



## ADVERTISING CORAL REEFS WITH UNDERWATER PANORAMAS: AN APPLICATION STUDY ON PRESENTING INFORMATION TO PROSPECTIVE DIVERS

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# ADVERTISING CORAL REEFS WITH UNDERWATER PANORAMAS: AN APPLICATION STUDY ON PRESENTING INFORMATION TO PROSPECTIVE DIVERS

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Key words: marine tourism, tour knowledge, dive information, panorama.

## ABSTRACT

This paper describes the development and empirical practice of the underwater panorama system at two landmark dive spots at Green Island, Taiwan. Recreational scuba diving has become popular on coral reefs. Information highlighting dive spots can assist prospective customers with selecting their dive destinations. Underwater panoramas are a new approach for presenting such tourist attractions. The system's hardware includes a tailored cylindrical housing containing a spherical digital video camera. Its panoramic images enable people to come closer to the real underwater world. Footage can be viewed using PCs, laptops, tablets, and other common digital viewing appliances. The imagery streams give visitors a spherical preview of the underwater world at a specific dive spot. In a still panoramic image, the underwater features of the dive spot are supplemented with location-based service and tourist information, thereby presenting a rapid reference to potential viewers.

## I. INTRODUCTION

Coral reefs constitute a highly diverse environment offering various habitats for countless marine organisms. Clear water and spectacular underwater scenery attract many tourists who swim over reefs to observe coral, invertebrates, and colorful fish (Milazzo et al., 2006; Meisel-Lusby and Cottrell, 2008;

Uyarra et al., 2009). Recreational scuba diving has become one of the most popular activities on coral reefs (Davis and Tisdell, 1995; Hawkins et al., 2005; Buzzacott, 2008). Tourist divers gain a great level of satisfaction while enjoying astonishing scenery and interacting with underwater wildlife (Mundet and Ribera, 2001; Orams, 2002; Cater, 2008; Heyman et al., 2010; Stoeckl et al., 2010). The dive industry is prosperous in many coral-reef coasts (Davis and Tisdell, 1995; Buzzacott, 2008; Garrod and Gössling, 2008). A maritime destination has several underwater attractions, and each has its own characteristics (Yang et al., 2008; 2011; Nash and Chuk, 2012). Tourist vacation time is limited, making it logistically difficult to visit all available dive attractions. Dive spot information therefore becomes essential in helping prospective customers select dive destinations and arrange vacations.

Tourists remember much of the tour information that they acquire over multiple experiences at a given destination. Furthermore, information can be found in external sources that include magazines, guidebooks, travel programs, authority council publications, consultation with friends and relatives, travel agents, and the Internet (Bieger and Laesser, 2004; Cai et al., 2004; Roussou, 2004; Hyde, 2008; Liburd, 2012). Information is commonly presented by textual descriptions along with pictures, flash, animation, or video. If the information either comes to a prospective customer's notice or gets closer to authentic experiences, tourist divers find it easier to choose suitable dive spots.

The panorama is an alternative way of visually presenting information about tourist destinations. Panoramic images assist users in viewing and navigating real world landscapes. In comparison to the images captured by a camera with a normal lens, panoramas have elongated fields of view and are usually employed in vacation marketing. Using this technology to present a destination can trigger customer awareness (Osman et al., 2009). Using the Internet in combination with rapidly developing communication and information technology such as Web 2.0 applications and location-based services, destination panoramas are becoming more advanced. Not only can an attraction's landscape be presented, but location-based

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services and local knowledge can also be contained in a panorama. Web-based digital panoramic content can be viewed using PCs, laptops, and mobile devices like tablet PCs and smartphones. A contemporary panorama provides the customer a modicum of convenience while making vacation arrangements. Furthermore, it generates value and drives changes in the tourism industry; e.g., virtual tours (Govers et al., 2007; Osman et al., 2009; Yan et al., 2009; Guttentag, 2010; Liburd, 2012; Tussyadiah and Zach, 2012).

