – of the instrument is determined collectively by three main factors: i) the positioning of the pickups, transducer and speaker; ii) the tuning (open, stopped or damped) of the strings; iii) the gains, colour and frequency of the signal sent to the speaker. To date we have fixed (i) and focused on technical and musical explorations of string (ii) and signal (iii) manipulation, with our approaches informed predominantly by our practices as a cellist and as a live coder.

4.1 Adaptive DSP in Installation

In installation, the cellos are controlled algorithmically. Installed as a durational drone duet for no cellists, we experimented with a variety of adaptive DSP processes to differentially condition the signals of each cello in response to environmental sound. Just as two acoustic cellos played in the same space induce vibrations in the other, in this set-up the cello's interact acoustically, as well as digitally, responding to each other, as well as other sounds in the environment.

Figure 5: Feedback Cellos in installation at Fort Process, Newhaven, 2016

4.2 Extending Extended Cello Technique

The Feedback Cello looks like a cello, but the self-resonating behaviour demands and inspires new extended technique. Bowing or fingering the cello in a traditional manner interrupts the vibrating strings and so are largely avoided, but new sensitives and sonic possibilities arise. For example the distance from string to pickup becomes a new 'control parameter', and combined with sensitive gain adjustment (via footpedals) affords an expressive range of amplitude and tone from dulcet tones to quite bright, harsh yelps. Whilst traditional fingering in the left hand interrupts a self-sustaining string, this opens a new sensitivity to glissandi actions, which can be manipulated to create complex timbres reminiscent of overblown woodwind.

The sustained oscillations created by the feedback also enable new percussive preparations: bolts, sticks or other objects stuck between the strings can be set in continuous motion, and drift along strings toward nodes of vibration

Figure 6: Exploring Feedback Cello extended technique at Fete Qua Qua Festival of improvised music, the Vortex, London, 2016

4.3 Live Coding the Feedback Cello

The signal pathway for the live-coder runs from pick-ups through an audio interface into SuperCollider before being sent to the in-built speaker and transducer. In SuperCollider we can monitor incoming signals and explore mechanisms for exciting and damping the strings. A Watt governor-like [1] process has been developed which attempts to continually push the system towards saturation; the signals from the pickups are individually processed and summed, and then scaled by the inverse integral of the signal. This gives rise to dynamics where frequencies battle for dominance; it forces the system to become highly sensitive to subtle changes in the feedback loop, and these changes tend to result in the system moving to new points of stability or in oscillation between attractors. A multichannel frequency-shifter patch creates rhythmic pulsation as out of phase frequencies interact with resonances of the strings. In another patch, synthesized sound is injected into the system via a ducking compressor, creating interactions between the digital sound and acoustic feedback. To create rhythmic sound, the feedback can be limited or enhanced through sequenced gating. When live coded, the strings become a delicate and nuanced interface for manipulation of the instrument, with subtle touch and damping actions bearing a large influence on the system. The instrument presents a rich, tactile and complex interface to more abstract digital processes.

4.4 Multi-instrument Acoustic Networks

It is of course possible to send the cello signals other than those emanating from its pickups. We are currently experimenting with multi-instrument, multichannel feedback trio for two Feedback Cellos and Threnoscope [5]. The Threnoscope is a software compositional system created by ixi audio for drones, live coding and microtonal, spatialised composition [7] which has multichannel outputs. The Threnoscope's N outputs are diffused across a multichannel (N-2) system and the two Feedback Cello's in built speakers. This affects the resonant response of the instrument, and at the same time changes the resultant Threnoscope output. In this setting three people perform on three instruments which form a single dynamical drone system that has a decided liveliness of its' own: everybody is playing, nobody is in control.

5. FUTURE PLANS

The next phase of instrument design will focus on further exploration of pickup and transducer positioning, possibilities for adding another set of sympathetic strings, and meth-

Figure 7: Feedback Cello duo performance at the Festival of Algorithmic and Mechanical Movement, Sheffield, 2016.

ods for on-body gestural gain controllers. New approaches to continuous, adaptive tuning are also being considered by replacing the traditional wooden cello pegs with machine heads which can be mechanically and therefore programmatically controlled. Current software developments include machine listening (frequency and amplitude) to achieve tighter control in the feedback loop, and facilitate inclusion of various complex and adaptive dynamical system models of homeostasis and entrainment etc [4].

6. SUMMARY

This paper outlines the motivation for and design, construction and performance possibilities of the Feedback Cello, a self-resonating, actuated instrument. The cello is activated by sending the signals of pickups mounted under each string to a built-in speaker and on-body transducer. It contributes to a growing family of self-resonating musical instruments which embrace the musical agency of electromechanical feedback system, and connects this field with the long history of experimental, extended string techniques and more recently evolving live-coding practice. A range of modes of interaction and performance are described and future directions outlined.

7. ACKNOWLEDGEMENTS

Halldór Úlfarsson for initial inspiration and ongoing collaboration in instrument design and construction.

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