Fiber Optic Ocean: Merging Media for Data Representation

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ABSTRACT

This paper explores the interactive art installation, Fiber Optic Ocean, portraying the consequences of technology's invasion of oceans. Three life-size shark skeletons are trapped in an ocean made of fiber optic threads. This 20-foot-by-20-foot installation combines fiber optics with sculptural elements and data-driven light and sound design. Data visualization and sonification emerge from the use of two data sets: human data (tweets per second) and shark data (speed of live sharks tagged with GPS). This paper examines the affordances and constraints of design with fiber optic threads. Using fiber optics in this media context expands the expressive opportunities for artists and creates a platform for representation of data.

Keywords: Interactive art installation, fiber optics, data visualization, data sonification, ecosystem, sharks, GPS data, internet

1 MATERIALITY, MEDIUM, MEANING

In the age of immaterial data there is still a close-knit connection with meaning and materiality in arts and design. The most famous paradoxical statement of McLuhan "The medium is the message" is frequently misunderstood as "medium affects the message that we are communicating" while he means "medium or technology that we use to communicate changes us and society."

According to Murray, medium and material "in common parlance" are broadly used terms. Medium may mean anything from a "set of charcoal pencils to a multinational entertainment corporation" [1]. Herrmann suggests that "material is usually understood as medium" [2] in the arts. Murray defines medium as a "combination of materials and cultural practices that is used by human beings to support the intentional creation of meaning." She also notes that "a medium is both material and cultural: a stone and chisel only become a medium for writing when a society develops practices for marking the stone and interpreting the chisel marks." [3] In that sense, material is one of the components of medium.

In this paper, I will use "fiber optics" as a material not as a medium. Flusser in his discussion of materiality reminds us that matter and energy expand on a spectrum: "solid<liquid<gas<high-energy" [4]. Fiber optic threads are on the two opposite ends of this spectrum. While fiber optic threads are solid, they carry light in a visible form which can also make data visible. Containing these two properties simultaneously, solid form and high-energy, gives fiber optics a unique set of affordances and limitations.

Norman defines the term "[a]n affordance is a relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used" [5]. He names negative affordances as constraints. The basic physical affordances and constraints of fiber optic threads are as follows:

Fiber optic threads can emit light; are flexible and create wavy forms; can allow constructing large sculptural forms; serve as giant output devices allowing use of light, color, sound and live-data; merge with drawings; intertwine on additional sculptural elements. However, the distance that they can carry the light is limited; their light is impressive only in darkness; threads can be fragile and are easily damaged; requires extensive planning since long threads can easily entangle during construction. It is also difficult and costly to control the color or illumination of each fiber optic thread separately. I will explore these affordances and constraints with examples in the related works section.

Heideger describes the relationship between the thing (material) and the artwork as "the art work is, to be sure, a thing that is made, but it says something other than the mere thing itself is, allo agoreuei (allegory). … In the work of art something other is brought together with the thing that is made" [6]. The material of an artwork can store information and carry it through time and space, allow participation, break taboos, create shock via the abject (blood, excrement), and as Heideger mentions can serve as a metaphor or allegory and supply an intertextual message by associating certain themes, another text, artwork, or event.

For example, fiber optics may associate the following concepts: ethereal light, elusiveness, ghostly beings, data, internet, sabotage, global surveillance, oceans and ecosystem, ownership of oceans, giant telecommunication companies, capitalism and more. For example, Snowden's whistleblowing incident involved governments' tapping of fiber optic cables. If an artist decides to make Edward Snowden's sculpture with live-data and fiber optic threads, the material will be an essential part of the meaning.

2 RELEVANT WORKS AND MEANING MAKING STRATEGIES

2.1 Defining a Fluid and Elusive Form

Existing interactive art installations using fiber optic threads are generally non-interactive costume designs and light sculptures. The known examples such as Taegon Kim's costume design, Sans Titre (Robe Pour 3 Personnes) [7], and Rosaline de Thélin's holographic light sculpture Time Smiles [8] are visually enchanting but they are neither interactive nor data-driven. These pieces define a fluid form in space by using fibers as contour lines, invoking the intangible, ethereal, elusive quality of light.

