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AquaPrism: Dynamically Altering the Color of Aquatic Animals without Injury by Augmenting Aquarium

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ABSTRACT

We propose an augmented aquarium that dynamically alters the color of translucent aquatic animals without injury. This technology produces colored aquatic animals that glow in the dark in a standard fish tank at home. For regulating the color, a monitor displaying colors is installed behind the fish tank. The fish tank becomes dark owing to light-shielding caused by the combination of polarizing sheets coated on the front and back sides of the fish tank. The bodies of translucent aquatic animals in the fish tank alter the polarized light to unpolarized light. Therefore, the background pattern on the monitor can be viewed through the bodies. Accordingly, the aquatic animals are colored by the pattern. This technology does not require injurious procedures as required by previous painting methods, such as injections of dyes and tattoos by lasers. In this study, we describe the representation capability of color and the variation depending on the types of aquatic animals. We also investigated the safety of this technology and the potential interaction by monitoring the behaviors of aquatic animals.

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords

Aquarium; Color-altering; Aquatic Animals; Animal-Computer Interaction; Polarization.

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(A) Translucent Glass Catfish in a Normal Fish Tank

(B) Translucent Glass Catfish in AquaPrism

Figure 1: AquaPrism: An augmented aquarium that dynamically alters the color of aquatic animals without injuring them

INTRODUCTION

Aquariums have attracted humans since the distant past. They aid in creating a relaxing, soothing environment in many places where they are placed [9, 6]. Aquariums are generally used in waiting rooms of doctors and child-care centers as they are effective in entertaining humans and calming their anxiety [13, 4]. Moreover, numerous individuals maintain aquariums as a stress management hobby at home [14]. In this case, an aquarist owns aquatic animals such as fishes and shrimps and keeps them in fish tanks, which are typically constructed using glass or high-strength acrylic.

Keeping visually appealing, naturally colorful aquatic animals in a fish tank at home is not always feasible. As a result, aquatic animals have been artificially colored by a hypodermic syringe containing a bright fluorescent color dye to appeal to consumers [18]. A survey carried out in 1998 revealed that over 40% of colored fish displayed indications of viral infection, compared to 10% of uncolored fish. The infection is likely to have been caused by the transmission of the virus from one fish to another via an infected needle or by a reduction in the resistance to the infection caused by stress from the injection process [15].

In this research, we propose an augmented aquarium that dynamically alters the color of aquatic animals to any color, without injury (Figure 1). In this paper, we call this setup AquaPrism. AquaPrism can reproduce the appearances of deep-sea aquatic animals such as comb jellies in a fish tank at home (Figure 2). Deep-sea aquatic animals glow in the dark, and a few animals generate rainbow colors with their bodies [24]. They draw the attention of numerous individuals in marine museums. However, they are usually highly fragile and incapable of tolerating fluctuations in water quality, salinity, or temperature [26]. Therefore, most of these aquatic animals, which have visually appealing appearances, are not convenient to breed.

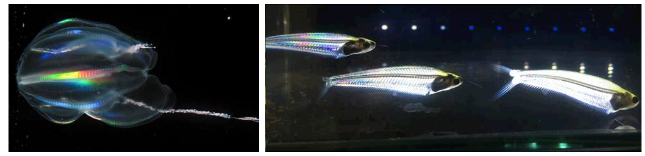
AquaPrism can reproduce the visual appeal by using translucent aquatic animals widely available for amateur aquarists. The color is regulated by a liquid crystal display (LCD) monitor installed behind the fish tank. Polarizing sheet coated on the front and back sides of the fish tank and the monitor make aquarium fish appear colored and glowing in the dark. This technology does not require harmful procedures required by previous painting methods, such as injections of dyes and tattoos by lasers (Figure 3).