Providing an underwater panorama of coral reefs is an altogether new approach (Chen et al., 2012; Marks, 2012), and is not just an application to tourism. In this study, the authors used panoramic photography to capture scenes of dive spots for the purpose of providing dive information. Two hot dive sites, “Big Mushroom” and “Longfin Batfish School,” at Green Island, Taiwan, were used as examples. Three functions were contained in the panorama by (1) acting as a traditional tourist information map showing dive tour service locations, (2) providing location-based service information about Green Island Airport, Nanliao Port, Green Island Visitor Center, hotels, home stays, restaurants, dive centers, and dive spots, and (3) transmitting knowledge about underwater animals, thus giving tourist divers a greater level of satisfaction when interacting with underwater wildlife. Brief information on a few particular species was also offered, for example species name, distribution, and ecological characteristics.

## II. MATERIALS AND METHODS

### 1. Methodology

To put the underwater panorama idea into practice, the authors mainly followed “Design Processes,” which is a multi-step methodology for problem-solving in or performance-improvement of an activity (Fig. 1) (Takeda et al., 1990). The step, “Suggestion,” is to identify potential solutions that can be drawn from existing knowledge. An attempt at implementing an activity according to a selected solution is the “Development” step. Implementations are then evaluated and shown in “Evaluation.” The Development and Evaluation steps are frequently iteratively performed during the design effort, during which new knowledge is generated and accumulated. This knowledge is used to create new works that are evaluated to accumulate further new knowledge. The partial completion of the cycle back to the “Awareness of the problem” step is indicated by the “Circumscription” arrow. The “Conclusion” means the termination of a project design process (please refer to the left side of the dashed line in Fig. 1).

For evaluation under the Design Processes methodology, our underwater panoramic design efforts were modified and proceeded as follows (Fig. 1, right side of dashed line):

(1) Creative way of presenting information – When prospective tourist divers make vacation arrangements, information on the dive destination is essential. It is commonly presented by text in combination with gorgeous images, and is

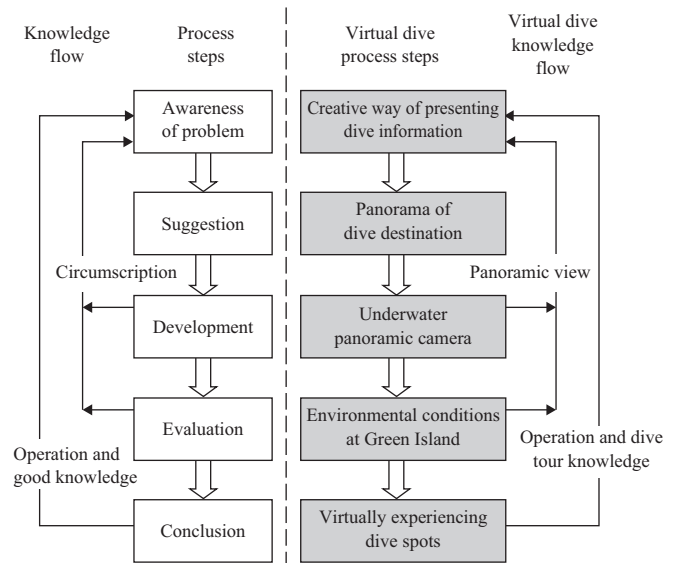


Fig. 1. The left side of the dashed line represents the “Design Processes” Methodology. The right side of the dashed line depicts the process as modified for its application to the underwater panorama concept.

available in various publications and websites. Information provided in a creative way may arouse more customer interest and increase motivation to visit the destination. In comparison with traditional text descriptions and local photos/videos, a very-wide-angle representation of the physical space is better able to introduce the entirety of a landscape’s scenery. Embedding 360° panoramic tours within a website allows visitors to easily view the sights and experience a strong immersive feeling that will arouse their interest in going diving.

(2) Dive destination panorama – Underwater panoramic images showing divers surrounded by fish above coral reefs in clear seawater can produce the effect of a closer relationship between humans and nature. The panoramic view is not just a broader image. Based on the development of the Internet, instant communication, and information technology, modern panoramic technology offers more functions. The destination’s panorama may include the location of the dive site, identification of location-based services, and tour information, all being easily accessed by many display systems. In comparison to traditional types of information, the underwater panorama offers customers a different point of view for experiencing dive spots using a virtual display.

