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The Airborne Instruments nUFO: a Movement Based Musical Instrument for Possibility Space Exploration

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ABSTRACT

The Airborne Instruments nUFO (nontrivial/new flying object) is a new movement based Digital Music Instrument designed for maximal motional freedom of the performer. A handheld wireless *Interactor* digitizes large scale movement via a 9-axis IMU together with a set of 8 touch-sensitive pads for fine motor finger action. The corresponding software, *nUFO_App*, applies elaborate meta-mapping strategies (called *Influx*) to the movement data to inform a number of sound processes such that even very simple movements create complex changes in the sound, which frees players from distracting technical concerns, and empowers them to focus on playing by listening and intuitive motion.

The nUFO distills 15 years of research into complex sound synthesis, just-in-time programming, modal control, and meta-control strategies with a physical *Interactor*, ergonomically designed from scratch for intuitively exploring the possibility spaces of such systems.

Figure 1: **The nUFO played in TOUCH and MOVE mode**

CCS CONCEPTS

- **Human centred computing → Interaction design →** *Interaction design theory, concepts and paradigms;*
- **Applied computing → Arts and humanities →** *Sound and music computing;*

KEYWORDS

DMI, Influx, MetaControl, Post Control, sensor, mapping, wireless, interaction, entanglement, NIME, OSC, SuperCollider.

1. INTRODUCTION / BACKGROUND

Figure 2: **The Hands**, **the lady's glove**, **The Finger**.

The nUFO is inspired by the classic work of Michel Waisvisz *The Hands* and Laetitia Sonami's *lady's glove*, who pioneered digital realtime-performance and performed groundbreaking music-by-movement with the aid of self-devised, sensor-based interfaces. Like many more recent similar works in the NIME context (e.g. Dominik Hildebrand's *The Finger* and others), their instruments/ setups were/are so highly tailored to their personal artistic practice and concepts that making them available for others as is makes little sense. On the other hand, making general music interfaces based on inexpensive motion tracking devices and gestural sensors has almost become its own genre practiced in local and international communities like MoCo, NIME, ICMI, or MovLab Berlin.

Between singular artist's developments, repurposed consumer electronics and DIY module kits for making instruments [1, 2], there is an interesting niche area: a unique fully formed musical instrument (like the former) crafted with state of the art digital lutherie [3] made available as a product (like the latter), with an open source code base that is completely modifiable. This is what motivated us to develop the nUFO beyond prototype stage.

We distilled the most salient insights and concepts from our research in realtime digital music performance in the Generative Arts Class at Berlin University of the Arts into an instrument that embodies complex sound processes with rich 'inner life', making them playable with what we consider a radically new interaction paradigm, equally engaging for expert and novice players.

2. KEY CONCEPTS

2.1 Airborne

Like wireless audio connections for microphones and guitars, current music technology now offers a variety of wireless controllers that free musicians also from data cables.
For motion tracking devices, the *x-osc* [4] and the *riot* [5] are elegant wireless building blocks for music interfaces, dance, etc. nUFO used these in prototypes to leverage that freedom as fully as we can imagine: We aimed at designing for a maximum of degrees of freedom, which is neither bound to a physical support nor to a specific part of the player's body. Yet, every movement performed with it becomes meaningful for the resulting music.

2.2 Non-Triviality

According to the pioneer of Second Order Cybernetics, Heinz von Foerster, any machine that responds with the same output for the same input is trivial, while machines or systems that do not always react the same way to the same stimuli are non-trivial [6]. If a bicycle behaves nontrivially, we consider it faulty and take it to the repair shop; if a human being would behave as trivially, e.g. by responding to a repeated question with the exact same answer over and over, we would likely suspect a mental disorder.

So how much non-triviality is desirable in things people use to make music? We find it intriguing when programs advance from sound production tools to interesting playing partners. This gradually blurs established notions of causation and authorship and allows the performer to partly turn into observer, in accordance with von Foerster's [8] integration of the observer into the cybernetic control cycle which marks the shift from first- to second-order cybernetics. Evidently, nontrivial musical machines require a paradigm shift in artistic and aesthetic approaches: Improvisation within a context of human performers values communication, exchange, reaction, contrast and the unforeseen beauty of surprise [9], which, like a good conversation, is very near to the flow of improvising most people do most of the time every day. Musical cultures from free jazz to experimental electronics cultivate such forms of realtime composition - see Bowers [10] for an expanded view on "improvising machines" and their embedding in contemporary music aesthetics.

2.3 Entanglement

Entanglement is a useful concept for considering processes in ecosystems in the natural world: many factors of cross-influence between almost all elements in a system dynamically contribute to that system's behavior, which challenges conventional views on causality [11].