Carlo Bernardini in his Fiber Optics Sculptures [9] uses fiber optic threads as straight lines while the majority of other artists create wavy forms. Straight threads create an illusion of reflection, one of the basic properties of light, in a playful way by beaming from one wall to another.

2.2 Creating Large Sculptural Forms

Fiber optic threads enable artists to create vast electronic sculptures. Bruce Munro's light installation Field of Light [10], is a series of light installations covering acres of land in botanical gardens and deserts. He spreads the fiber optic threads through out the landscape and the end of the long threads create plant-like glowing forms. While his system has the potential to be a data visualization piece he does not explore that direction.

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2.3 Constructing a Display for Data Visualization

Jong Yu Lee's Filament Mind [11], commissioned for Teton County Library, uses 5 miles of fiber optic threads and visualizes searches by the library visitors. Filament Mind does not use sound or sculptural elements. Data visualization is achieved with the changing color of the light. Filament Mind serves as a giant output display for visualizing live-data. The low cost of fiber optic threads and their length and flexibility of the threads affords the creation of these giant displays.

Fiber optic threads are illuminated by DMX light engines, which are controlled by custom written software. As a result, sculptural pieces created by fiber optic threads can also serve as giant output devices. Such sculptural pieces can visualize a variety of input such as live-data, bio feedback, sensor and camera input. While this opportunity seems full of expressive potential, DMX based light engines have limited output options. They can only turn the lights on and off and change the color. These limited options currently constrain the meaning-making strategies.

Another constraint arises from the difficulty of controlling the color or illumination of each fiber optic thread separately. Depending on the thickness of the fiber, a bundle of fiber optic threads, fifty to three hundred fibers, are plugged into one light engine. In that case, one light source determines the response for a large set of fibers. For example, one hundred fibers change their light and color at the same time. Artists Ligorano and Reesein in their Fiber Optic Tapestry [12] created a tapestry from fiber optic threads responding to live-data. Ligorano and Reesein used individual LED lights to illuminate each fiber separately giving themselves wider control to create a responsive display. The patterns on the tapestry change based on data. While their approach pushes the limitation of the DMX light engines, display objects created with fiber optic threads still have limited vocabulary.

2.4 Merging with Drawings or Drawing with Fibers

End-glowing-fiber optic threads can supply strong dot-like lights. In Behind the Veil [13], Lyn Godley uses end glowing fiber optic threads similar to brush strokes in pointillism, a technique in painting leading to neo-impressionism. Godley places the fiber optic threads and the light engines behind digital prints of her drawings. The fibers penetrate the drawing creating glowing points. In her piece Envelop [14], end-glowing-fibers blink and create an illusion of motion. A printed photograph of a swan flaps her wings. In Girl Interrupted [15], Kira and Edward use fiber optic threads for drawing to create a nude female body.

2.5 Intertwining with Sculptural Elements

Jung Pil Shin in his sculptural piece Fly High [16] illuminates an airplane wing and turbine engine with fiber optic threads. The wing and tribune made of cage like wires encapsulates the threads. Glowing threads give sense of motion to the sculpture.

3 Our Project: Fiber Optic Ocean

Underwater fiber optic cables have not been frequently explored in the arts. They came to public attention after the global surveillance scandal revealed by Edward Snowden in 2013. We found only one art piece: artist Trevor Paglen taught himself scuba diving and in 2015 made a series of photos of underwater cables by chasing an answer to the question "Well, can you just go in there and find them?" [17]. We used fiber optic threads to address ecological problems about underwater fiber optic cables while pushing the existing meaning making strategies further. Murray suggests "[a] designer must be able to envision multiple approaches to the same design problem, including novel approaches that exploit the affordances of new materials" [18]. We created a large fluid form that forms a live-data visualization display using light, color, and sound as output. We aimed to create an organic connection between sculptural elements and fiber optic threads and benefited from the plasticity of the drawing medium. In our survey of artworks, we have not seen a piece that uses fiber optics in relation to data driven sound. Nor have we seen a piece that benefited from all the physical and conceptual affordances of the fiber optics.