Previously, the purpose of aquariums was appreciation, and there was no interaction between humans and aquatic animals in aquariums. AquaPrism will be capable of generating an interaction wherein aquatic animals convey their conditions to the owner by varying their colors. For example, a fish with parasites generally drags its body along the ground. However, tracing the behavior of transparent aquatic animals was not feasible by extant optical tracking systems. AquaPrism enables tracking systems to trace the movement of aquatic animals as a situation with bright aquatic animals against a dark background is suitable for optical tracking. Accordingly, AquaPrism can enhance the relationship between aquatic animals and humans.

RELATED WORK

Artificial Coloring

There are several methods for introducing artificial colors into aquatic animals. The aim of the coloring is to render the aquatic animal brighter in color and more visually appealing to consumers. These methods occasionally cause health hazards to aquatic animals [18]. There also have been several campaigns to persuade aquarium shops to sign a pledge not to sell dyed fish in various countries. Moreover, the artificial colors are not permanent and generally fade away in six to nine months.



(A) Comb jellies (B) Translucent Aquatic Animals widely available for aquarists

Figure 2: AquaPrism can produce colored aquatic animals that glow in the dark in a standard fish tank at home. This technology reproduces the mysterious appearance of deep-sea aquatic animals such as comb jellies, using translucent aquatic animals widely available for aquarists.

(A) Dye injection via syringe (B) Tattoo using a laser

Figure 3: Aquatic animals have been artificially colored to appeal to customers. (A) is a fish colored by a hypodermic syringe containing bright fluorescent color dye. (B) is a fish tattooed by a laser with a dye. These procedures are likely to be injurious to aquatic animals. A survey demonstrates fish colored by injection to exhibit four times more indications of virus infection than uncolored fish.

Dyes

Dyeing is a common method for creating artificially colored aquatic animals. This method uses a syringe to inject a dye into the aquatic animals. The animals may also be dipped in a dye. Figure 3 (A) illustrates an aquarium fish colored by a hypodermic syringe containing bright fluorescent color dye.

Lasers

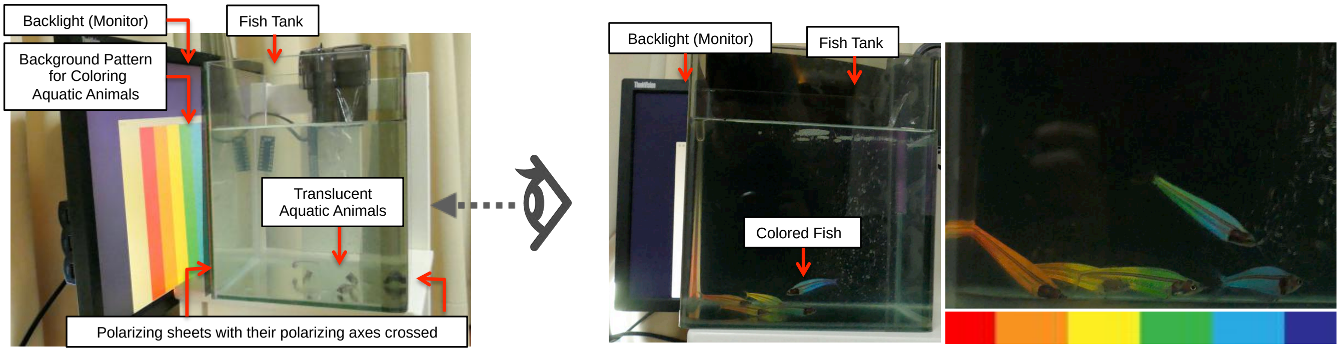
Low-intensity laser with a dye can alter the color of aquatic animals. However, it is necessary to tattoo them in this method. Figure 3 (B) a few aquarium fishes tattooed by using a laser with a dye.

Hormones

Hormone administration can render aquatic animals brighter in color. However, it is likely that it renders female aquatic animals infertile.

Genetic modification

Introduction of genes for fluorescent pigments also achieves coloration without injections or physical modification of the fish themselves.



