SCIENCE OR ART? "SONIFICATION IN THE AGE OF BIOCYBERNETICS REPRODUCTION": A CASE STUDY OF THE ACCESSIBLE AQUARIUM PROJECT

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ABSTRACT

With digital art being pervasive, art, technology, and science seem to be no longer separable and have been *re-integrated*. In fact, art history shows that when combined with them, art could give birth to a ground-breaking masterpiece. Based on that, we pose a simple question, "Can we analyze sonification works from the viewpoint of digital art aesthetics?" As a case study, we try to place the Accessible Aquarium Project (AAP) at the intersection of scientific research and art. Relying on term, "biocybernetics", we discuss aesthetic meanings of the AAP in terms of new temporality (dynamicity), transformed relationships (combined gazes), dialectic improvement of the original (interactivity), and enacted collective art-work (embodied cognition). We hope this review will help illuminate the artistic contribution of interactive sonification and explore future directions. Further, this work is expected to contribute to facilitating discussions of aesthetics about the sonification works in the auditory display community.

1. INTRODUCTION

1.1. Background: Art, Technology, and Science

The connections between art, technology, and science are much tighter than is commonly recognized [1]. Historically, artists, technicians, and scientists often integrated their work in order to imitate and understand life [2]. For example, artists of the Renaissance were inspired by the sciences of optics, anatomy, and *linear perspective*, which influenced their artistic creations. Over the years, the connections between artists and scientists have waxed and waned (e.g., artistic emphasis on Baroque and Rococo, and Romanticism in eighteenth and nineteenth centuries). In the twentieth century, Walter Benjamin discussed even the threatening relationship between technology and art, particularly when technology is used to reproduce art (as in photographing a piece of art) [3]. Despite this evidence of separation, the close connections between them have still continued and reemerged. As Richard Wagner had dreamed, it seems likely that we will soon arrive at the age of "Gesamtkunstwerk" (collective art-work) [4].

1.2. Objective and Scope

In this paper we will examine some advances in the work of scientific sonification, highlighting connections with aesthetics and art. To this end, we present a case study of the Accessible Aquarium Project (AAP) at Georgia Tech. Given that this is a case study, our approach is largely exploratory rather than systematic or comprehensive and thus, we explore the project from multiple views of aesthetics. Specifically, we examine what has been achieved in the project and present a rough conceptual analysis by matching keywords used to describe project activities with various concepts used in contemporary aesthetics.

1.3. From Musical vs. Non-musical Framework to Scientific Research vs. Digital Art Framework

The sonification community, including the International Community on Auditory Display (ICAD), has typically distinguished sonifications from music works (sometimes tacitly, sometimes more explicitly). Thus, it is not surprising that work in sonification tends to focus on function, and as a result is sometimes of weaker aesthetic quality. In a recent set of analyses, Vickers asked whether sonification is better placed in science (ars informatica) or in music (ars electronic) [5, 6]. He seems to conclude that distinguishing between musical and non-musical sonifications is neither particularly helpful nor meaningful [5]. In fact, empirical evidence indicates that aesthetics influences performance as well as user acceptance in auditory displays and sonifications [7-9]. With this focus of music-oriented discussion, there has not been much debate on the place of sonification (specifically, "interactive sonification" in the current paper) in the continuum of scientific research and digital art, which may help identify its novel aesthetic meanings.

2. THE ACCESSIBLE AQUARIUM PROJECT

To improve the accessibility of exhibits and promote universal design in aquariums, researchers at Georgia Tech have studied real-time interpretive sonification as a strategy for translating visual aspects of live animal exhibits [10, 11]. The project initially focused on designing sonifications for individuals with

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vision impairment to convey the informational (e.g., animal type, location, and movement) and affective (e.g., the feeling or mood perceived by visitors) aspects of live exhibits. This not only enables visitors with vision impairment to experience an exhibit, but also provides a shared experience so that visitors with and without vision impairment can discuss their understanding and impressions of the exhibit. To accomplish these goals, multiple approaches have been employed, including modeling the relationship among docent, audience, and exhibits [12]; analyzing salient features of the aquarium tank that grab a sighted audience's attention [13]; matching various musical features with the movement of fish in the tank [10, 11]; and studying the technical and artistic decisions musicians make when interpreting animal exhibits through music [14]. As an extension to this work, an interactive system is being developed to provide a wide range of visitors (e.g., children and sighted audience in addition to visually impaired audience etc.) with the opportunity to be engaged with the exhibit using tangible objects to imitate the movement of animals [15, 16]. Sonifications corresponding to the moving tangible objects can be paired with real-time fish-based interpretive sonifications produced by the original interpretive system to generate a cooperative musical fugue.

