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MOTION TRACKING OF A FISH AS A NOVEL WAY OF CONTROLLING ELECTRONIC-MUSIC PERFORMANCE.

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Abstract

The three-dimensional motion of a fish is mapped onto various electronic music performance gestures, including loops, melodies, arpeggio, and 'D.J like' interventions. We combine an element of visualization using a LED-screen installed on the back of an aquarium, creating a link between the fish's motion and the sonified music. This audiovisual addition provides extra information about the role of the fish in the music, enabling the perception of versatile and developing auditory structures during the performance, beyond the sonification of a momentary motion of objects.

Popular electronic music performances exemplify situations where highly structured music defines the mood and the social interaction between people within the same space. This style of music typically combines accessible musical phrases with variations that enhance the experience for the human ear [1]. Many clubs and electronic venues often create multisensory environments in an attempt to enhance the clubber's experience. Introducing an interactive musical aquarium achieves this due to subtle similarities between the movement of fish in an aquarium and the electronic music style.

From the auditory to visual domains, fish exhibit a wide variety of swimming patterns and behaviors in responding to their environment. These movements are visually attractive to human eyes, and have also been found valuable for use in cognitive studies [2] and psychological therapy [3]. Their hydrodynamic shape and body movements (which are also related to their size and type), merge into the aquatic locomotion that has captivated audiences for thousands of years [2, 4]. The earliest recorded reference to fish motion is perhaps Aristotle who in the 4th century, tried to relate the fish's fins to its straight motion, somewhat anticipation of the physical basis by Isaac Newton in the 17th century [2].

This unique locomotion can be both patterned and random, and therefore our translation of the fish's movement into musical syntax observed the following rules: on the one hand, the fish's repetitive paths can be captured as rhythm, while on the other hand, occasionally random movements can trigger surprising musical responses and effects. An example of an electronic club music genre that has analogous properties is 'minimal-techno' [5]. Minimal techno, characterized by slowly developing rhythms that exploit the use of repetition while also making generous use of FX effects and sounds. This genre idea is used as an inspiration for this work on translating the motion of a fish into various electronic music styles as a new way of expressing the interaction between visual and auditory senses in club and electronic music scenes.

In music computing, there has been an increased interest in identifying new ways of expressive interaction with interactive music systems [6-8], i.e. systems that express gestures to generate and control musical parameters and signals for virtual instruments [9-13]. Another emerging area of study is the sonification of various phenomena in nature by analyzing data or tracking objects. This includes water sonification [14], music based on climate [15], music maps of the routes of stars [16], and sounds based on molecules and bio-molecules [17, 18]. The aim of our work is to create an expressive interactive performance with a stimulating phenomenon such as the sonification of fish motion outlined above by using tracking motion.

The use of tracking visual motion in real time (e.g. tracking body dancing, natural phenomena or animals' motion [19]) and sonification of motion is now a relatively manageable task due to the popularization of high-speed cameras and tracking devices such as the Kinect™ [20-21]. Yet the translation of these ideas into an intriguing onstage musical performance remains challenging, both technologically and artistically [22]. This is likely a result of the significant gap between the demonstration of an idea in a research framework ("in the lab") and the creation of a compelling live performance. When performing, the artist must consider many parameters, such as the quality of the music, the visual interpretation, the audience's ability to understand the artistic ideas, and above all, the ability to maintain the audience's interest throughout the performance. Therefore, the artist's challenge is to turn a new technological art idea into an enjoyable and pleasant experience for the audience in a live show, exhibition or club. This work presents the idea of creating and playing music from the motion of a fish and offers a development of this idea into an onstage performance.

Performance Background

The first central music work which addressed the challenge of translating fish movement into music was produced at the San Francisco Tape Music Center by Ramon Sender, in 1962 [23]. In this work, entitled "Tropical Fish Opera", four instrumentalists used a tank as music scores for an improvisation performance. Recently, sonification using optical tracking was proposed by Walker et al. in 2008 [24], and later by Baldan et al. in 2012 [25]. Their works describe the idea of multiple fish sonifications according to their location and size in the aquarium. Their studies demonstrate a restricted method of sonification, which is important for the general study of sonification and implementation of sound from visual events. However, their auditory results did not seem to make an attempt to stimulate the attunement of the observer to various music phrases, or to develop music structures with time. Moreover, their works were mostly focused on solving technological issues of motion tracking with many objects, rather than directly applying it to the creation of music or to the combination of their technology with time-based performance.