(A) System Configuration (B) Observer's view (Front) (C) Background Pattern and the Color of Fish

Figure 4: The system configuration of AquaPrism. As illustrated in (A), a monitor displaying a pattern for coloring aquatic animals is installed behind a fish tank. A popularizing sheet with its polarizing axes at 0° is coated on the back side of the fish tank. Another polarizing sheet with its polarizing axes at 90° is coated on the opposite side of the fish tank. (B) is a view from the front side. In the dark, an observer views glowing and colored aquatic animals in the fish tank. The color of the aquatic animals is regulated by the background pattern displayed on the monitor. Here, we use a multi-colored pattern, as illustrated in (C).

Dynamically Altering Colors

A few marine museums have equipment for projecting colors on fish by certain projectors. For example, Sumida Aquarium and Sea Paradise in Japan conduct shows using sardine swimming in a fish tank. Projectors project colors on the fish in the fish tank and dynamically alter their color [2, 17, 1]. However, it is likely to cause considerable stress to the aquatic animals owing to the strong lights projected on them. AquaPrism can also alter the color of aquatic animals visually. However, it does not use color projection and strong light sources. Observers view the color behind the fish tank though the bodies of the aquatic animals in the case of AquaPrism. Therefore, the light source can be a light for aquariums, a monitor, wallpaper, or natural light from a window.

Interaction between Aquatic Animals and Humans

TalkingNemo is an augmented reality system that enables interaction between aquarists and an aquarium fish [12]. This system tracks the position of the fish in a fish tank and displays speech balloons beside it. This method aids humans in understanding their emotions. This system uses a computer-vision-based technique to detect the position and condition of the fish. However, techniques such as background subtraction and object recognition are not stable if the backgrounds are occasionally altered or the aquatic animals are highly translucent [23].

Dynamic background is necessary for aquariums used for entertainment. For example, Eloul et al. proposed an aquarium setup for music performances. In the system, a fish swims in a fish tank in front of a monitor, and the background images and music alters in accordance with the behavior and the position of the fish. Therefore, the fish plays the role of a disc jockey (DJ) in the music performance [10, 3].

A light source emits IR light onto the bodies of fish. The intensity of infrared (IR) light reflected from their bodies can be used for tracking the fishes' positions in a fish tank [16]. Nevertheless, the size of the fish tank must be limited owing to IR absorption caused by water [5]. AquaPrism configures bright aquatic animals swimming in front of a dark background. This situation aids tracking systems in tracing the behaviors of aquatic animals in an aquarium [25].

AQUAPRISM

Contribution

AquaPrism can reproduce glowing aquatic animals in the dark similar to deep-sea aquatic animals. This technology can dynamically alter the color of translucent aquatic animals. Previously, aquatic animals have been colored by physically modifying the animals themselves to appeal to customers. This method is occasionally injurious to aquatic animals. AquaPrism augments aquarium by altering the color of the aquatic animals in it without injuring them. This technology can be an alternative solution for enhancing their attractiveness by color alteration.

AquaPrism can regulate the color of aquatic animals dynamically. Therefore, this technology can enhance the entertainment property of aquariums. For example, in AquaPrism, the color of the aquatic animals can be altered in synchronicity with ambient music.

AquaPrism renders aquatic animals traceable by a camera. This function is beneficial for generating Animal-Computer Interaction in Aquarium by altering the color of aquatic animals depending on their health conditions or emotions.

System Configuration and Methodology

The system configuration is illustrated in Figure 4 (A). In this study, we prepared a $10L$ $(23 \times 20 \times 25cm)$ fish tank made of glass. The fish tank has a few translucent aquatic animals in it. As illustrated in the figure, we prepared few aquarium fishes called "Translucent Glass Catfish." We put a polarizing sheet each on the front and back sides of the fish tank. Their polarizing axes are crossed. An LCD monitor displaying a background pattern is installed behind the fish tank. In this example, the screen displays a multi-colored pattern.