3. AAP FROM THE AESTHETIC VIEWPOINT

What kinds of elements of this "assistive technology" research project can have aesthetic meanings? One premise of the present paper goes beyond the conventional standards of aesthetics, such as musical completeness or "emotional mechanisms" of music [e.g., 17]. Of course, these are still considered as aesthetic elements, but they might not be sufficient metrics of contemporary aesthetics given that we have experienced progressive shifts in art (e.g., Marcel Duchamp's Fountain (1917) or John Cage's 4'33" (1952)). Through experiencing the age of sound scape composition, acoustic ecology, or musique concretè [18, 19], and MIDI (Musical Instrument Digital Interface), the concept of music (not only music genre, but more generally in art) 'writing' has changed into music 'editing'. Thus, the advent of the age of mechanical reproduction has already arrived in music. Then, how can we start to conceptualize and assess the aesthetics of music works? What kind of additional metrics of aesthetics can we identify? Among them, what elements can we apply to interactive sonification works? Given that the AAP engages with an ecosystem of animals, this paper turns its discussion to the 'biocybernetics': How can the efforts of the AAP be mapped onto the aesthetic elements of biocybernetics, and how could aesthetic efforts be enacted?

3.1. Biocybernetics: Biologically-Inspired Sonification

According to Mitchell [2], the "biocybernetic reproduction" can be defined, in its narrow sense, as "the combination of computer technology and biological science that makes cloning and genetic engineering possible" (p.483). However, it can also refer to the new technical media that are transforming the conditions of all living organisms in its broader sense. The word "cybernetics" stems from the Greek word, "steersman" of a boat and thus, suggests a discipline of "control and governance"
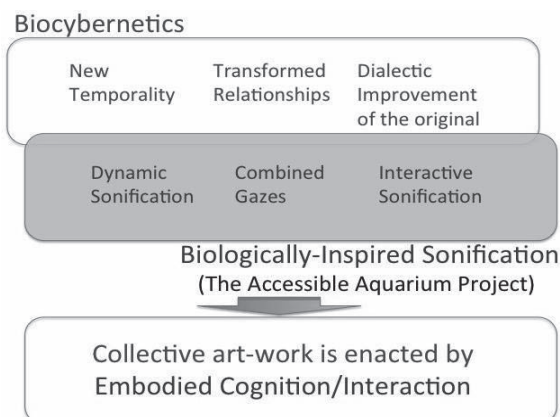

Figure 1. Conceptual diagram of aesthetic meanings of the Accessible Aquarium Project.

[20]. Based on that, cybernetics is "the entire field of control and communication theory," whether in the machine or animal. Then, "bios" refers to the sphere of living organisms which are to be subjected to control, but also resist the control [2]. Taken together, biocybernetics refers to the field of control and communication; and yet simultaneously, it relates to the resistance to control and communication. This contrasted polysyllabic word is a sort of paraphrase of the traditional dialectics between nature and culture, humans and tools, analogical register and digital code, image and world, or the "Imaginary" and the "Symbolic" in Lacan's terminology [21].

In the sonification domain, there have been attempts to represent biological signals using sounds. One of the earliest examples of sonification using EEG (Electroencephalogram) signals is the "Music for Solo Performer" from 1965 by Alvin Lucier (http://www.ubu.com/film/lucier.html), founder of Sonic Arts Union. In the ICAD community, there have also been some sonification works using biological signals (e.g., heart rate [22] or brain waves [e.g., 23, 24]. The main difference between the AAP and those projects is that the biological signals come from movements of *animals* in the AAP (i.e., more difficult to control and communicate) instead of humans.