Entanglement also allows powerful conceptualizations of human movement: even conceptually simple movements (arm up and down) are the result of coordinated action of dynamic groups of muscles, integrated by learning, experience and potentially training. Outside of special cases (e.g. physiotherapy), one almost never activates single muscles in isolation. A more analytic approach to the actual muscular activity of a specific movement is only relevant for research, not for human everyday's practice – even the highly sophisticated movement training of professional musicians or dancers rarely resorts to the vocabulary of anatomy. Having named concepts of movements (arm up/down) is generally sufficient, and leaves much space for variety that inflects named movement types with expression, specificity, personal style and for unnamed movements that defy categorization.
We use such a holistic notion of movement with the nUFO's *Interactor*: rather than analyzing motions (e.g. by gesture recognition), which would reduce their dimensionality, in our implementation, we directly inform the sound processes with the high-dimensional digitized versions of these entangled movement components.

2.4 Possibility Space

In our sonic research, we think of digital sound processes as multidimensional spaces. On a Theremin, which exposes only volume and pitch to be modulated by the performer, all possible sounds can be drawn on a square field, which results in a two-dimensional sonic Possibility Space. The more parameters a process accepts as inputs, the higher order its Possibility Space will have. Correspondingly, the Possibility Space of a process with a dozen parameters is immense and it's improbable to reach every possibly interesting parameter configuration in a musician's lifetime.This approach to sound synthesis encourages exploration strategies for traversing these spaces. For our systems, we developed a number of ways of such "Possibility Space Travel" (a.k.a. MetaControl or Post-Control): random generated and human selected presets, Brownian motion, Random Orbits [12], and Influx (see below). The nUFO incorporates the most effective ones.

Applied to movement, our concept of Possibility Space entails a performer's range of action in physical space. Constrained within the 3 cartesian dimensions along the temporal axis, and bound by physiological limits of acceleration and speed, this motional range forms a highly complex Possibility Space. So our instrument is intended a mediator between these two spaces, that, instead of trying to find one perfect mapping, offers a multitude of them, so as to provide the musician with a maximal Possibility Space of musical options at any given time during performance.

3. IMPLEMENTATION

3.1 Interactor, MetaControl and Sound Library

The nUFO is composed of three parts:

1. The hardware *Interactor* is a disk-shaped, domed device with sensors for movement and touch, as well as two rows of four push buttons each on the back side.
   The other two parts are software modules in the *nUFO_App* which is written in SuperCollider and runs on a computer:
2. The *MetaControl* layer receives the sensor data stream from the *Interactor* (or other controllers/GUIs), processes them by an *Influx* and maps them onto the sound process parameters.

3. The *Sound Library* offers a range of 24 sounds; up to four can be played polyphonically, all informed by the *Interactor*.

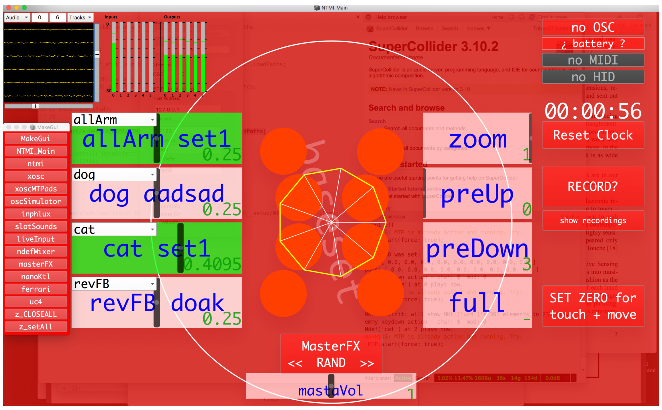

Figure 3: **A screenshot of the *nUFO_APP's* GUI**

3.2 MOVE and TOUCH Interaction

The nUFO offers three modes of gestural interaction (see fig. 1):

• In *MOVE* Mode, the *Interactor's* orientation, translational and rotational acceleration become influence sources. The values from a built-in IMU, which senses 3 dimensions each of acceleration, rotation and orientation, are sent at 50 Hz framerate by WiFi as generic OSC data.

By design, there is no way to move the object without influencing all process parameters of the active sound(s) via entanglement. This leaves the range of meaningful movements wide open, allowing performers to discover which forms of movements work well for the current setup context and their aesthetic preferences. In the terminology of Jack et al. [13], this design bottleneck is as wide open as we can imagine.

• In *TOUCH* mode, the fine motor skills in our fingers [14] come into play. Eight Capacitive Sensing pads on the front side translate figure pressure into sensor data, processed like the *MOVE* data. Ergonomically arranged for 4 fingers of each hand, they provide "finger space" [15] that lends itself for subtle articulation and phrasing.[1]

• *FULL* mode combines influence from *TOUCH* and *MOVE.*

These modes cover a wide range of gestural affordances, from micro-motoric subtlety to gestures at more theatrical scales.

3.3 Influx

Influx [16] is a software library offering tools for exploring concepts of entangled influence on running processes. One can begin with conventional one-to-one mappings where, as usual, each interface element controls one process parameter (Fig. 4 left). Mappings can then be gradually »entangled« by means of a weight matrix as found in neural networks, such that every control element influences other process parameters as well by some (small or large, positive or negative) amount (Fig. 4 right). While the sound producing process and it's parameter space remain unchanged, different mappings will make different regions in the possibility space accessible, and even familiar processes offer new sonic options in phrasing when influenced via different entangled mappings, as gestures are translated to oblique trajectories in possibility space.

