SubmergeShots: A VR-based Serious Game for Enhancing Marine Bioscience Knowledge and Conservation Awareness

Yiting Liu, [1]Mengyao Guo[2]and Ze Gao[3*]
[1]University of Sydney, Sydney, Australia
[2]Shenzhen International School of Design, Harbin Institute of Technology, Shenzhen, China
[3]Hong Kong University of Science and Technology & Hong Kong Polytechnic University, Hong Kong SAR
liuyiting000413@163.com, coco.mengyao@gmail.com, zegao@polyu.edu.hk

Abstract

Virtual reality (VR) combined with serious gaming provides a novel approach to enhancing knowledge and awareness in marine bioscience education. This approach led to the development of "SubmergeShots", a VR game that simulates underwater photography to provide an immersive educational experience on the Great Barrier Reef. The game guides users through pre-dive preparations, underwater photography, and post-dive procedures without real diving risks. It addresses challenges like equipment handling, safety, and ethical marine life interactions while promoting conservation awareness. Built using Unity, SubmergeShots features three levels, including 'game over' scenarios for inappropriate actions as warnings. Collaboration with underwater photography institutions may realize further educational value and professional certification. Overall, this project pioneers an engaging VR game for training underwater photographers and marine science learners, fostering skills and environmental consciousness through immersive experiences.

Keywords

Virtual Reality, Serious Game, Immersive Training, Underwater Photography, Marine Bioscience, Conservation Awareness

Introduction

Underwater photography has evolved with technology from arduous beginnings to a tool that enhances scientific and artistic appreciation of aquatic ecosystems and fosters environmental awareness. Despite advancements in accessible technology, such as GoPros for citizen science, challenges remain, including physical risks and negative impacts on marine life. Our project "SubmergeShots", a serious VR game, addresses these issues by providing a safe, immersive training environment for underwater photographers, simulating the Great Barrier Reef, and guiding users through dive preparation, photography, and risk management to post-dive equipment care, thereby equipping photographers with the skills for real-world operations without harm to the marine environment or themselves.

Research Background

The invisibility of water bodies required researchers to use equipment to observe them indirectly. To assist in the research of marine bioscience, the first underwater photo was attempted and completed in the 19th century. It was arduous, encountering problems such as difficulty adapting various equipment to underwater environments and differences in personnel's diving abilities. However, it reflected the usefulness of photography for underwater research [9]. With the development of technology, people have become interested in underwater photography, a powerful tool to enhance people's understanding of the unknown and beautiful aquatic ecosystems [5]. Underwater photography also provides a unique perspective for artistic creation, posing challenges to the photographer's technology and innovation. An increasing number of inexpensive and convenient devices allow every person to access and take underwater photographs [1]. For example, using "GoPros" is one of the effective ways to do citizen science in the marine environment, particularly for studying coral habitats [12].

However, the risks of underwater activities cannot be ignored. When diving, wearing a mask or helmet is necessary, but this will reduce people's perception of their surrounding's vision and depth. Meanwhile, underwater brightness and contrast will decrease, leading to increased difficulty in object detection, causing slow response [10]. In addition, photographers may also be attacked by animals, such as being accidentally injured by great white sharks, which may mistake humans for seals [2], or provoke them through touch or other wrong behaviours [11].

Although many existing projects and products are related to diving safety, unlike regular diving, underwater photographers also need to pay attention to how to use and protect equipment to complete tasks successfully underwater. Research has shown that goal-oriented diving behavior, such as photography, impacts marine habitats more than normal diving [4]. To capture more beautiful biological photos, photographers usually use "Mock Sticks" or hands to guide animals into better shooting positions. But this may lead to some organisms, such as sea lilies, having their appendages cut off. Some microorganisms may experience behavioral changes or stress responses due to hand touch [6] [7].