3.1 Concept

Human beings' invasion of nature expands to the air, forests, ocean depths, and underground. Oceans are becoming a murky mix of plastic and chemicals. Oil spills, unsustainable fishing, shipping, indestructible plastic waste, chemicals from industrial production, fertilizers from agriculture, tourism, untreated sewage, fish farming and climate change, are transforming the oceans irreversibly.

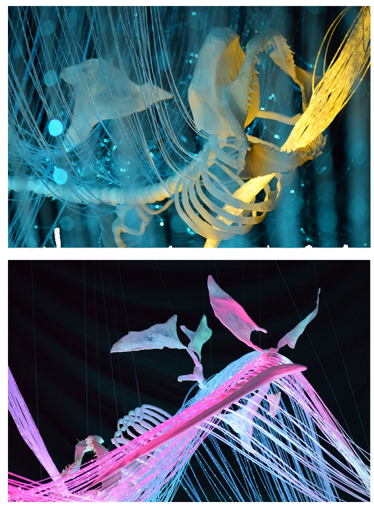

Figure 1: "Fiber Optic Ocean", (2015). vimeo.com/139216831.

Fiber Optic Ocean, an interactive installation, speculates on the future by trapping sharks in an ocean composed of fibers. (Figure 1). We used the threads in two groups: one group forms the ocean and the other forms bundles that penetrate the bodies of the sharks. The fiber optic threads constituting the ocean blink based on Tweets per second symbolizing the human use of the Internet. The bundles penetrating the sharks blink at a rate based on the speed of live sharks tracked with GPS data. The piece procedurally composes choral music generated from both of these data sets. Trombone notes represent the dominating ocean that has turned into a mass of fiber optic cables. Screaming choral voices characterize the suffocated sharks.

"As of early 2017, there are approximately 428 submarine cables in service around the world" [19]. Underwater surveillance cameras are revealing that sharks are attracted to fiber optic cables and biting down on them. One theory is that the magnetic field around the fiber optic cables is stimulating the receptors in sharks' mouths and luring them to perceive the cables as prey. Google and AT&T are covering the cables with kevlar-like matting to protect the cables from breaking due to shark attacks. Currently, there are few fiber optic cables going through the oceans. In the future, it is likely that each developed country may build their own Internet infrastructure in order to protect their government from information leaks. In this speculative future, the massive number of fiber optic cables going through the ocean will confuse and overwhelm the sharks and affect the entire ecosystem. The current struggle between sharks and technology is a pristine symbol of the ongoing conflict between nature and culture. The two sides clash nose to nose on a thin fiber optic line. Incongruously, while we are trying to connect with other human beings with our fiber optic cables we are disconnecting from nature.

The sharks biting fiber optic cables may not be a substantial problem. We took this case as a metaphor to allude to a larger issue. The mindless use of technology is a result of corporations' impact on daily life. Individuals feeling powerless when confronting a corporation is similar to the symbolic sharks trapped in *Fiber Optic Ocean*. The screaming sharks resemble us: individuals trying to survive in the age of corporations.

Ferster elaborates on abstraction in design stating, "the level of detail is presented prima facie, but its interpretation is in the eye of the beholder" [20]. We created a complex visual and auditory experience that comments on the consequences of human "progress". We anticipate that the symbolism and details in this piece will invite viewers to project their own creative interpretations.

3.2 Merging Media and Expanding Meaning Making Strategies

One important affordance of fiber optic threads is that they enable artists to create large sculptural forms. The majority of previous art pieces built with fiber optic threads are sculptural forms that operate as light installations. There are further expressive opportunities that could push sculptural pieces to be more than a light installation.