In 2011, Nikolaidis et al. [26] generated a general model for dynamic sonification of visual movements into 'low level' elements such as pitch and panning as well as with 'high level' elements such as melodic attraction. Still, by relying solely on this

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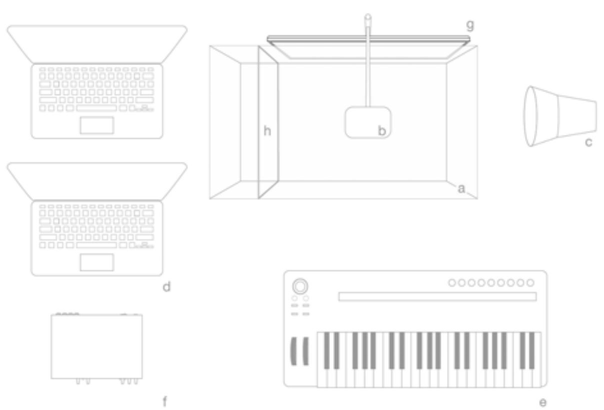
model, the music observed would be limited to the tracked objects in a specific time. In order to avoid such specific momentary movements, we combined a background screen that can interact with the movement of the tracked object, rendering the musical melody and ideas more complex and diverse. For example, painting the movement of the fish in real-time can serve as a memory of the fish routes. Then, when this information is captured on the screen, it can be used to implement large-scale musical ideas without losing the relation between the music and its motion, as we hope to achieve in creating rhythm, arpeggio, or loops. Above all, we must also take into account aspects of visual and music perception, aesthetic value, and logistical organization, so to provide a performance that appeals to musicians and non-musician.

Installation

Sketches of the aquarium equipment and photographs from live installations are shown in Fig. 1 and Fig. 2 respectively. The fish is positioned in an aquarium on a stage as depicted in Fig. 2a. In order to detect the 3D motion of the fish, two FireWire cameras are positioned at the top of the aquarium (Fig. 1b) and at the right side of the aquarium (Fig. 1c). Three parameters —Position, Velocity, and Acceleration— are translated to control musical gestures and triggers. Computing the fish's motion and all the music elements are made with two laptops (Fig. 1d), a synthesizer (Fig. 1e), and one portable audio card (Fig. 1f).

Fig. 1. Sketch of the equipment used during performances and exhibitions. All the equipment is portable, and setting up time is approximately 1hr. (© Shaltiel Eloul. Photo: Gil Zissu.)

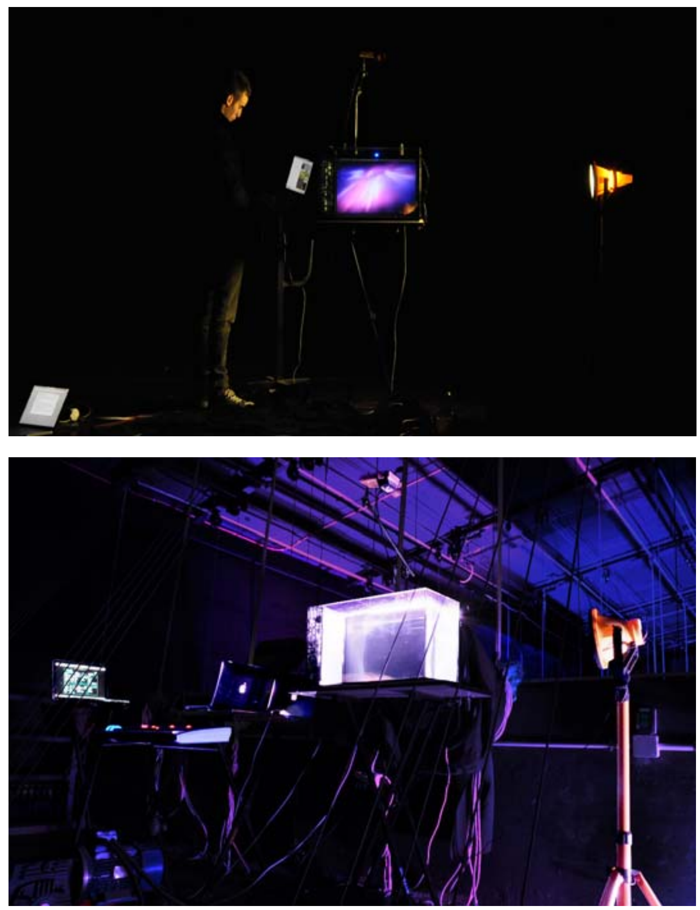


We further combined a visual interpretation with a LED-screen (Fig. 1g) positioned on the backside of the aquarium. The visual is also controlled by the fish's motion and by music triggers using a third laptop. We found that this addition of visual interpretation is crucial for understanding the interaction between the fish and the music, as will be explained later in this section.

