

# Digital Fabrication and Manipulation Method for Underwater Display and Entertainment

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Figure 1: (a) Cartesian Divers designed using our method. (b) A mermaid is floating in the middle of water tank by PID control. (c) A girl is looking at the message.

## CCS CONCEPTS

•Computing methodologies →*Shape modeling*;

## KEYWORDS

Digital Fabrication, underwater entertainment, 3D print

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## 1 INTRODUCTION

Underwater expression is attractive. It seems like underwater objects are floating like anti-gravity scape by buoyancy, and it is also impressive that bubbles rise while refracting the light. In this work,

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we aim to combine digital fabrication with interactive technology and expand underwater expression. To achieve this, we focused on a classic science experiment called the Cartesian Diver. Because of growing interest in the materialization of computer graphics, digital fabrication technologies have recently emerged as one of the most important application fields in real-world-oriented computer graphics. In particular, research on digital fabrication that gives dynamics properties is common. Spin-it [Bächer et al. 2014] presents design method for spinning objects by optimizing rotational dynamics properties. Some studies use non-contact manipulation. For example, ZeroN [Lee et al. 2011] controls the magnetic field to manipulate the object and uses it as a floating screen and input user interface(UI). Our work connects digital fabrication and non-contact manipulation that uses the space transmission power (water pressure) around the object (the diver). [Koike et al. 2016] proposes a design and manipulation method for the diver. In this work, we updated the method and investigate stability of PID control. Furthermore, we propose some applications.

## 2 IMPLEMENTATION

Our implementation has two phases; fabrication and manipulation.

In the fabrication phase, we created an algorithm to calculate the appropriate amount and position of the cavity inside 3D model. As the conditions for the 3D model to function as the diver,

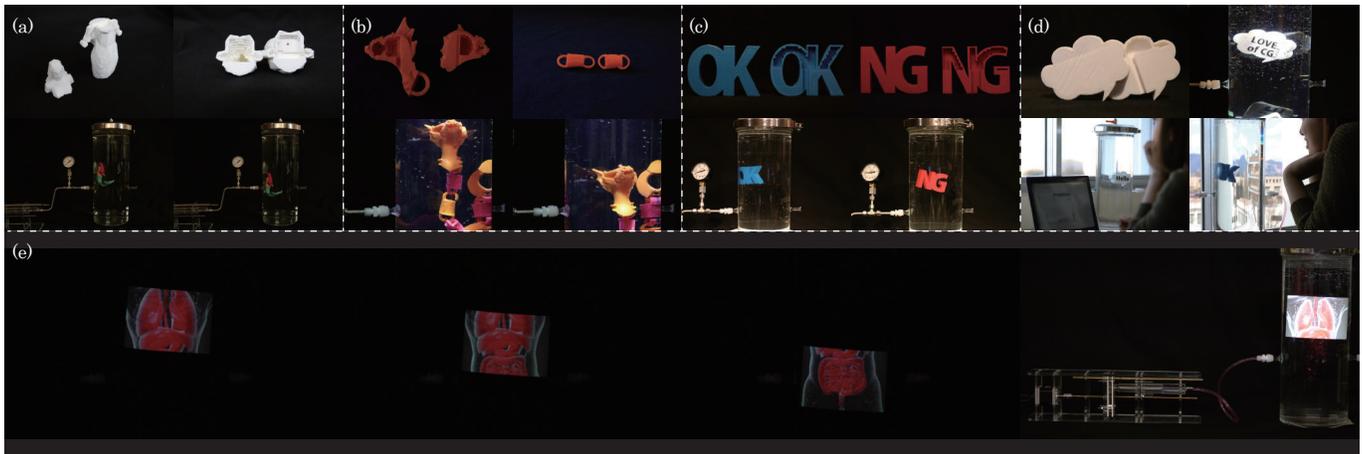


Figure 2: Various applications of this work.

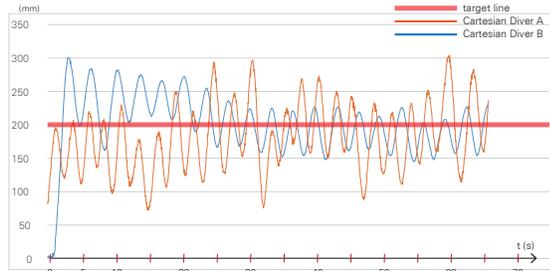


Figure 3: This graph shows behavior of two Cartesian Divers while PID control that manipulates them to stabilize at the target line. Red line is a target position, and A (Orange line) is smaller and lighter than B (Blue). B is moving steadily than A.

- it has to float when you first put it into a water tank.
- it is necessary to have a hole which water enters the object when water pressure is applied to the water tank.
- rotation moments should not be occurred so that the object floats up and down with the correct orientation.

In the manipulation phase, we developed an equipment to manipulate the diver. It has a glass tank connected with motor-worked syringe pump. (Figure 1(b)) We can applied water pressure to water tank by moving the syringe pump. And it also has a camera connected PC to feedback the position of the diver in water tank for PID control.

### 3 RESULT

We designed various shaped 3D models showed in Figure 1(a). Behavior of two divers under the PID control is showed in Figure 3.

Although it seems that there is some shake due to camera tracking delay, the diver keeps floating in the middle of water (target line) tank without hitting the upper part or the lower part of the tank.

## 4 APPLICATION

### 4.1 Various shaped 3D models

We designed a mermaid (Figure 2(a)) and a dragon (Figure 2(b)). The body of the dragon consists of some parts, so it shows funny movements when water pressure is applied.

### 4.2 Messaging

We designed the diver that has information presentation function. We fabricated the diver in the form of alphabet (Figure 1(c)) and Figure 2(c)) and the form of a speech balloon (Figure 2(d)).

### 4.3 Moving screen

We propose a diver which works as a screen in the water tank. Figure 2(e) expresses scanning the body tissue.

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