ProDive: Projecting and Interacting Underwater

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Figure 1. Scuba diver using a torch light to observe a Manta Ray on a night dive.

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Abstract
This position paper discusses and motivates a design space as well as interaction paradigms for projection not on water but under water. Projection surfaces have evolved from fixed white boards to any physical item that we decide to change into displays. Water itself is now used as 2D or 3D projection screens [1, 4], "touch screens" [5] and even as interaction paradigms [6, 9]. We discuss here why underwater projection can and need to evolve and how existing interaction paradigms are being challenged underwater.

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ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

General Terms
Design, Human Factors

Introduction
Thanks to advances in projection technologies, we can expect in the future years that any physical element can become a display. While we master projection in "air", projection in water is still at its premises. In recent years, water displays have been proposed [1, 3,

Figure 2. Scuba diver geared up. The red circles indicate the gauges the diver will have to pay attention to once underwater.

4] usually consisting of screens of droplets with a projection onto the droplets; but also various types of interaction techniques involving water [2, 5, 6, 7]. Additionally, Takahashi et al. [9] and Watanabe [11] both present interaction with water in the bath tub.

While current literature focuses on projection *on* water, we here focus on projecting *in* water, i.e. underwater. As a matter of fact, projecting under water gives the opportunity to project on an ecological surface, which is constantly moving and changing shape, creating a real challenge both for projecting and for interacting with the projection. A very interesting aspect about projecting underwater is that the projection is not appearing on a physical graspable object anymore but instead on a whole projection "space".

The underwater world is populated by many forms of wildlife and visited by scuba divers eager to discover this wildlife, the ocean floor and even wrecks. It is also populated by divers working on constructions such as subsea pipelines or even military divers working on removing explosive devices that fell underwater for example. Depending on the sea and weather conditions, divers can be confronted to poor visibility and little to no lighting when reaching the bottom of the ocean. For this reason, torchlights have become an essential item in the diving gear (Figure 1).

In this position paper, we argue that underwater projection is the next step after torchlights to improving divers' experience. We present scenario of use for underwater projection as well as interaction challenges and novel interaction paradigms.

Situation with diving

A minimal diving gear consists of a diving suit, a compressed air cylinder, various hoses, a weight belt, a pair of boots and fins, mask, snorkel and various instruments. The various gauges give indication on: the pressure in the air cylinder, depth, time spent under water, direction (i.e. compass) and temperature. Those various pieces of information are located on different parts of the diver's kit as on Figure 2 and the diver will need to frequently consult them during the dive to ensure to not run out of air for example.

An experienced diver will have additional diving kit, such as: a diving knife, line cutter, decompression tables, a surface marker buoy to sign the presence of divers to close-by boats, multiple torchlights; all attached to the diving suit.

Scenarios of use for underwater projection

Torchlights have multiple functionalities. They can be used to provide light in a dark environment, to help not lose sight of another diver when visibility is extremely low (Figure 3), to alert another diver from the presence of dangerous animals and also to find sea animals that are hiding in rocks (Figure 4). We propose below some scenarios of use for underwater projection as enhancements from the current usage of torchlights.

Ambient Display

Using a projection as an ambient display would allow for the diver to have information about their different gauges for example without having to check them individually. In the future, the diver could project in front of them the direction they are facing for example. They could also get a signal before they reach their air reserve and have to go back to the surface. In a first

Figure 3. In a low visibility environment, divers will only be seen by their diving buddy thanks to their torch light.

Figure 4. Torchlights can be used to find wildlife.

time, this could be implemented by changing the colour of the underwater torchlight beam depending on the air level; this could also be done by increasing or decreasing the light intensity.

This scenario could also allow for divers of the group to monitor the status of other divers without having to reach others' gauges but just by glancing at the light beam. This could also be used in parallel with temperature captures in the diving suit that would alert divers of hypothermia.

Augmented Reality

As with handheld projection systems, the ocean floors can be augmented using augmented reality techniques.

ENCOUNTERING WILDLIFE

An augmented reality system can for example recognize whether an encountered wildlife if dangerous for the diver or not. As with Tang et al. [10] real-time plankton recognition system, other wildlife could be recognized and the colour of the beam or projection could change depending on the animal or plant it is pointing at. This would increase divers' and wildlife safety.

GUIDANCE SYSTEM

When entering caves and wrecks, the diver struggles to estimate whether there is enough space for them to get in or not. Indeed, it is very difficult for a diver to know how much space they need to enter a hole with their full gear on. Using a pro-cam system, a camera could measure the size of the hole and compare it to the divers' size equipped and let the diver know whether it is safe for them to enter the cave.

