Realization of Robot Fish with 3D Hologram Fish using Augmented Reality

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Abstract

The present research designed a tracking system of fish with 3D holographic augmented reality (AR). To track the fish, OpenCv through a camera with an algorithm was used. 3D holographic fish followed color marks that were used to track the fish. If the marks disappeared, 3D holographic fish stopped swimming. This process was repeated until the algorithm stopped. This experiment showed that 3D holographic fish followed the real fish.

Keywords: Robot fish, 3D holographic fish, Augmented reality, Color mark

Introduction

The new robotics technology has emerged in various fields including bio-mimicking robotics [1,2]. The 3D hologram needs an advanced system that requires high computational time. Fast processes are required for improving algorithms of computer-generated holograms [3]. The main purpose of this study is to create 3D hologram fish that follow the path of robot fish. The proposed 3D holographic system consists of robot fish, cameras, radio frequency (RF) modem, drawing table, scanner, beam projector, and personal computer (PC) (Fig. 1).

The color of fish was detected first in the system. Many factors affect sensors for detection [4]. The major factor considered in this study was color. The algorithm was created to sense the color of the robot fish to track. The detecting algorithm allowed the holographic fish to swim along the path of the robot fish by tracking the color without any interruption. The experiment result was satisfactory and exhibited at the Daejeon National Science Museum, Daejeon, South Korea.

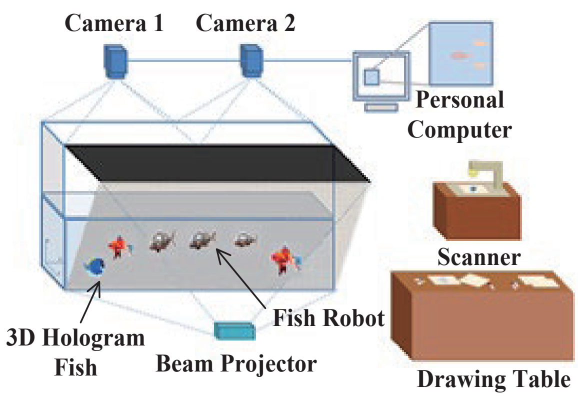


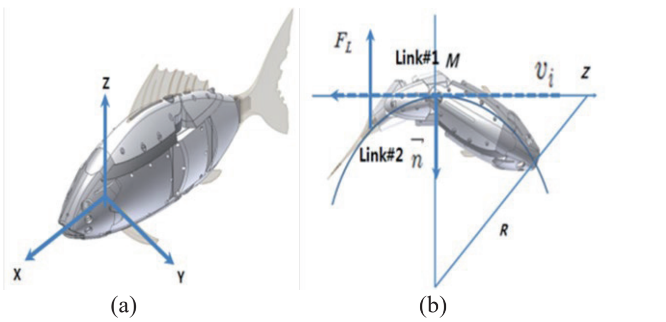
Fig. 1. Schematic diagram of the 3D holographic system.

Modeling to control the robot fish

A biomimetic robot system was developed for an aquarium. Components in the robot fish are shown in Fig. 2. The components need to improve performance to mimic the swimming. The bodyweight of the robot fish must be balanced [5]. The various components in the system included a radio frequency module, PSD sensors, two servos all of which were connected to an AVR microcontroller. Sensors tracked the path of the robot fish. The weight balancing unit balanced the robot fish using the sliding method. The slider was used to slide the weight balancing unit. When the unit moves towards the head of the robot fish, the robot fish swims down. The weight balancing unit moves to the tail, it floats as shown in Fig. 2. The fish movement was analyzed with Eq. (1) [6].

$$y_i(x, t) = \left(C_1 x + C_2 x^2\right) \sin\left(kx - 2\pi f t\right) = \left(C_1 x + C_2 x^2\right) \sin\left(kx - \frac{2\pi}{M} i\right), \qquad (1)$$

where $y_i(x,t)$ is the displacement in the x-direction, C_1 and C_2 are constants to satisfy the required condition, $k=2\pi f t$ is multiples of the body wave or length, ω is the angular velocity, and f is the frequency. According to Eq.(2), the feedback is given in the closed-loop.