Figure 4 (B) is the view of the fish tank from the front. The aquarium becomes dark owing to the light-shielding caused by the combination of polarizing sheets on the front and back of the fish tank. The fishes appear to be colored because the bodies alter the polarized light from the back to unpolarized light. Therefore, we can view the background pattern on the monitor through their bodies. Consequently, AquaPrism can regulate the color of aquatic animals by altering the background pattern (Figure 4 (C)).

The polarizing axes of polarizing sheets must be a combination of 0° (parallel to the ground) and 90° (Perpendicular to the ground) to configure an entirely dark fish-tank. LCD monitors emit polarized light; however, the angle of polarization varies depending on the types of monitors. In our setup, the polarizing axis of the LCD monitor was approximately 45° (Lenovo ThinkVision LT2223p). If we place a polarizing sheet with its polarizing axes at $-45°$, the screen becomes dark because of the light-shielding. However, reflected lights from the side and bottom of the fish tank are not shielded in this case (Figure 5 (A)). This is attributed to the fact that reflection alters the angle of polarization from 45° to approximately $-45°$. If the polarizing axes are 0° and 90°, the fish tank becomes entirely dark (Figure 5 (B)).

The fish tank must be made of glass or cast acrylic. This is because a fish tank made by extrusion molding alters the polarization property when it is placed between two polarizing sheets. This optical property makes complete light-shielding unavailable.

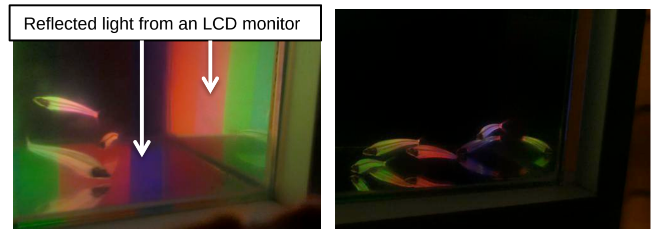
SAFETY

The Effect of Backlight to Aquatic Animals

If the brightness of the monitor installed behind the fish tank is excessively strong, the light is likely to injure the aquatic animals in the tank. AquaPrism requires a backlight for glowing and coloring aquatic animals. However, the light intensity need not be high. The reason is that the observer views the pattern (displayed on a monitor) through the bodies of the aquatic animals. Therefore, the brightness can be lower if the observer is able to recognize the background pattern. Previous systems use projectors to color the bodies of fish, and thus, the light intensity must be high for the color to be visible. On the other hand, AquaPrism can achieve color regulation with less light intensity than that of natural light from a window. Therefore, the required light source should be safe for aquatic animals. Figure 6 illustrates AquaPrism placed on a table beside a window. Aquatic animals in ApuaPrism are glowing by natural light. By placing transmissive liquid crystal display behind the fish tank, we will be able to alter the color of the aquatic animals by natural light or a room light.

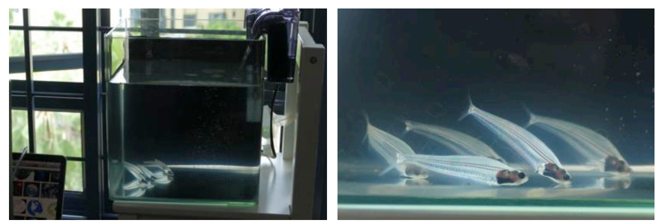
The Effect of Polarized Light on Aquatic Animals

Light from natural sources such as the sun and moon are unpolarized or, at most, weakly polarized. However, polarization of light is common in nature in the atmosphere and in water. It is known that most underwater scatter causes polarization that is approximately horizontal in orientation.



(A) Polarizing axes 45° and -45° (B) Polarizing axes 0° and 90°

Figure 5: For configuring an entirely dark fish tank, the combination of polarizing axes must be 0° (parallel to the ground) and 90° (perpendicular to the ground). Another crossed combination of 45° and $-45°$ also cause light shielding; however, this cannot shield the light reflected from the side and bottom of the fish tank, as illustrated in (A). If the axes are the combination of 0° and 90°, the reflected light is also shielded, as illustrated in (B).