Mitchell suggests that the biocybernetic reproduction has replaced Walter Benjamin's mechanical reproduction [3] as the fundamental technical determinant of our age. Benjamin earlier argued that the advent of photographic copies resulted in the "decay of the aura," a loss of the unique presence, authority, and mystique of the original object. In contrast to Benjamin's major concern about the mechanical reproduction, the biocybernetic reproduction (1) provides a new temporality, which can be said as a sense of accelerated – so, indefinable and transient stasis of our age, (2) makes the (transformed) relationship between the artist and the work more flexible (i.e., more distant and more intimate simultaneously), and (3) improves the original rather than making an inferior or decayed version of the original [2]. Applying these three macro consequences of the biocybernetic reproduction to micro phenomena of the AAP, we present how the AAP has tried to resolve and integrate this conflicting tension between bios and cybernetics, or between "incalculability" and "control".

3.2. New Temporality: Dynamic Sonification

Simple auditory display methods such as auditory icons [25] or earcons [26] have served as direct feedback to a user's activity. In the same line, even though spearcons [27] and spindex [9] could be created on the fly, they are still considered as somewhat static sound feedback. Audification [28] is another common sonification technique, where a series of data is converted to samples of a sound signal. It plays sounds without interruption, so it is perceived just as hearing music. The AAP can be categorized as an interactive sonification using parameter mapping [e.g., 28, 51], where data features are mapped onto acoustic attributes such as pitch, tempo, timbre, etc. (not only one-to-one mapping, but also many-to-many mapping). This mapping can generate seamless musical sounds based on the movement of fish. It is very hard to generate exactly the same sound in any moment because of the characteristics of live animals.

What kind of aesthetic experience does this sonification offer? Casting back to Hegel's aesthetic theory, with sculpture and painting, the audience can see objective works as a result of artistic activities; but those are not vivid productions on their own [29]. In contrast, with music being played or improvised (especially when a player's inspiration is added to the original score), people can experience an artistic production (or process) in front of their eyes. Likewise, dynamic sonification of the AAP, instead of using a prerecorded sound, can obtain a similar position to music in Hegel's aesthetic world. Further, dynamic sonification goes along with new temporality in that this real-time sonification is constantly changing and can hardly be exactly reproduced again. Moreover, information from animals instead of humans makes this work farther from Benjamin's mechanical reproduction by being harder to control because animals' intentionality is harder to predict. This improvisation based on the animal movement can include similar musical genes or structures just as in embryo cloning, but it can iteratively evolve. With the introduction of interactivity (in 3.4) to the AAP, it can be rendered as an even more unique work.

3.3. Transformed Relationships: Combining Gazes

The traditional "Western linear perspective" in Fine Art presumes that artists and audience have a strong authority as an observer. In other words, linear perspective becomes possible only far from an object. This is a technical argument within art history. However, this type of distance disappeared in art (e.g., anamorphosis in Hans Holbein's Ambassadors (1533) – in which a distorted skull lies diagonally across the bottom of the frame, which is meant to be a visual puzzle as the viewer must approach the painting nearly from the side to see the form morph into an accurate rendering of a human skull. Currently, art does not allow for this type of dichotomy (an authoritative observer vs. a passive object). Not just the relationship between an artist and a work, but the relationship between audience and the work has also been shifted. For now, the audience is placed in the middle of an experience in terms of time and space. Observer-object roles can no longer take place in digital art [30].

In the AAP, one of the initial attempts to inform the computer vision technology was to investigate the visual features that attract people's gaze [13]. In that exploratory work,

people reported on attributes such as color and motion, lending insight to their perception of the visual display. If we can define aesthetics as the study of our perception of the whole environment, not just objects of beauty [31], this exploration can also be considered as a basic aesthetic activity.

As Vickers suggested, sonification works often could benefit from the application of the aesthetic practices that are employed by artists [5]. In the spirit of that admonition, AAP researchers worked directly with musicians (e.g., Laurie Anderson), and learned about how they translated animal movements into musical language [14] in order to apply their strategies to the sonification algorithms. This mimicking of an artist's creative process to create novel art work is not new. Many musical 'automata' [32] were developed to imitate a famous musician or age (e.g., Baroque). Strictly speaking, musical automata do not reproduce any specific work. Instead, their algorithms [33] analyze, extend, integrate various styles and structures, and recreate a brand new masterpiece.