Fiber optic threads can define flexible form in space. Intertwining them with sculptural elements expands the possibilities for creating meaning. For example, the shark skeletons are curved in postures that reflect physical pain (Figure 2). The blue glowing fiber optic threads forming the ocean go through the ribs and jaws of the shark skeletons, trapping them excruciatingly. Meaning arises from the relationship between the sculptural elements and the fiber optic cables: shark skeletons entangled within a fiber optic ocean. An ocean made of fibers is a purposeful exaggeration.

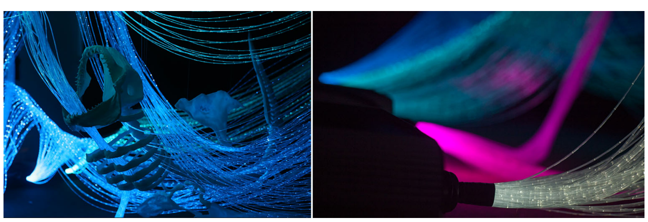

Figure 2: Curved postures of the sharks, fiber optic threads, bundle of fibers illuminated by light engines

When fiber optic threads are used to define a form in space they also imply an atmosphere. Including a soundscape is an opportunity to enhance or redefine this atmosphere. As lights and colors can be controlled with live-data, camera or sensor input, sound can be generated with the same data.

For example, in Fiber Optic Ocean, both data sets, tweets per second and speed of sharks, control the lights and sound. Dominating full trombone notes are generated by the human data (Tweets per second). This same data also controls the blinking of the fibers composing the ocean. The sound of the ocean is ever-present, adding a new note each measure of the piece. The ocean acts as the bass line and changes with the amount of human data detected. When the amount of human data is low, the ocean is calm and soft, and the chord progressions are pleasant. When the amount of human data is high, the ocean is fierce, loud, and blaring, and the chord progressions are more edgy.

In parallel, the screaming vocals are generated by the shark data, coming from live sharks tagged with GPS trackers through Ocearch site [21]. Again, the same shark data controls blinking of bundles that are going through the ribs and jaw of the sharks. Whereas the ocean sound is unrelenting and constant, the sound generated from shark data is more expressive. The choir sounds are generated by choosing from pre-written musical patterns upon beginning each measure of the music. So when shark activity is low, fewer screams are heard. When shark activity is high, more screams and more complex musical patterns are heard. Additionally, the pitch of the screams varies with shark activity; shark screams are much higher when they are more active.

Live-data connects the piece to a larger whole. This piece is not interactive in a traditional sense. There is no simultaneous reaction to visitor's presence or gestures. The piece responds to cumulative actions of humans and sharks. In our installation, the speed of the Internet represents the human ambition for progress, the intention to connect with other humans, the invasion of nature. The speed of live sharks symbolizes their freedom to move and exist peacefully. The relationship between these two different data sets enabled us to symbolize the relationship between technology and nature.

3.3 Sculptural Process

Fiber Optic Ocean is a 20-foot-by-20-foot interactive installation. We sketched a shark skeleton that is simple and recognizable by using museum databases, books, and educational models (Figure 3). We combined various skeleton pieces from different types of sharks into one design. One of the team member's background in comics and graphic novels was effective in creating formal distortions that are common in comics. In this case distortions of shark skeletons were a vehicle to convey the pain.

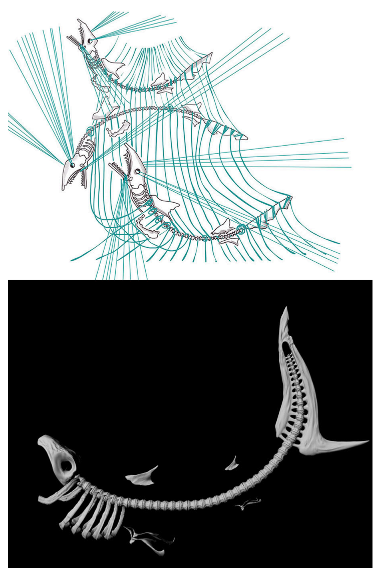

Figure 3: Sketch of the installation and a 3D modeled shark similar to the sketch.