(a) (b)

Fig. 2. (a) Robot fish orientation and (b) link angle rotation in the aquarium.

$$error = \sum_{i=0}^{n-1} \int_{x,t}^{x_{end}} \left| g(x) - f(x) \right| \qquad (2)$$

$$\theta_i = a_i \sin\left(2\pi f t + p_i\right) \qquad (3)$$

Then, the frequency of the robot fish was determined by using the light-hill analysis. The movements of fish follow all trajectories [7]. While the fish are swimming, they should follow the trajectories and maintain the balance of the bodies [8]. The tracking speed depends on the load condition. The controller adopts a proportion integration and derivative system with the appropriate constants in Eq. (4).

$$\mathrm{PID}(s) = K_p + K_d s + \frac{K_i}{s} \qquad (4)$$

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where K_p is the proportional gain, K_d is the differential gain, and K_i is the integral gain. The amplitude and waveform equation is given as Eq. (5).

$$\omega(s) = \frac{K_m / R_a J}{s + \left(R_a B + K_b K_m / R_a J\right)} V_a(s) \tag{5}$$

where $\omega(s)$ is the speed of the robot fish, K_m is the motor gain, R_a is the armature resistance, J is the moment of the inertial of the motor, B is the thermal property of the motor, and K_b is back gain.

To control the link angle, the Simulink model is used as shown in Fig. 3. The first block was for the dynamic motion of the robot fish and the remaining blocks were used to control the link angle of the robot fish. The link angle output (LAO) has expressed in Eq. (6).

$$LAO = \frac{s^2 K_m K_d + s K_i K_p + K_i K_m}{s^3 R_a J + s^2\left(K_m K_b + R_a B + K_m K_t K_d\right) + s\left(K_m K_t K_p\right) + K_m K_t K_i} \tag{6}$$

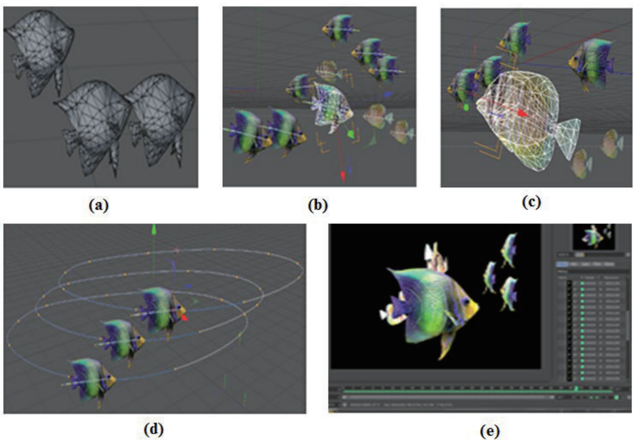

Fig. 3. Step of reproducing a 3D Hologram: (a) Modeling, (b) Coloring and Texturing, (c) Rigging, (d) Animating, and (e) Rendering.

3D holographic world

A. Hologram

A hologram is an interesting technology and used for different activities such as video games, movies, teleconference, presentation, and virtual reality realms. The hologram is used to follow and apply the real image for creating virtual images and allowing the object to follow the real path [9]. We designed the 3D hologram by using Cinema 4D and Pepper's Ghost Technique for 3D hologram projection.

B. Cinema 4D

Cinema 4D is a 3D modeling application developed by MAXON Computer GmbH. This application is capable of making animation, motion graphics, modeling 3D objects, rendering for various 3D modeling applications. We used this application for 3D hologram modeling and animation [10-12].