Going beyond these basic aesthetics, one of the most important shifts of the AAP regarding the "gaze" (or Lacan's "regard" of an authoritative observer) issue in art is to introduce an additional (counter-) viewpoint directed at the audience by adding a camera focused away from the exhibit [15]. Based on this combination of the two cameras' viewpoints (one pointed at the fish and the other pointed at the audience) and an invitation for the audience to be in the middle of the artistic scene, the AAP achieves the transformed relationship between audience and objects referenced by Mitchell. Just as Benjamin contrasted the era of manual and mechanical reproduction with the examples of the painter and the cameramen [3], Mitchell replaced the cameraman with the designer of the virtual spaces and electronic architectures [2]. To Benjamin, the painter maintains a natural distance from reality, whereas the cameraman penetrates deeply into it. On the other hand, the designer of virtual spaces of the 21st century can use the new techniques and maintain both distance and an intimate relationship with reality (e.g., a physician who operates from a distance using virtual robotics; a composer who programs a machine that improvises to create unique soundscapes based on live action of swimming fish). The audience of the AAP can maintain a distance as an observer and simultaneously be in the object position.

3.4. Dialectic Improvement of the Original: Interactivity

In addition to dynamicity and combined gazes, "interactivity" plays a critical contribution to the aesthetic conceptualization of the AAP. Recently, interactive sonification [34] has been introduced to extend the strength of sonification and enhance its application in terms of data exploration [e.g., 35, 36], user interface [e.g., 37, 38], and interactive learning [e.g., 39]. This interactivity has come to be fused in the AAP fairly recently [15].

The previous version of the AAP contained coherent reactivity with a consistent feedback loop between animals and sounds, but it did not allow for interactivity between the animals and audience. Rafaeli [40] has suggested that a distinction between quasi interactivity (e.g., two way communication or reactive communication) and full interactivity depending on the nature of the communication responses. Both reactive and fully

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interactive communications require that communicants respond to each other. However, with quasi interactivity, the content of response may have a reaction to previous messages, but full interactivity acknowledges prior responses. In other words, to contain full interactivity, responses should incorporate references to the content already exchanged and conjure up memorable interactive exchanges. Based on Rafaeli's discussion, the previous sonification system can be categorized as quasi interactive communication. Once the animal moves, the sonification system creates music based on that movement. However, when the animal moves again, the new movement is autonomous and thus, it is not a response to the previous messages. Also, the corresponding new melody based on the new movement is not necessarily a response to the previous melody. Hence, this system does not enable interactive communication between the animal and the sonification system. Moreover, there is generally rare interaction between the animal and the visitor. [1]

In the latest interactive sonification configuration, however, communicants respond to each other in full interactivity. Once the animal-based sonification system generates a melody 1, the audience (or the audience-based sonification system) will generate a counter-melody 1 in response to the original melody 1. Then, a new melody 2 is generated not only based on the newer movement of the animal, but also structurally based on the counter melody 1. Therefore, the melody 2 incorporates references to all of previous messages and responses (see [16] for a more detailed explanation about interactivity of the AAP). Therefore, this new work adds full interactivity to the sonification of live exhibits, by communication exchange between animal– and audience–based sonifications. Note that in this interactive activity, audience-based sonification does not simply replicate the animal-based sonification, but extends and develops the original further. In other words, the audience-based sonification system has potential to produce an improved sonification as well as an identical twin of the original sonification.