Applicative Methodology

The Live- and Time-based art we present is created to address a central concern to the engagement of technology with the interactive design of music and visual experience. The experience of the performance relies on the ability to integrate the independent fish motion into familiar structures of electronic music. These involve loops, 'D.J. like' effects such as panning, filtering, and also creating live melodic layers over an existing electronic track. In order to succeed in connecting the audience to the performance, we decided to avoid demanding cognitive ideas, which might easily distract the audience from the integration of the visuals and the music. On the other hand, we felt that the musical concept should be continuously developed and varied in order to maintain the audience's curiosity and the performance structure. Therefore, we attempted to develop the performance slowly, moving from the most transparent interactions between the fish and the music to more complex patterns of behavior. During the design of the performance, we examined a number of aspects in order to understand how to maximize the interaction between the observer, the fish's motion, and the music.

Fig. 2. Photographs from various installations. The upper photo was taken during installation in an auditorium. The lower photo was taken in installation made in the lighting actuators and machines floor, above a theater stage. (© Shaltiel Eloul. Photo: Gil Zissu, 2013.)



We swiftly realized that playing music based on more than one fish makes the connection between the sound and the motion of the fish(es) difficult to capture and barely understandable. Focused on deciphering the fish's role in the creative process, the observer becomes distracted from the whole experience. We also realized that the visualization behind the aquarium can play an important role in allowing the observer to understand the fish role. Our choices of visual effects are relatively easy to understand, and thereby constitute a 'bridge' between the fish's motion and the music, making the experience of the performance understandable, and subsequently allowing the observer to enjoy the performance. Furthermore, in order for the observer to distinguish between the background music and the fish's role, the musical style needs to be

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popular and full of constant familiar patterns. The background music cannot involve solo lead parts as it confuses the observer.

The fish's natural behavior (whether it swims slowly or quickly, etc.) and the ability to maintain the right water conditions in the aquarium (temperature, oxygen bubbling, and water filtering) are essential aspects of the performance. Additionally, from ethical and practical standpoints, we must ensure that the fish's life is pleasant before, during, and after the show by allowing him to move in a natural way. We therefore designed an aquarium with a preamble separator that also provides a standard 'hiding place', common in many fish tanks. All the equipment of the aquarium, including a bubbler, filter, and heater, were also positioned with in the 'hiding space' (Fig. 1h) allowing the fish to live in comfortable conditions. Given the logistical and aesthetic aspects of the performance, we built a portable aquarium with a wheeled stand, allowing for fast construction and portability between installations (Fig. 2). It is important to mention that our fish, a "dominant red zebra cichlid", did not show any sign of distress before, during or after the performance. The fish ate normally, moved calmly and explored the tank, showing some curiosity by tracking the visualization of the screen at the back of the aquarium. The fish could also move into his 'hiding place' at any time.

Technology and Performance Methodology

We developed a modular program using Max/MSP/Jitter [27] environment containing three different patches that allow the use of three standard 2.4 GHz. In this way, we achieve smooth motion of the visual effects and avoid significant digital signal latency (DSP). The first patch controls the image processing for tracking the fish and translating it into a position, velocity (speed) and acceleration. The second patch handles music translation and DSP, and the third controls the visualization of the LED-screen on the back of the aquarium.

This tracking process is implemented using the computer vision for Jitter library, cv.jit-1.7 [28]. Two low-latency FireWire cameras (model) are used to capture the fish with resolution of 320:240 pixels, yielding up to 25fps (Fig. 1). A paradigm for tracking the fish in the performance is implemented as follows: during the first step, normal image handling is used to optimize contrast and brightness to make the colors more distinctive and compressed. In the second step, an unusual background subtraction is applied, as normal continuous background subtraction [29] is not applicable to this system, given that the fish may move slowly or remain still, leading to an unsatisfactory detection of position. To overcome this, we apply a static background subtraction that is renewed on the empty half of the aquarium, whenever the fish is swimming in the other half. This helps make the subtraction far enough from the fish's or its shadow position. Following that, the blob tracking (ID position and size) is introduced from the cv.jit tool box, which uses binary image followed by a Kalman filter to track the true fish position [29]. In the last step, the tracked position is simply low-passed filtered to minimal fluctuation while still maintaining a practicable latency, around 50ms. A low-cut filter takes a series of tracked matrices and cuts off any large distance fluctuations by applying the following formula:

(New Position) = (Last Position) x 0.95 + (New detected position) x 0.05.