(A) AquaPrism beside a Window (B) Glowing Fish by Natural Light

Figure 6: AquaPrism requires lights from the back; however, the backlight need not be strong. The brightness can be less than that of natural light from a window. Therefore, the required light source is highly likely to be safe for aquatic animals.

For this reason, being exposed to polarized light is not an exceptional condition for aquatic animals living in the water [7, 22].

A few previous studies have revealed that certain types of animals have polarization sensitivities [11, 8]. For example, cephalopod mollusks (squids, octopus, and cuttlefish) exhibit the capability to view and analyze polarized light [20]. According to a study on octopus, they are capable of discriminating polarization variation within an object, and objects that appear featureless to a human can exhibit visual structure when viewed by an octopus [19]. They use this capability to identify prey that would otherwise be invisible. Cuttlefish use regulated reflection of polarized light to produce species-specific signal [21]. Other cuttlefish can recognize the pattern on their bodies; however the intended message is still unclear.

In conclusion, polarized light from AquaPrism is likely to affect aquatic animals that can view polarized lights; however, it is not likely to injure them because polarized lights are common in their aquatic habitat.

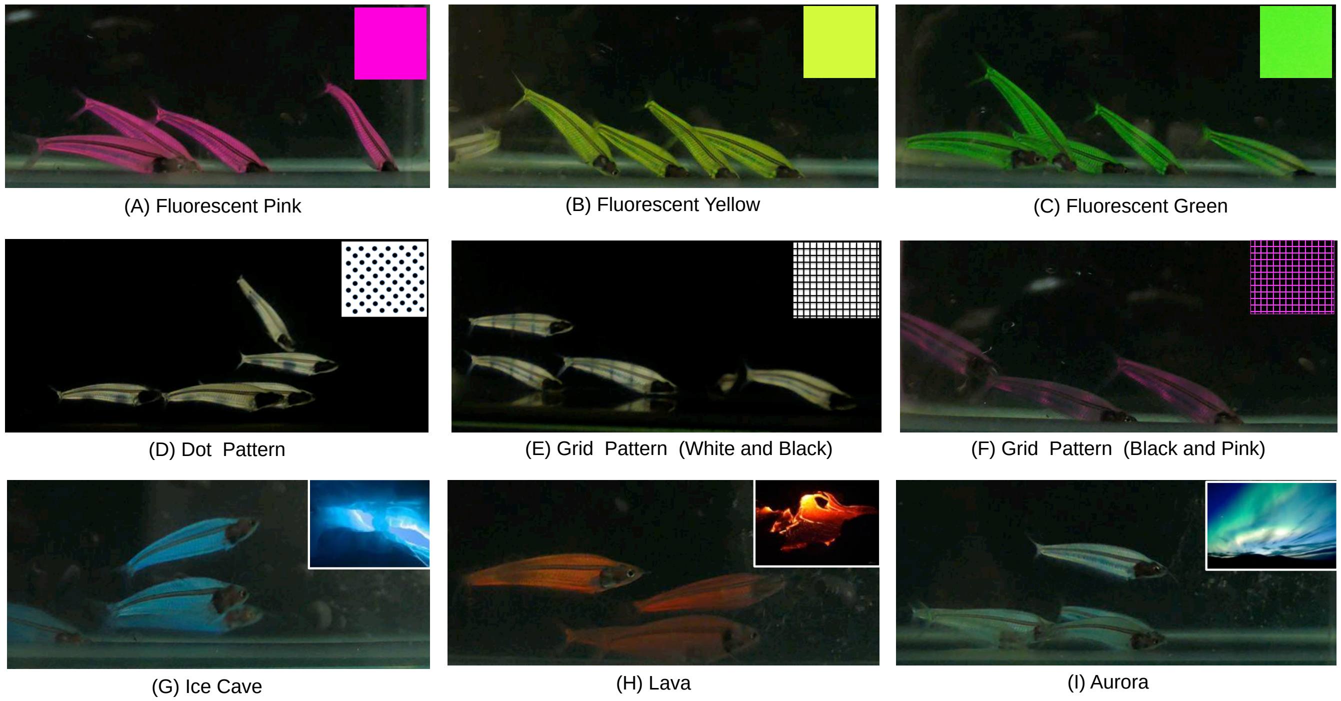


Figure 7: The color of aquatic animals with various types of background patterns. We prepared three types of single-color backgrounds (A, B, C) and three types of patterns (D, E, F). According to the tests on color representation, the color by AquaPrism appears as bright as those by previous methods such as injection of a fluorescent dye by a syringe or low-intensity laser. According to the tests on pattern representation, we succeeded in viewing the pattern on the bodies of the aquatic animals. However, when the fish is at a distance from the monitor, the pattern is blurred. Figures (G), (H), and (I) illustrate the color and patterns of aquatic animals with various types of pictures in the background. The pictures are captured from videos shot by using Panasonic FZ-1000. (Exposure:0(A-C), -1/3(S-F), +1(G-F) ISO:3200)

PERFORMANCE TEST

Representation of Color and Pattern

We conducted tests on the capability of AquaPrism to represent color and pattern. We used various types of background patterns and examined how they alter the color of aquatic animals. For this test, we prepared five translucent glass catfish swimming in AquaPrism.