Project Description

Virtual reality (VR) can help users complete immersive experiences more safely, combined with games, and educate users through entertainment to understand relevant information unconsciously [3]. The project "SubmergeShots" is a

serious game that provides underwater photographers with a VR immersive training experience (see Figure 1). Using the Great Barrier Reef as the model, based on the actual underwater photography process, the game is divided into three levels: preparation before diving, photography and risk response during diving, and equipment organization after diving. Players must complete the tasks set for each level to enter the next level and unlock rewards. The project's purpose is to assist underwater photographers in completing training in a safe and low-risk manner and to accumulate experience for practical operations.

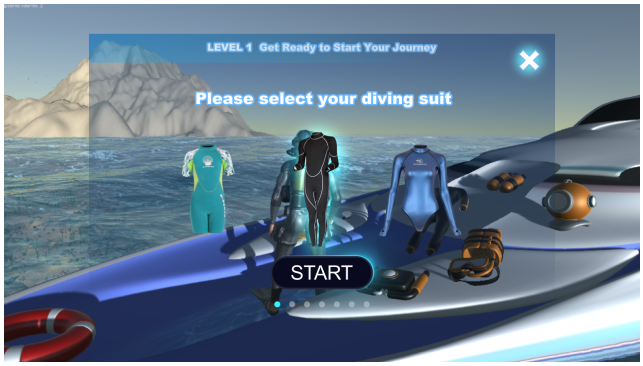


Figure 1: The Interface of Level 1, SubmergeShots. ©Credit by Authors.

Related Works

Immersive environments allow participants to remember and evoke stronger emotional resonance [13]. Users receive visual stimuli from virtual scenes and cooperate to complete treatment tasks. Meanwhile, immersive VR can significantly improve learning efficiency, enhancing learners' enjoyment and attention [8]. The underwater environment belongs to extreme environments and is not suitable for basic training. For underwater photography, direct underwater training may cause casualties, camera damage, and unexpected risks that are difficult to deal with. Therefore, the immersive approach also fills these limitations.

Infinite Scuba is a Steam game developed and released by Cascade Game Foundry SPC (see Figure 2a). It collaborates with multiple professional researchers and the Dividing Equipment and Marketing Association (DEMA) to provide users with realistic and accurate diving scenes and equipment. Users can explore the underwater world through actual divers, including understanding animals, exploring underwater artifacts, and cleaning up corals. Users unlock rewards by completing tasks such as learning to dive and find designated creatures, thereby gaining knowledge and increasing environmental awareness. However, the mechanism and visual design are unrealistic, with no specific interactive prompts, and users are limited in understanding their error operations during the gameplay. For example, when players engage in deep diving during descent and ascent, the pressure on the lungs caused by water pressure often requires more prolonged recovery. As a result, the ascent time should be longer than the descent time, and players must do the "safety stop". However, the players can unlock bonuses to achieve rapid ascent, which does not align with real-life situations where rapid ascent could lead to pulmonary barotrauma. Therefore, the game fails to provide players with accurate feedback that corresponds to reality.

Amphibian is a VR scuba diving simulator that can be used in terrestrial environments (see Figure 2b). Compared to ordinary VR games, it visually provides users with simulated ocean scenes and uses headphones to provide auditory experiences. It also builds a sports platform and safety belt to simulate the buoyancy and resistance encountered in diving. Users only need to lie on the platform and wear relevant equipment to experience scuba diving on land. Meanwhile, various sensors simulate breathing movements and water temperature changes, providing users with a tactile and sensory experience. This offers deeper inspiration and possibilities for the subsequent development of "SubmergeShots". We can modify and iterate based on it, adding a training section for underwater photography and providing users with a comprehensive underwater photography experience.

The Future Interfaces Group at Carnegie Mellon University has developed a portable device that can be placed under VR glasses to achieve tactile feedback on the lips (see Figure 2c). It has multiple pulse modes to recognize and make the user's lips vibrate. For example, it simulates the feeling of a spider crawling in the user's mouth. The survey results show that the tactile sensation of the lips enhances immersion, realism, and other experiential factors. This has inspired our project by enhancing tactile feedback to simulate user feedback, such as being bitten by animals due to improper underwater operation. It allows users to immerse themselves and truly experience the consequences of incorrect behavior.