Divers could also be given directions via the underwater projection either in the shape of arrows, or with a colour guidance or even by changing the projection angle to what their path should be in a given ship wreck or cave.

ASSISTANCE FOR UNDERWATER WORK

Handheld augmented reality systems can be used to help field workers with their job [8]. Similar systems can be created for divers who work on subsea constructions, such as welders who go underwater to fix pipes or improve existing constructions. An underwater augmented reality system would help divers assessing the situation so they would not have to go forth and back between the surface and the dive site or would spend less time underwater; therefore limiting pressure effects on the human body.

Interaction challenges

The main challenge about interaction for a diver is that all of the five senses are altered in some way under water. *Smell* is fully impaired; *taste* is affected by the mouth piece material; *hearing* is limited to sounds that propagate under water; the perception of *touch* is distorted by the water itself and often the temperature, moreover most divers wear gloves; and finally *sight* depends on the time of the day, depth of the dive and the meteorological conditions. In terms of movements; on one side they are reduced by the diving equipment such as the hood that can prevent the head from turning; and on the other side the range of possible movements for a person are increased by the weightlessness of the environment.

While underwater projection provides visual feedback, available to multiple divers; visual feedback alone may not be sufficient. *Audio* and *Haptic feedback* can then be used in complement. Haptics could alert the diver of a new event; a small electric current could for example create a pinching sensation in the diver's gloves.

Interaction paradigms

With projecting on water, one can "touch" the water to interact with the projection [9]. Underwater, the environment itself becomes a potential display area; moreover there is no shape or texture to touch. We could use shadows by hiding parts of the beam but the water environment will distort the projection.

Since the diver is in the same environment as the projection; it seems like the underwater can be assimilated to a virtual reality environment where users are within the same space as the items being displayed. We could therefore consider applying virtual reality techniques to interact with underwater projection.

Conclusion

This position paper considers the case of using water as a display and look in particular at the case of projecting underwater. It presents scenarios of use and challenges in using current interaction techniques for projected displays.

References

[1] Barnum, P. C., Narasimhan, S. G. and Kanade, T. A multi-layered display with water drops. *ACM Trans. Graph*. 29, (2010), 1-7

[2] Dietz, P. H., Westhues, J., Barnwell, J., Han, J. Y. and Yerazunis, W. Submerging technologies. In *ACM SIGGRAPH 2006 Emerging techno.*, ACM (2006), 30.

[3] Eitoku, S.-i., Nishimura, K., Tanikawa, T. and Hirose, M. Study on design of controllable particle display using water drops suitable for light environment. In P*roc. VRST'09*, ACM (2009), 23-26.

[4] Eitoku, S., Tanikawa, T. and Suzuki, Y. Display Composed of Water Drops for Filling Space with Materialized Virtual Three-dimensional Objects. In *IEEE VR 2006*, (2006), 159-166.

[5] Mann, S., Janzen, R. and Huang, J. "WaterTouch": an aquatic interactive multimedia sensory table based on total internal reflection in water. In *Proc. MM'11,* ACM (2011), 925-928.

[6] Pier, M. D. and Goldberg, I. R. Using water as interface media in VR applications. In *Proc. CLIHC* 2005, ACM (2005), 162-169.

[7] Sato, M., Poupyrev, I. and Harrison, C. Touché: enhancing touch interaction on humans, screens, liquids, and everyday objects. In *Proc. CHI'12*, ACM (2012), 483-492.

[8] Schall, G., Mendez, E., Kruijff, E., Veas, E., Junghanns, S., Reitinger, B. and Schmalstieg, D. Handheld Augmented Reality for underground infrastructure visualization. *Personal Ubiquitous Comput.* 13, (2009), 281-291

[9] Takahashi, Y., Matoba, Y. and Koike, H. Fluid surface: interactive water surface display for viewing information in a bathroom. In *Proc. ITS 2012*, ACM (2012), 311-314.

[10] Tang, X., Stewart, W. K., Huang, H., Gallager, S. M., Davis, C. S., Vincent, L. and Marra, M. Automatic Plankton Image Recognition. *Artif. Intell. Rev.* 12, (1998), 177-199

[11] Watanabe, J.-I. VortexBath: study of tangible interaction with water in bathroom for accessing and playing media files. In *Proc. HCI International 2007*, Springer-Verlag (2007), 1240-1248