Figure 7 (A), (B), and (C) illustrate the color of aquatic animals when the background patterns are fluorescent pink, yellow, and green, respectively. We selected these colors because translucent aquarium fish are generally colored by fluorescent color dye, as illustrated in Figure 3 (A). According to the test on color representation, the color by AquaPrism appears as bright as that of previous methods such as the injection of fluorescent dye by syringe or low-intensity laser. Therefore, this technology exhibits the potential to replace previously-used injurious methods for coloring aquatic animals.

Figure 7 (D), (E), and (F) illustrate the results of a test on the capability of pattern representation. Aquatic animals have been tattooed to display patterns on their bodies to appeal to customers. We examine if AquaPrism can represent patterns on aquatic animals. In this test, we prepared a few types of patterns as the background pattern, such as grid and dot. Figure 7 (D), (E) and (F) are the results when the patterns are dots, black-and-white grid, and pink-and-black grid, respectively. As a result, we succeeded in viewing the pattern on the bodies of the aquatic animals. However, when the aquatic animals are at a distance from the monitor, the pattern is blurred. We also observed that the pattern is distorted by the aquatic animal's body because the light is refracted. This representation capability should also depend on the transparency of the aquatic animal. By tracking an aquatic animal and placing a pattern immediately behind it, we will succeed in sustaining the pattern on the body as a tattoo. Therefore, AquaPrism also exhibits the potential to be a substitute for tattooing.

Figure 7 (G), (H), and (I) illustrate the color and patterns of aquatic animals with various types of pictures of nature. Figure 7 (G) and (H) illustrate the color of fish when the background patterns are images of an ice cave and lava, respectively. Figure 7 (I) is the case of Aurora. The fish appear to exhibit the color of ice in Figure 7 (G) and reflect the color and pattern of lava on their bodies in Figure 7 (H). The colors produce impressions of environmental conditions such as frigidity and heat. The bodies of fish cannot represent the details of the patterns; however, all the results appear to create impressions of the environments in the pictures. This result illustrates that AquaPrism can be used for entertainment purpose because the aquatic animals appear to alter their color and pattern depending on the local demands. AquaPrism can provide a distinctive expression by using actual aquatic animals in marine museums, restaurants, and home and other places where individuals maintain this augmented aquarium.

Tractability of Aquatic Animals

If tracing the movement of aquatic animals is rendered feasible, we can detect unusual behavior in them caused by disease. This tracing capability enables an interaction wherein aquatic animals convey their conditions to the owner by altering their colors depending on the causes. We conducted a feasibility test to examine the traceability of aquatic animals in AquaPrism.