This low-pass filter is essential in order to get a stable and smooth estimation of the fish's speed. The coordinates of the fish give the position at any frame, and with its first-order discrete derivative magnitude (scalar speed that we denote in V) is then evaluated using the following formula:

$$V = \sqrt{\frac{\Delta x^2}{f} + \frac{\Delta y^2}{f} + \frac{\Delta z^2}{f}}$$

Where f is the frame rate of the input signal, Δx, Δy, and Δz are the differences between two subsequent frames in the tracked position of x (horizontal axis), y (depth axes), and z (vertical axis and the height of the aquarium), respectively.
In the same manner, the acceleration magnitude (a) describes large changes in the fish's motion and follows:

$$a = \frac{\Delta V}{2f}$$

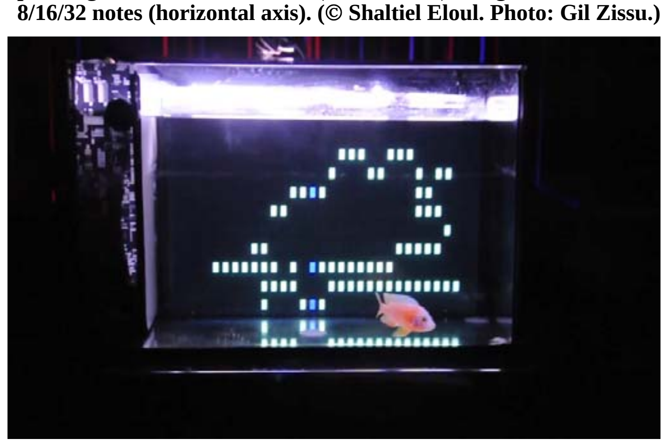
After the tracking paradigm is computed in the first laptop, the data is sent wirelessly via TCP/IP protocol to the audio translation and to the visual-screen patches in the two other laptops.

Audio and Visual Translation Patches

The position, speed, and acceleration parameters of the fish are translated to control music gestures and triggers with four presets that control and influence the music differently in order to achieve a variety of experience for the observer: Creating Loops, Music Dialog, D.J. Gestures, and Melody Composition.

Creating Loops **-** This preset translates the fish's movement into painting cells in respect to its x-z pathways in the aquarium. These are visualized on the background of the Led screen (Fig. 3). These painted cells trigger samples in a matrix as a standard loop machine. The rows describe the sampled sound, which is prepared in advance, and the columns are the metrical position within the bar (1/32, 1/16, or 1/8 of a bar). The sounds used are from electronic drum kits, glitches, and other noisy sounds. Delay and reverb effects were added when the fish arrived at corners. The loop results in an abstract structure when using 32 beats per bar, or a repetitive rhythm and danceable loop when using 8 beats per bar.

Fig. 3. The "looper" preset: the fish creates a musical rhythm by painting a matrix of 10 sounds (vertical axis) along bar consists 8/16/32 notes (horizontal axis). (© Shaltiel Eloul. Photo: Gil Zissu.)



In addition, the BPM of the loop can be predetermined by mapping the speed of the fish to an experimental value between V (speed, 0 – Vmax) →120-240BPM.

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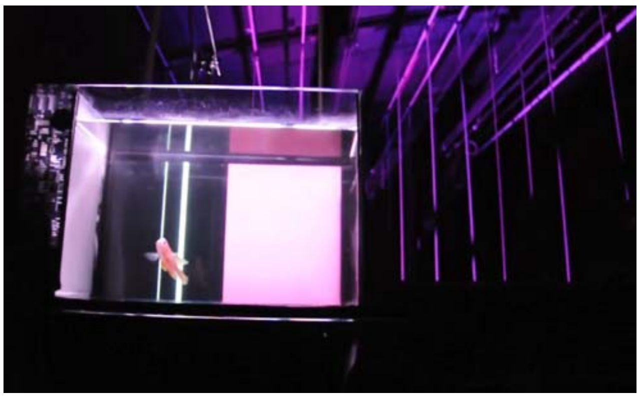
Music Dialog - In this preset, the aquarium is split into two sides: left and right (see Fig. 4). Each side is programmed for a different musical style and visual atmosphere. In this preset, the fish controls the type of music and visual effects by swimming in each section of the aquarium. The visualization of the Led screen is made using OpenGL in Jitter visual programming (Fig. 4). Using this preset allows clarity via a sharp shift in the music according to large change in the fish position. It helps the observer to easily understand the components of the system: the fish motion, the visualization of the screen, and how it merges to music gestures.