Experimental Result

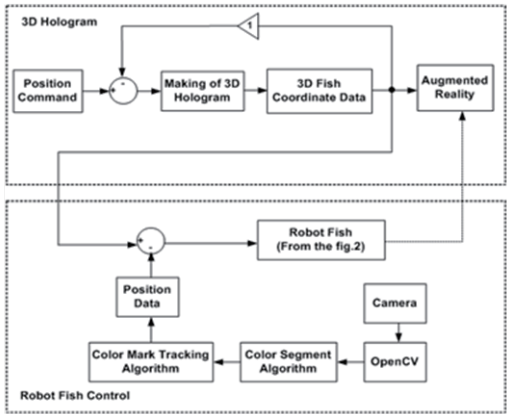

Fig. 4. The proposed augmented reality system

Image sensors, radio frequency modem, and aquarium software programming were the components in the system. The designed robot fish was controlled by the servo motor using a battery. The continuous motion of the robot fish was captured by the cameras and sent to the PC [13-16]. Tracking of fish is shown in Fig. 5. In Fig. 6, the different colors of the robot fish were traced. The directions of the motion of all fish are shown in Fig. 7.

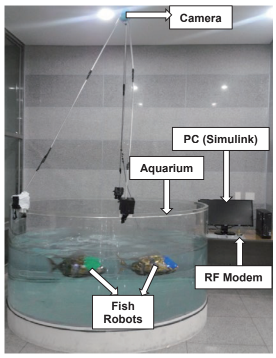

Fig. 5. The realization of robot fish using OpenCV.

Fig. 6. Color detection with OpenCV.

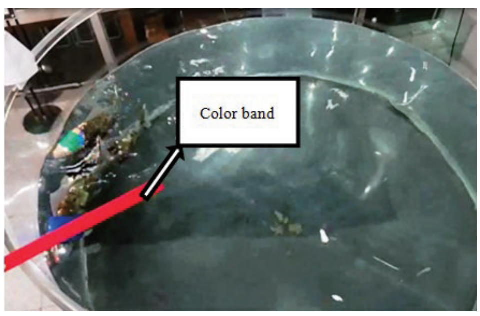

Fig. 7. The color mark tracking control of the robot fish.

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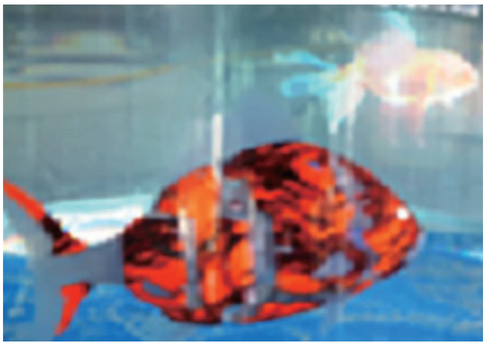
(a)


(b)

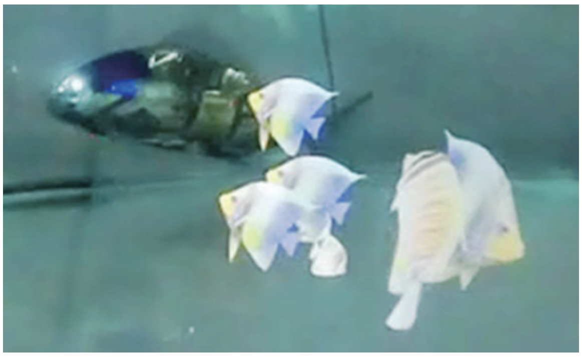

(c)

Fig. 8. (a) Tracking of 3D fish (b)3D fish following Real Fish (c) 3D Holographic Fish

The two robot fish swam in opposite directions to each other. We sent the data to control and track the robot fish by using color marks from the RF modem. The robot fish paused when the color mark disappeared. The RF modem sent and received the data in a single unit with a low carrier frequency. Figure 8 shows the 3D holographic fish followed the path of the robot fish and the realization of the augmented reality.

Conclusion

To monitor the coordinates of the robot fish in the aquarium, we used the color segment algorithm and the designed robot fish as the object to be detected for positions by using OpenCV. This algorithm detected and tracked the robot fish and made the 3D holographic fish follow the robot fish. The movement of the holographic fish stopped when the color mark disappeared. The successful installation of this system was exhibited at the Daejeon National Science Museum, Daejeon, South Korea. For future research on 3D hologram, this research provides the basis of creating 3D hologram fish in AR and robot fish tracking control techniques.

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