We used a tracking system configured by a software library named "BlobDetection for Processing." This software detects brighter blobs, which are areas whose brightness are higher or lower than a particular value in an image. Figure 8 illustrates the results. White boxes indicate detected aquatic animals. Figure 8 (A) illustrates a result wherein the background pattern on the monitor is a white image. In this case, the fish (Translucent Glass Cat) displayed a single white color on their bodies. In situations wherein these bright fish were swimming against a dark background, the tracking system was more or less capable of tracing the movement of the fish. The tracking system was also capable of detecting the fishes in the case of a colorful background pattern (Figure 8 (B)).

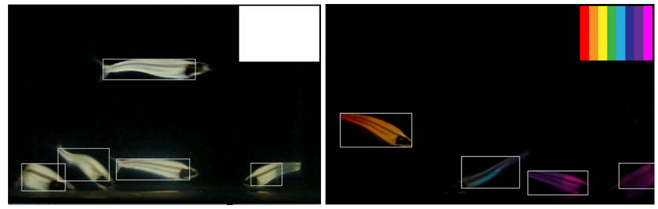
We verified that the traceability was reduced when the room light was bright. In addition, the system lost track of the fishes when a few of them overlapped some of the other fishes. The video used for Figure 8 (A) and (B) were captured in a dark room.

In conclusion, tracing translucent aquatic animals is feasible in AquaPrism. However, it is necessary to develop a proper tracking system for continuously detecting aquatic animals in brighter room condition. In addition, an algorithm that can recognize fishes even when they are overlapped is required.

LIMITATION

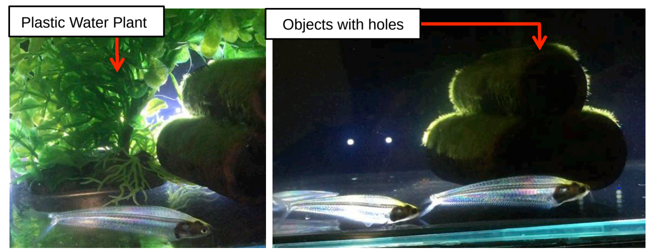
Objects in Fish Tank

Preferably, fish tanks should have a few objects such as water plants and stones in it. These objects in the fish tank provide places for aquatic animals to conceal themselves. This installation reduces stress in the aquatic animals in the aquarium. However, objects in the fish tank are likely to cause problems for AquaPrism because they can shield the light from the background pattern. This situation renders complete light-shielding unavailable, and the darkness in the fish tank is reduced, as illustrated in Figure 9 (A). When placing objects in AquaPrism, aquarists are required not to place objects at the back of the fish tank as they shield more light. Alternatively, aquarists are advised to place objects with holes that transmit light from the back (Figure 9 (B)).



(A) White Background Pattern (B) Multi-color Background Pattern

Figure 8: AquaPrism make translucent aquatic animals traceable by an optical tracking system. (A) and (B) are results when the background pattern was white and colorful, respectively. White boxes in the Figures indicate detected fishes. AquaPrism produces bright aquatic animals swimming in the dark background, and this is an ideal situation for tracing their behaviors by computer-vision-based techniques.



(A) Object Stopping Light from Back (B) Object Transmitting Light from Back

Figure 9: Objects in a fish tank may stop light from the background pattern. In this case, the darkness is reduced in the fish tank as shown in (A). Placing object where they do not shield light from back or objects with holes as shown in (B) are preferable in AquaPrism.

Warning Coloration

Background patterns similar to warning coloration are likely to stress the aquatic animals. We noticed that when we displayed a pattern illustrated in Figure 7 (F), fishes in AquaPrism appeared to express surprise. We suspect this to be a result of the similarity of the pattern to warning colors. Vicious animals generally advertise their presence to other animals through warning-coloration. Warning colors are generally a combination of vivid red/yellow and black. Therefore, this combination of colors should be avoided for use as background pattern for AquaPrism. We tested certain other patterns that are likely to intensify their fear. We displayed a white-black grid, a vivid pink color, and a multi-color pattern wherein the color varied with time, on the monitor behind the fish tank. As a result, the aquatic animals in the fish tank did not display special reactions as those with the pink-black grid. The response should depend on the type of aquatic animal; however background patterns similar to warning pattern are not preferable in general in AquaPrism.