(3) Underwater panoramic camera – The concept of capturing underwater panoramic scenes is new. Equipment includes a spherical digital video camera with a tailored waterproof housing. It appears similar to a regular digital camera (with housing) commonly used by tourist divers, but is far more complex. The camera is a pentagon prism. Each of the five vertical sides and the sixth, sky-oriented horizontal side has a separate lens. Images captured by the six lenses are stitched together with image warping, automatic alignment, and image blending functions to produce a panorama. The



**Fig. 2.** Big Mushroom dive spot (left), one of Green Island's famous underwater scenic spots, is an isolated reef supporting a very large coral colony on the reef top. Longfin Batfish School (right) is also a well-known scenic spot, with this image showing an interaction between divers and several batfish.

original images determine the quality of the panorama, and the tailored housing was designed to ensure that the camera would perform well while capturing images. The housing that was constructed for the spherical digital video camera is innovative.

(4) Environmental conditions at Green Island – There are no existing lighting modules suitable for the camera housing. Seawater clarity and sunlight conditions determine whether the creatures appear dimly or brightly, influencing image attractiveness. Green Island waters dominated by Kuroshio currents remain warm and clear all year round. In comparison to other maritime destinations, the sediments, nutrients, and other pollutants from terrestrial runoff do not significantly reduce water clarity, allowing sunlight to penetrate into deeper waters. These conditions make Green Island ideal for camera use and result in one of the most popular dive destinations around Taiwan, and thus it was the authors' first choice for the experiment.

(5) Virtual experiences at dive spots – The images of a wide variety of creatures as well as their interactions with divers are captured and displayed by the panorama. This vibrant information opens a window for prospective customers through a virtual experience. In addition, wildlife information, dive spots, dive centers, and the tourist information center are available in panoramic views. The underwater panorama is therefore very helpful to customers making dive vacation plans.

## 2. Study Sites

Green Island is near the southeast coast of Taiwan. Its waters are dominated by the Kuroshio current, which is warm and clear. Coral reefs and associated creatures are abundant (Yang et al., 2008; Chen et al., 2009; Huang et al., 2009). From a giant coral colony to artificial reefs, from schooling batfish to individual pigmy seahorses, from the path between cliffs to the sunken ship, the island's fantastic underwater attractions and amazing creatures lure countless tourist divers (Soong et al., 1999; Chen et al., 2009; Yang et al., 2011; Chen et al., 2012). Green Island has become an important dive destination of Taiwan. Two landmark dive spots, "Big Mushroom" and "Longfin Batfish School," were selected for panoramic photography. The former is an isolated reef having a very large poritid colony on the reef top (Fig. 2, left image) (Soong et al.,



**Fig. 3.** Undersea panoramic photography equipment included a laptop, spherical digital video camera, cylindrical waterproof housing, and IEEE-1394b cable.

1999), and its fish assemblages are remarkable. The latter site is renowned for harboring schooling longfin batfish, *Platax teira*, which are characterized by an ovate and laterally-compressed body, elongated dorsal and anal fin rays, and dark bars through the eyes and behind the head (Fig. 2, right image). Tourist divers gain satisfaction through observations and interactions with this and many other fish species.

## 3. Equipment and Operation

Field work at Big Mushroom Coral Reef and Longfin Batfish School was done on November 1, 2011, the sites being accessed by dive boat. The main equipment included a spherical digital video camera, waterproof housing, signal cable (20 m long), and laptop equipped with a GPS receiver (Fig. 3). One person remaining on the dive boat was responsible for monitoring and recording images via the laptop. The camera was operated by three scuba divers. Captured digital images were transmitted with a IEEE-1394b cable and stored on the laptop, which contained software for managing image acquisition, spherical and panoramic image production, and camera settings. In consideration of budget, maintenance, and durability, the idea of using pentagon prism housing was abandoned in favor of a cylindrical housing having better resistance against rough usage that could cause housing deformation and leakage.