Technical Realization

Visual Design "SubmergeShots" is a virtual simulation of the Great Barrier Reef, the world's largest coral system off Queensland's coast, Australia. It's a UNESCO World Heritage Site, famed for its diverse marine life and a diver's haven. The Great Barrier Reef is in good health but is also under pressure from tourism, fishing, agriculture, coastal development, and land and water pollution. Therefore, it is crucial to correctly interact with the Great Barrier Reef and its organisms, reduce human factors' impact on coral reefs, and protect them. For the design of game elements, when selecting related equipment at Level One, we selected classic products from professional diving brands as the correct option. In contrast, the wrong option selected more likely problems, such as excessively colorful diving suits and yellowed and old diving goggles, to make clear choices for players. In Level Two, if players make mistakes, the game will warn the players visually impactfully, such as when a shark approaches but players mishandle or make the wrong response, which may lead to "bloodstaining the ocean". To give players a clearer understanding of their choices, each option will be highlighted with a blue light as a distinguishing feature.

Game Mechanics The project is built by Unity and divided into three levels, corresponding to preparation before diving, underwater photography, and equipment organization after photographing (see Figure 3). For level 1, there are seven

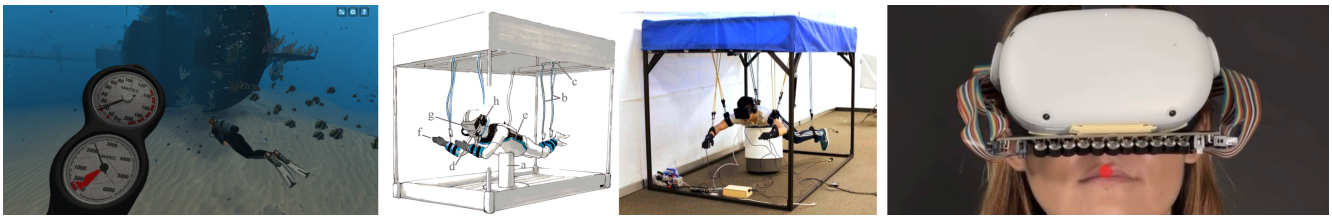


Figure 2: (a) The Infinite Scuba, Steam Game; (b) The Amphibian, VR Diving Simulator; (c) The Mouth Haptics, A Portable Device. ©Credit by Infinite Scuba, The Amphibian and The Mouth Haptics.

main tasks, with the first four tasks related to diving equipment. Firstly, inspecting the diving face mirror is required, and players need to check whether the color of the silicone skirt edge is dark yellow. Next is to check the diving suit (see Figure 4a), including style, color, fit, and damage. At the same time, check whether the heel strap and buckle of the fins are damaged and whether the fins are deformed or not. Task three is to check for discoloration and water leakage in the purge valve plug, mouthpiece, and snorkel. Task four is to check whether the gas inside the scuba cylinder supports the completion of the shooting. Task five is to check the usability of the photography equipment's functionality. Task six is to inspect the underwater casing of the photography equipment for signs of aging and water leakage. Finally, there is a usability check for the flash, lens (whether the lid is open), and storage card. Players need to complete standardized wearing and inspection according to the task sequence and prompts to ensure the safety and usability of themselves and their devices underwater. After completing all the tasks in level 1, the system will record the player's answers and match them with the corresponding tasks in level 2 and the game result.

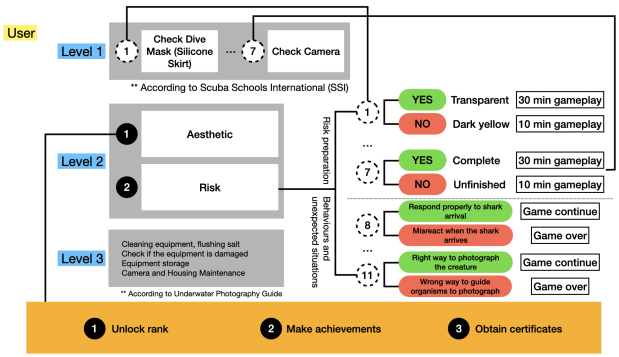
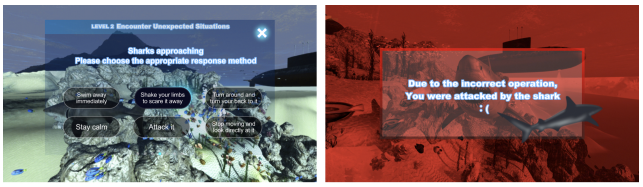


Figure 3: The Workflow of SubmergeShots. ©Credit by Authors.