(A) Silver Hatchet (B) Glass Catfish (C) Yamato Shrimp (D) Norman's Lampeye

Figure 10: Variations among the types of aquatic animals. AquaPrism is effective if the animals have translucent parts such as fins on the body. For example, Silver Hatchet does not appear to be translucent in a regular fish tank; however, it glows in the dark as illustrated in (A). Each aquatic animal exhibits distinctive characteristics in AquaPrism. We observed that Glass Catfish exhibits an iridescent rainbow color notwithstanding whether white light strikes the fish. These pictures in AquaPrism are captured by Panasonic FZ-1000. Exposure: +0.33, ISO:3200, F:3.3. A white aquarium light is used as the backlight.

Transparency of Aquatic Animals

For aquatic animals to be capable of exhibiting color alteration in a fish tank fitted with AquaPrism, their bodies must be translucent. We mainly used a type of translucent aquarium fish (illustrated in the figures in this paper) because this aquatic animal is highly transparent.

AquaPrism is also effective with most other aquatic animals because aquatic animals generally have translucent parts on their bodies, such as fins and shells (Figure 10). Each aquatic animal exhibits distinctive characteristics in AquaPrism. Silver Hatchet does not appear to have a body that is translucent in a standard fish tank; however, certain parts transmit light (Figure 10 (A)). Glass catfish exhibits an iridescent rainbow color when white light strikes the fish (Figure 10 (B)). Transparent shrimp and killifish also glow in AquaPrism apart from their heads (Figure 10 (C, D)).

According to the test using various types of aquatic animals in AquaPrism, fish fins are translucent in general and exhibit the optical property to alter polarized light to unpolarized light. For this reason, AquaPrism should be effective with certain types of aquarium fishes that have long and big fins, such as goldfish and betta. Moreover, the technology is likely to be capable of altering the color of other types of translucent aquatic animals such as jellyfish, sea anemone, and clione.

Change Interval of Background Pattern

Continuously altering background patterns did not particularly affect the aquatic animals in our test. Therefore, we suspect that their color can be altered numerous times at short intervals when we use AquaPrism for an entertainment purpose. However, we should reduce the alteration interval and the vividness as much as feasible to moderate the wariness of the aquatic animals because the situation is unnatural for them.

CONCLUSION

We proposed an augmented aquarium that dynamically alters the color of aquatic animals without injuring them. This technology represents glowing aquatic animals in the dark as deep-sea aquatic animals, in a typical fish tank at homes.

We conducted performance tests on the capacity of AquaPrism to represent colors and patterns. As a result, the colors of aquatic animals are altered in accordance with the color of the background patterns. To summarize, this technology exhibits the potential to replace previous injurious methods for coloring aquatic animals.

According to a test on the traceability of translucent aquatic animals in AquaPrism, bright aquatic animals in a dark background permits optical tracking. Tracing of their behaviors will enable interactions between aquatic animals and humans. For example, if a tracking system can recognize unusual behaviors of aquatic animals because of disease, AquaPrism can alter their color to inform the owner of their conditions and the causes.

The aquatic animals must be translucent for alteration of the color in AquaPrism. We also examined the capability of AquaPrism with certain types of aquatic animals such as hatchet, shrimp, and killifish. As a result, AquaPrism appears effective with most of the aquatic animals because they generally have translucent parts such as fins and shells.

In conclusion, AquaPrism can enhance the relationship between aquatic animals and humans by providing technology for altering their color without injury, compared to other methods such as injections and tattoos by lasers. Moreover, AquaPrism is likely to enable Animal-Computer Interaction with aquarium by rendering translucent aquatic animals traceable.

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