Fig. 4. Music dialog preset: a fish determine the music's atmosphere. When he goes to the black side, the music becomes "noisy" with "flickering" of two vertical white lines, synchronized with the music rhythm. If he enters the pink side, the music is chill (relaxing ambience). (© Shaltiel Eloul. Photo: Gil Zissu.)



D.J. Gestures - The X, Y and Z coordinates of the fish control musical modulation and effects: cutoff filtering, pitch bend, volume, and L-R panning. In this case, the fish solely controls the background music, because the position and the speed of the fish are mapped to those parameters. Table 1 describes how these effects are mapped according to the motion of the fish in the aquarium.

Table 1: mapping of effects on the master music channel (background music).

Gesture	Parameter	Scale
Pitchband	X (0 -320 pixels)	-12 tone to +12 tone
Cutoff filter	Y (0 – 240 pixels)	500Hz -20KHz
Panning	X (0 – 240 pixels)	100% left → 100% right
Volume	V(speed, 0 –Vmax)	-3db → 0db

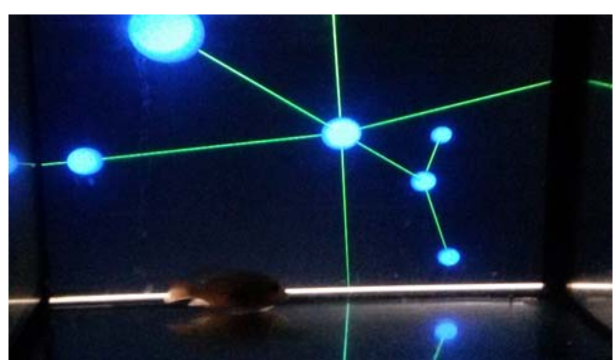
Given that the goal is to make gestures that are easy for an observer to understand but do not distort the background music, the mapping of the gestures is determined by trial and error. We combine the back LED screen with visual effects designed in Max/Jitter to enhance the connection between the motion of the fish and the musical gestures. One example of a simple type of enhancement is shown in Fig. 5, in which a tracking ball behind the fish changes shape, size and speed vibration bits according to the fish's velocity and amplitude peaks in the music audio (Made using OpenGL in Jitter visual programming).

Fig. 5. Photographs of a visual enhancement of the tracked fish on the LED-screen. A simple geometrical shape is following the fish and vibrates, changes size and colors to enhance the connection between the fish movements and music events. (© Shaltiel Eloul. Photo: Gil Zissu.)

Melody Composition - Baldan et al. [25] mapped sound parameters such as pitch, panning, and timbre, to a large number of fish according to different physical characteristics and positions, resulting in a very rich multiplicity of random sounds. In our work, the fish is in charge of the melody, in a role similar to the player of a synthesizer. The position, speed, and acceleration of the fish send MIDI messages to an external synthesizer (Novation – Ultranova™). The Midi messages trigger notes at certain acceleration. Many sound presets can be used with various ADSR envelopes, such as lead-synth, pads or strings. MIDI messages that are controlled by the fish's position and velocity are sent to the two wheels of the synthesizer: the pitchbend wheel and the modulation effect wheel, as illustrated in Fig. 6.

Fig. 6. The synthesizer allows the fish to play melodies of electronic sounds by sending midi massages. The synthesizer model is Novation/Ultra-nova™ . (© Shaltiel Eloul. Photo: Gil Zissu.)

Fig. 7. Arpeggio visualization in the LED-screen at the back side of the aquarium. Every ball is mapped into a pitch in the arpeggio. The fish can create the ball or virtually grab them in order to make an interesting development of the melody. The active pitch/ball at each moment in the arpeggio is lighted in white color. The tempo of the arpeggio is also affected by the speed of the fish. (© Shaltiel Eloul. Photo: Gil Zissu.)



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The preset is designed for the performance and is well suited to be solo parts above background music. The fish is restricted to playing specific types of scales (diatonic, pentatonic etc.) and has specific rules for each music phrase (see table 2). Each sound preset was determined using these rules. In that way, the listener can relate the motion of the fish to familiar patterns of popular music ideas that reflected from the characteristic motion of the fish.