(a) The Preparation Stage of SubmergeShots (b) The Game's Virtual Environment

Figure 4: The Preparation Stage and the Game's Virtual Environment of SubmergeShots. ©Credit by Authors.

Tasks that players have not completed in level 1 will trigger the corresponding outcome in level 2. For example, if players fail to notice the yellowing and aging of the silicone skirt of the diving mirror in level 1 task 1, it will lead to the game being over because the diving mirror enters the water. Level 2 is divided into two aspects: the aesthetics of the underwater world and the risks that players may encounter."Aesthetics" is mainly reflected in using Unity to model the underwater world (see Figure 4b), allowing players to immerse themselves in the charm of the underwater world. "Risks" are mainly divided into four tasks, corresponding to "8-11" in the workflow (see Figure 3). Task 8 is how to respond correctly when facing dangerous animals (such as sharks) (see Figure 5a). Task 9 teaches and assesses shooting skills, including flash position, power, lens testing, focusing, shutter speed, and composition. Task 10 deals with situations where the diving depth and oxygen level are not correctly estimated during the shooting process. The final task is interacting correctly with animals during the filming process. In level 2, except for task 9, which will not cause the game to end, the error completion of other tasks will cause the game to go over, and the consequences will be shown to the user to achieve the purpose of alertness and education (see Figure 5b).



(a) The Dangerous Situation of SubmergeShots (b) The Game Over Interface of SubmergeShots

Figure 5: The Dangerous Situation and The Game Over Interface of SubmergeShots. ©Credit by Authors.

After completing the underwater tasks in level 2, players will return to land to complete the Level 3 tasks. Level 3 is mainly for summarizing and organizing, preparing for the following underwater photograph, including equipment cleaning, salt washing, checking for equipment damage, equipment storage, and maintenance of cameras and underwater casings (see Figure 6). There are three main reward mechanisms in "SubmergeShots." The first is the leaderboard, where players can view their rankings. Players can also unlock achievements and receive recognition of professional abilities by completing tasks. In the future, we will attempt to collaborate with professional underwater photography institutions. When players complete all tasks, they can obtain professional certification.

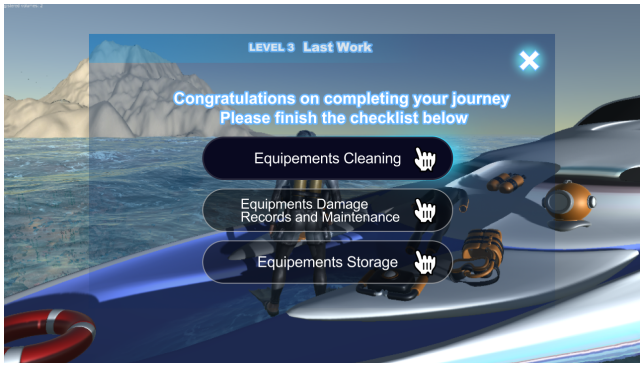


Figure 6: The Follow-Up Step of SubmergeShots. ©Credit by Authors.

Conclusion and Future Work

Using VR immersive serious games for training provides underwater photographers with a safer and more effective means of grasping the essentials of diving and photographic techniques. It allows them to build up transferable experience to real-life scenarios, enabling a composed response to unforeseen events. The game primarily capitalizes on visual stimuli; however, future iterations will aim to enrich the sensory experience. Further development will focus on integrating tactile feedback through sensors that can deliver vibratory cues during user errors and more lifelike simulations of biological interactions through varied pulse patterns. The auditory aspect of the game will also be enhanced to augment the visual depiction of oceanic environments.