There were two challenges to create these realistic but distorted shark skeletons. Except for the jaw, shark bones are made of cartilage, which decomposes quickly. It is almost impossible to access a complete shark skeleton. For our research we received guidance from The Fish Division of The Field Museum in Chicago. Fish researchers supplied us shark bone pieces (Figure 4). Using 3D scanning and modeling enabled us to be independent from physical reality and we were able to create the distortions that we designed. We produced the shark skeleton in pieces that snap onto each other.

Figure 4: Models used for 3D scanning of shark cartridges (tail, skull, vertebrae, fins) at the Field Museum.

To be able to transport the piece safely we wanted to use durable material. 3D printing of all three shark skeletons would have been extremely costly. Instead, we 3D printed only one shark skeleton then built silicone molds for each part except the ribs. Then we were able to make many copies of the vertebra, skull, and tail by casting with white resin. We used a real Mako shark jaw and covered it with resin in order to match its color with the rest of the skeleton (Figure 5).

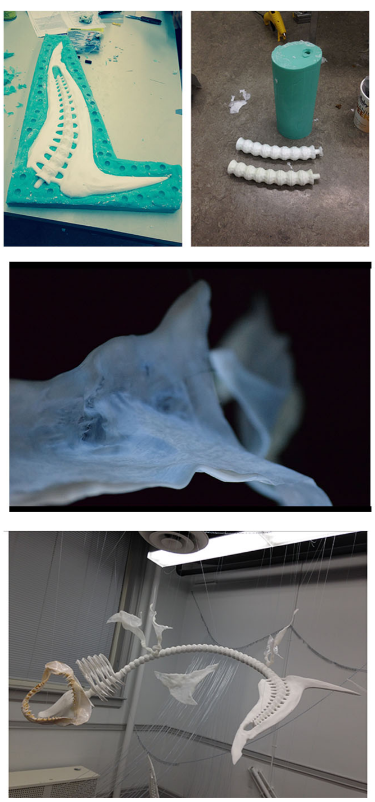

Figure 5: Two-piece mold for tail, single-piece mold for vertebrae, fins made of InstaMorph, a complete shark

InstaMorph, plastic grains for sculpting, becomes moldable when heated in hot water. Flat parts of the shark skeleton such as fins gave good results with InstaMorph, resulting in a fibrous, organic, transparent appearance (Figure 5).
To form the ocean, we considered various fiber optic threads offering different possibilities and limitations. Side glowing fibers were malleable and supplied non-homogeneous lights that enabled us to create an ocean responding the data in whimsical way. In order to create the continuous waves of the ocean, each fiber optic thread was hung on an individual hook (Figure 6).

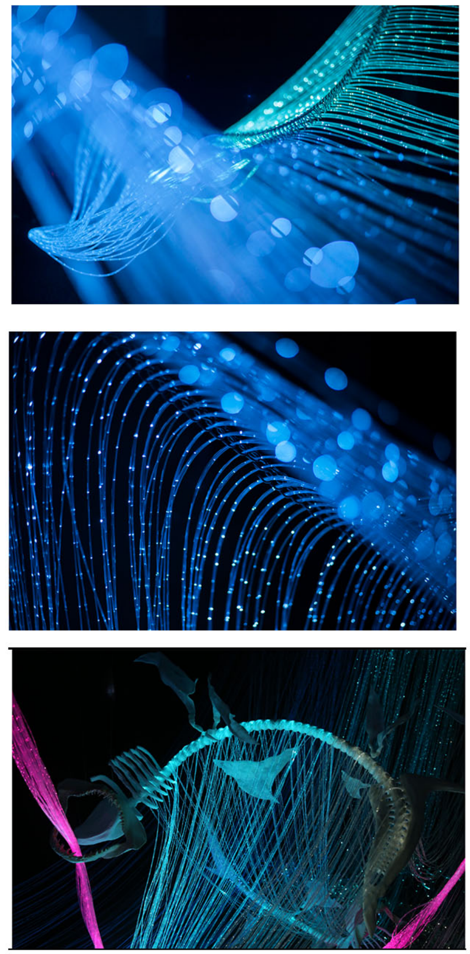

Figure 6: Use of chains, hooks, and the shark skeleton to create waves of ocean.