3.5. Collective Art-work Being Enacted: Embodied Cognition

All of the previous conceptualizations are finally enacted based on "embodied cognition" or embodied interaction in the AAP. Embodied cognition is a timely, relevant topic in the allied cognitive sciences, not just in interactive sonification [see the special issue in TOPICS 41]. Embodied interaction using interactive sonification has been shown as effective in various learning and training domains. For example, Antle et al. [42] have used an embodied interaction framework to elicit, train, and apply people's embodied metaphors as a means of developing intuitive fluency with music creation. Based on a specific metaphor of "music is physical body movement," they developed a computational system that helps children understand musical concepts such as melody, harmony, and rhythm in the form of intuitive, physical analogs. Howison et al. [43] have introduced an embodied interaction-based

instructional design, the Mathematical Imagery Trainer (MIT). They aimed at helping young students develop an understanding of proportional equivalence by applying the embodied cognition paradigm in which mathematical concepts are grounded in mental simulation of dynamic imagery. This is acquired through perceiving, planning, and performing actions with the body. Recently, in the sonification community, several interactive movement projects based on embodied interaction have also been introduced in sports training [e.g., aerobics, 44, rowing in a boat, 45]. All of these projects have suggested that fully engaging embodied interaction with sonified feedback is effective in enhancing learning and the user experience.

Based on this background, the recent AAP configuration allows the audience to engage with the live exhibits through tangible user interface objects (TUIOs) or with their body, which represents the animals in the exhibit [15, 16]. For rapid prototyping, researchers have taken a simple movement-to-sound mapping approach to complement the real-time interpretive sonification of live animal movement. Visitors can see (sighted audience) and hear (sighted and visually impaired audience) the movement of fish and mimic the movement (or the sound of the movement) by using their body. Then the x, y coordinates and the depth (z) of visitors' movement are processed and translated into musical sounds, which generates a counter melody just as in a musical fugue. For more detailed system configurations, see [15, 16]. In order to identify an optimal matching level of the audience's gestures and the corresponding sounds, a sound-matching "game" was also developed.

Wagner once envisioned that the success of future art depends on the achievement of collective art-work, "Gesamtkunstwerk". To him, "music drama" was the ideal format of collective art that would integrate all of the art genres including music, architecture, painting, poetry, and dance. Among others, he emphasized the crucial role of *actors* compared to *poets* or *musicians* in that their artistic goal can finally be achieved by actors who can change "willingness" into "possibility" [4]. In the similar line, Simon Penny mentioned in his recent interview [30], that the strategy of contemporary art should be modified from a 'representational' model towards a 'performative' model. This contrasted the traditional Descartes's dualism, which means there is no such separation between cognition and behavior, but there is a loop between the two. Therefore, the application of embodied cognition to digital art including sonification offers a new paradigm of aesthetic practice involving behavior design. Based on that, the scope of the aesthetics in digital art could be expanded by including a range of emotional, affective, and even tangible relationships with technology [46] just as in the AAP. By adopting the embodied cognition game paradigm, the AAP has extended its meaning from "machine musicianship" [47] to provision of easy to learn type "new musical instruments" (i.e., making music using toys or their body) to non-musicians.

4. CONCLUSION

By examining the multi-year Accessible Aquarium Project from an aesthetic viewpoint, we can trace out some of what has been achieved and identify new meanings, as well as glean some

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[1] Note that in some exhibits, and with some animals (e.g., belugas), there can be some more direct interaction with the exhibit visitors.

hints about where to go next. The aesthetic components addressed in the current paper are neither exhaustive nor mutually exclusive. This exploration should help frame some useful, timely questions about the aesthetics of interactive sonification works—unfortunately, it cannot answer them just yet. Based on the discussion here, some aesthetic aspects of other interactive sonification works could also be revealed. Of course, there might be more taxonomy to explain aesthetics of the AAP. We hope that this attempt can stimulate diverse discussions of aesthetics about the sonification works in the auditory display community. Given that not only historians and philosophers, but also researchers are able (indeed, encouraged) to pose this type of aesthetic question, researchers can play a multiple role as a director, artist, and critic simultaneously, just as Wagner did with his music drama. This self-commentary is the process to find out further directions and "inevitability" [48] of new types of interactive sonification works. Some researchers contend the end of art [49]. However, art is clearly not finished [50]. Just as in other artistic genres, there is no consensus on artistic strategies in biocybernetics [2]. However, when artists, technicians, and scientists collaborate, the sonification works can achieve clear aesthetic objectives, in addition to scientific objectives [5].

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