Moreover, the game will be designed to monitor physiological responses, provide bidirectional feedback, and log potentially hazardous data. Recognizing the potential for diving simulations to trigger phobias such as squalophobia or thalassophobia, we are exploring the integration of tasks that align with Virtual Reality Exposure Therapy (VRET) protocols. These tasks are intended not only for skill training but also to assist players in confronting and overcoming their fears to the greatest extent possible. Through these advancements, "SubmergeShots" will serve as a training tool and therapeutic platform, offering a comprehensive mental and physical approach to underwater exploration.

References

[1] Azzurro, E.; Broglio, E.; Maynou, F.; and Bariche, M. 2013. Citizen science detects the undetected: the case of abudefduf saxatilis from the mediterranean sea.

[2] Beard, D. 2020. Longtime shark photographer urges caution, not hysteria, after fatal attack.

[3] Bruno, F.; Lagudi, A.; Barbieri, L.; Muzzupappa, M.; Mangeruga, M.; Cozza, M.; Cozza, A.; Ritacco, G.; and Peluso, R. 2018. Virtual reality technologies for the exploitation of underwater cultural heritage. *Latest developments in reality-based 3D surveying and modelling* 220–236.

[4] Chung, S.-s.; Au, A.; and Qiu, J.-W. 2013. Understanding the underwater behaviour of scuba divers in hong kong. *Environmental management* 51:824–837.

[5] Currie, B., and Göttert, T. 2023. The value of photography in science and education: Photography through the lens of two scholars.

[6] De Brauwer, M.; Saunders, B. J.; Ambo-Rappe, R.; Jompa, J.; McIlwain, J. L.; and Harvey, E. S. 2018. Time to stop mucking around? impacts of underwater photography on cryptobenthic fauna found in soft sediment habitats. *Journal of environmental management* 218:14–22.

[7] Harasti, D., and Gladstone, W. 2013. Does underwater flash photography affect the behaviour, movement and site persistence of seahorses? *Journal of Fish Biology* 83(5):1344–1353.

[8] Mahmoud, K.; Harris, I.; Yassin, H.; Hurkxkens, T. J.; Matar, O. K.; Bhatia, N.; and Kalkanis, I. 2020. Does immersive vr increase learning gain when compared to a non-immersive vr learning experience? In *International Conference on Human-Computer Interaction*, 480–498. Springer.

[9] Martínez, A. 2014. "a souvenir of undersea landscapes:" underwater photography and the limits of photographic visibility, 1890-1910. *História, Ciências, Saúde-Manguinhos* 21:1029–1047.

[10] Morales, R.; Keitler, P.; Maier, P.; and Klinker, G. 2009. An underwater augmented reality system for commercial diving operations. In *OCEANS 2009*, 1–8. IEEE.

[11] News, W. 2011. Local underwater filmmaker says most shark attacks are provoked.

[12] Raoult, V.; David, P. A.; Dupont, S. F.; Mathewson, C. P.; O'Neill, S. J.; Powell, N. N.; and Williamson, J. E. 2016. Gopros™ as an underwater photogrammetry tool for citizen science. *PeerJ* 4:e1960.

[13] Wilson, C. J.; Soranzo, A.; et al. 2015. The use of virtual reality in psychology: A case study in visual perception. *Computational and mathematical methods in medicine* 2015.

Authors Biographies

Yiting LIU is an interaction design and user experience designer based in Sydney and Shandong. She is now a graduate student majoring in Interaction Design and Electronic Arts at the University of Sydney, obtaining her bachelor's degree from the University of Queensland, majoring in Information Technology.

Mengyao GUO is an award-winning Artist, Illustrator, and Graphic Designer based in Shenzhen and Macau. She is an assistant professor at Shenzhen International School of Design and Harbin Institute of Technology and a Ph.D. candidate in visual communication at the University of Macau.

Ze GAO is an artist and researcher based in New York and Hong Kong. He studied Multidisciplinary Fine Arts at the Maryland Institute College of Art and held an MFA in the School of Visual Arts in New York. With a background in art and technology, his research spans different practices and interests, including AI-generated content, virtual reality museum, interaction design, and human-computer interaction.