3.4 Software and Live-data

We chose to write the code in Java, using Maven as a framework and for dependency management. The code runs as a single standalone application that has many components. These components can be broken down into *sensors* and *behaviors*.

Fiber Optic Ocean gains its interactivity by reading in data in real time. It has two virtual sensors: a human activity sensor and a shark activity sensor. The human activity sensor monitors the amount of human usage of the Internet, whereas the shark activity sensor monitors the amount of movement of real sharks in the world's oceans. To be clear, neither of these are physical sensors. Rather, they are components of *Fiber Optic Ocean*'s codebase that collect and analyze data from the Internet.

The human activity sensor is currently implemented as a code object that queries Twitter for the rate of tweets per second. We spent time looking into monitoring actual Internet throughput as a means of tracking human activity, but the number of variables that can obscure the raw usage data meant a severe loss of accuracy, and therefore meaning. Servers can temporarily go down or rewrite routing tables, which can affect Internet speeds momentarily without human intervention. Though Twitter may seem to be a more indirect measure of human activity, it is actually more direct for this reason.

The shark activity sensor is more complex; unlike Twitter, there is no existing shark activity API. However, we got in touch with Ocearch, a non-profit organization that researches sharks, providing an online visualization of the positions of sharks. In order to access this data, we used an open source package called Selenium, which is commonly used by developers to run end-to-end tests on web applications by interacting with dynamic web pages similar to how a human browses the web. The shark activity sensor initializes an instance of Selenium that periodically browses to the shark tracker and downloads the latest shark information. Our shark sensor is specifically interested in the number of miles that sharks have traveled in the previous 24 hours, which it uses to calculate the instantaneous overall speed of the sharks.

3.5 Musical Composition

Since music has a lot of rule components, we chose to hold some of them constant and vary others.

Constants:
1. Tempo (80 BPM)
2. Meter (4/4)
3. Voices (Choir and Trombone)
4. Scale (Western, chromatic)
5. Rhythm of bass line (downbeat of each measure)

Variables:
1. Volume
2. Chord / Inversion
3. Voice leading
4. Number of voices
5. Rhythm of melody

The procedural music composition is a rule-based system that adjusts the variable components listed above by comparing sensor data with a set of rules, which define everything from how many notes there are in an octave to which chords can follow a given chord, ordered by musical pleasantness. The rules were carefully tested and revised in order to maximize the fluidity of the music and prevent it from repeating musical ideas on loop.

Here is an example of one of our chord definitions: a basic major triad.

M | 0,4,7 | 0,2,1 | 0: 7/M, 2/m; 1: 5/M; 2: 4/m, 0/m7, 0/m; 3: 4/dim, 4/dim7

Parts of a chord definition are separated by the | character. The first part is the name of the chord. “M” is the common musical symbol for a major triad. The second part is the list of notes in the chord, indicated by the number of musical half-steps from the root note. The third part is a list of possible chord inversions that indicates their musical pleasantness. In this example, the root-position is most preferable, and the first-inversion is least preferable. Finally, the fourth part is the list of chords that may follow the chord being defined, again ordered by pleasantness. The number before the slash indicates the chord’s relative root position, and the symbol after the slash indicates the name of the chord. This example demonstrates that chords in and of themselves cannot be used to indicate pleasantness or listenability, which is why we do not rank the chord in its definition. It is the progression from one chord to the next where the emotion lies.

4 Thoughts and Reflections

This paper offers a survey of meaning making strategies for making art and design with fiber optic threads. There are further affordances of this material waiting to be discovered. We used all affordances that we identified in one piece by putting them in relation to each other. We included sonification in our design which was omitted by other artists. The interaction of various affordances helped us push the existing meaning making strategies. Most significantly, the material that we used was an essential part of the concept: the speculative future and the possible impact of underwater fiber optic cables on ecology.

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