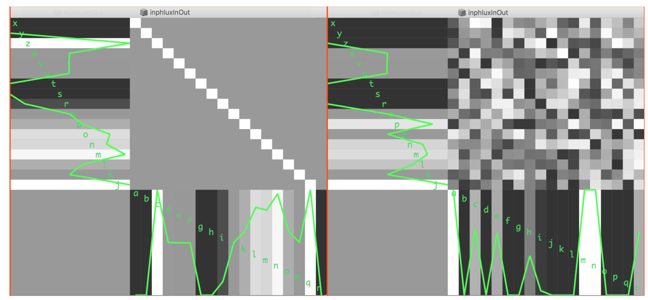

Figure 4: **Screenshot of 2 Influx GUIs with inputs (top left), weight matrix, (top right), and outputs (bottom right). Left Influx has a diagonal weight matrix resulting in a 1-to-1 mapping; right one has a heavily entangled matrix.**

As a Post Control strategy, Influx works somewhat counterintuitively: How can we cognitively simplify access to complex processes by inserting an additional layer of technical complication? The declared goal is that an opaque but rich mapping makes it quite impossible for the performer to keep acting according to analytical reasoning ("This fader changes the filter frequency"), but rather invites for a shorter loop of explorative interaction: "Do I like the sonic result of my gesture?". Joel Ryan emphasizes the importance of letting go of analytical thinking for music making: "The kind of attention that is employed in playing and listening to music is more about coordination and fusion than the parametric atomizing of experience" [16]. A mental model of the synthesis engine and its parameters is not needed in order to play music with it, and not worrying about technicalities can free up cognitive resources for musical concerns. With experience, these mappings become mental maps for intuitive anticipation of movement action and musical result.

3.4. Presets

The nUFO implements seven Influx presets, which are different weight matrices that cause different behaviors of instrument "response" [17]. They are color coded and can be switched from the *Interactor.*

A second layer of presets stores landmarks in the Possibility Space of a sound process (i.e. a point coordinate in its parameter space) to indicate the starting point of the trajectory with the *Interactor* in resting position. The "zoom" pot sets the maximal excursion radius around this point that the gestural interaction can access. Both behavior and sound presets are persistent and

1 Cf. the Snyderphonics Manta <www.snyderphonics.com/manta.htm> as an example of a modern, general-purpose touch interface based on the same technology, whose musical application goes back to the Buchla Thunder of 1989 and further into early analog synthesis.

deterministically reproduce same sonic output for same gestural input.

While this does not fit the technical definition of nontriviality, the permutational explosion of possibilities (in sensor dimensions, matrix presets, sound processes and spund presets) makes the playing experience nontrivial, striking a balance between surprise and intentional influence.

3.5. Complex Sound Synthesis

The main source of the desired non-triviality in the nUFO are the complex, nonstandard sound synthesis processes. The *NTMI_App* ships with two dozen synthesis algorithms, four of which can be chosen to play at the same time. The inner life of the continuous sound processes is not only caused by modulators like LFO's, but mostly by complex internal feedback and delay paths. The resulting signals often exhibit chaotic behaviour, yielding noisy sounds of finely tunable coloration, as well as plain periodic sounds with the modulation parameters at minimum, and, between the two extremes, a sheer endless amount of emerging patterns of self-modulation at timescales that affect either rhythm, timbre or pitch: "stepped havoc waves", as Rob Hordijk [18] calls them.

Sounds with such inner structure often keep changing for long stretches of time without manipulation of their exterior parameters, which allows the performer to change her role to listener/observer (see 2.2). Once influenced by the player, the resulting sound development can become extremely rich, and navigating towards good-sounding attractor points in possibility space via the Influx mapping is a very rewardingly musical activity.

4. CONCLUSION / OUTLOOK

Our prototypes have gone through 3 full iterations, with changes and adaptations informed by our own performance experiments, and by rich anecdotal information from ca. 50 informal user tests, ranging from electronic music fair visitors and university students to handpicked professional musicians.

The central research questions arising from these tests are: how does interacting with a nontrivial instrument affect the musical experience of performer and audience, and what mental model of the instrument makes the experience rewarding? Anecdotal impressions from our tests indicate that people with extended musical training have a high investment in the idea of control as a skill, and thus may feel they have more "to lose". This appears more pronouncedly in male players, while female players and children seem quicker at embracing and enjoying the unique character of nUFO's interaction model. In the near future, we plan to study these topics in depth with more formalized user tests.

The other thread we follow is developing the nUFO towards a marketable hardware product, with an open source software package. We believe nUFO's openness for customizations towards different mappings, sounds or even different applications to interact with (e.g. visuals), will be an attractive feature, as users identify more with an instrument they have modified for their personal artistic ideas. They will be able to share elements of their personalizations as they see fit via the Airborne online portal [19].

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