Table 2: mapping the preset parameters for playing a melody.

Preset rules	Type	Mapping
Scale	Octave, Random, Diatonic, Pentatonic, Chromatic.	X, Y or Z
Range	±1 octave → ±4 octave	-
Pitch bend	Midi command (0-127)	X, Y or Z
Note On	Midi trigger	Threshold acceleration: V=0 → 20% from V_{max}
Note Off	Duration millisecond	0ms – 4000ms

One enhancement and development of this preset that we combine in the performance, is by using the visualization of the LED back-screen to play arpeggio without losing the relation between the melody and the fish motion. When the fish accelerates or makes a turn, it creates notes that are presented as a 3D balls connected by wires (Fig. 7). The notes then make an arpeggio melody and the tempo of the arpeggio is determined by the speed of the fish. The visualization created with open GL and the open source Java library- TREAR.PHYSICS [30] to make a particles system, apply forces and handle positions in real time. In addition, when the fish bump into one of the ball, the ball sticks to the fish, and the fish grabbed the ball to change and develop the arpeggio melody.

Performance and Music Creation

All of the above presets are combined into two distinct performance modes. In the first mode, the fish creates the music by layers ab initio (e.g. creating a loop, adding melody, and then making gestures on the music that was created). Onstage, we first start the performance with one music element —the “creating loop” preset. It gives a clear visual idea of how the loop is created by the fish, and after getting an interesting loop containing the base beat, we can continue by adding more elements and layers. For example, adding arpeggios, or letting the fish play melodies with predefined sounds. When the music becomes rich we then let the fish be the “D.J” of the music by controlling effects such as filtering, panning, volume, and pitchband. Then we can repeat the set. As the audience is now more familiar with the role of the fish, they are typically able to achieve a greater engagement with the musical result. In the second mode, the music is set in the background, or played alongside performers on stage, and the fish affects the background music by controlling music parameters, changing the music atmosphere, or adding a melody.

We combined supplementary media of example video and example sounds that accompany the present article [31], showing the main ideas of the performance and additional information regarding experimental performances that examine the level of interaction. Another demo provides an audio file of unedited music created by the fish during the installation [32].

Lastly, a third audio file presents the result of the fish creating an arpeggio and controlling the parameters of background samples [32].

Conclusion and Future Work

We demonstrated a music technology project that tracks the motion of a fish to play and control electronic music in live performance. We propose a new understanding of the utilization of this music technology idea, taking it out of the "lab" and onto the stage. The complexity of the interaction between the fish and the music is minimized into a set of gestures / presets, extending earlier versions suggested by previous work [24-26] in the music performance aspect. In the same manner, we found that trying to combine more than one fish can easily garble the clarity of the interaction we sought. Our solution to the problem involved the introduction of a LED-screen at the back of the aquarium, allowing the observer to understand the fish’s role in music while also inviting new ideas for creating music. In order to allow more complex gestures and presets with more than one fish, interaction experiments should first be conducted on musicians and non-musicians in order to examine their perception of the level of interaction between the fish and the music, as well as the experience as a whole. In addition, more music presets are now examined in order to develop the performance into higher level of music melodies and higher interaction. For example, one new examined preset is to let the fish play an arpeggio with the combination of more than one fish that will be painted on the back LED-screen. This will let the melody to develop further into interesting and more complex structure without interfere the clarity of the interaction between the music and the fish's motion.

Acknowledgments

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31. It has been uploaded to Vimeo for accompanying this article: http://vimeo.com/72027888 (The video file is also provided as a supplementary file).

32. The sounds examples are provided as supplementary files to this article.

Biographical Information

Shaltiel Eloul is now a doctoral student, dealing with computational research in the physical and theoretical chemistry department, at Oxford University (UK). He is also a music artist and part of the performing music art group ‘syndrome’. During his academic studying, he also graduated in the Electroacoustic program in Bar Ilan University.

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Gil Zissu is a music and visual artist. His background is in graphic design and film, and now he is practicing as a student for' visual art' in the University of the Arts London. He is also the designer and film producer of the music art group ‘syndrome’ as well as a music member in the group. <www.syndrome.nu>

Yehiel Amo is a music performing artist, music producer, and an educator. He studied sound design, and his music production combines technological methods in live interactive projects. Among all of his music projects he is the producer of the technological music group ‘syndrome’, and the main young’s educator in ‘kibutz Shoval’, Israel <www.syndrome.nu>