The equipment can deliver 12 megapixels of high-resolution visual images at 15 frames per second, covering more than 80% of a full sphere. The images were rendered into a multimedia computer's digital space by the sphere panorama method. The sphere panorama reflected scenes at any direction in space including above and below the camera. We then created flash virtual tours with a walkthrough effect from the spherical panoramic images. To connect the individual scene images, a GPS receiver was applied in conjunction with the spherical video camera to record GPS data with stream files and to integrate with Google map files. GPS data were used to



Fig. 4. The sphere panorama was offered to the prospective customers in immersive view by a desktop display system.

locate the scene on a Google map. Users would then know the physical location where the photograph was taken, allowing the virtual tour to be more interactive. Consequently, it could be offered to users in an immersive display (Fig. 4). The panoramic images and videos could be downloaded from the internet and viewed on the user's computer. In addition, the authors developed an interface that users could easily access with a high level of control over the computer-mediated environment. An object-oriented database was developed to store tourism information and local knowledge. Tourism information and local knowledge were optionally provided according to the individual's interests and concerns. Customized functions were also prepared for virtually experiencing dive spots through user engagement.

### III. RESULTS

#### 1. Still Panoramic Images

The experimental panorama provided an alternative way of presenting to prospective customers a virtual experience of dive information for use in making vacation arrangements. Information about transportation, accommodation, dive centers, and dive spots for a dive tour were included and presented by either still panoramic images or videos. Here, the panorama was extended from the spherical to a planar view for explanations (Figs. 5, 6, and 7).

Information was primarily displayed in still panoramic images. Two rows of buttons were shown at the tops of the still images. The first row contained eleven buttons (Fig. 5), from left to right respectively functioning as (1) previous panorama, (2) zoom in, (3) zoom out, (4) shift left, (5) shift up, (6) stop, (7) shift down, (8) shift right, (9) home image, (10) full screen, and (11) next panorama. In the second row, ten



Fig. 5. Modern panorama revealing location, location-based services, and tour information. This example using the Green Island Visitor Center shows the application of the panorama on land. The authors developed an interface to give users an easy access to and a high level of control over the computer-mediated environment. The functions for access and control can be customized.

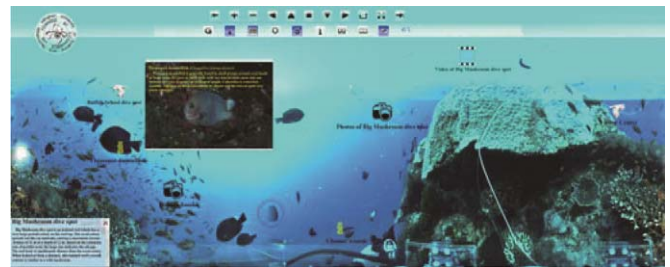


Fig. 6. Underwater panorama of the Big Mushroom dive spot.

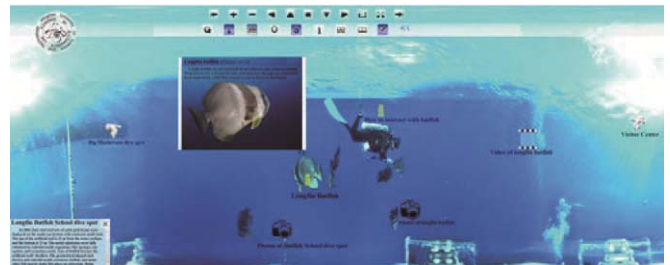


Fig. 7. Underwater panorama of the Longfin Batfish School dive spot.

buttons functioned to toggle various options on/off (Fig. 5), including (1) on/off flash game, (2) on/off first row, (3) on/off planar picture related to the current scene, (4) on/off all symbols on the image, (5) on/off a window of brief information in the lower left corner, (6) on/off user instructions, (7) on/off other panorama, (8) on/off panoramic video, (9) on/off hand-painted map of the spot, and (10) on/off Google map.

The panorama's location was indicated by an inset map in the lower right corner. The tour services and scenic spots labeled on the map could be clicked and the target panorama then viewed. Fig. 5 depicts the Green Island Visitor Center as an example. The symbol "i" reveals information about the closest object, for example a building. Brief information describing the visitor center is located in the window at the lower left corner of the image. After clicking the left "camera" symbol above the visitor center, a plan-view picture of an indoor scene is shown in a quick window.

A panorama of the Big Mushroom dive spot is shown in Fig. 6. The present scene was captured by scuba divers lifting the camera above their heads and staying 2 m away from the coral colony in the water column. The featured giant poritid colony, nearby acroporid corals, and numerous fish were revealed. A short vignette about the damselfish was accessed by clicking the closest “i” symbol, resulting in a window popping up that contained a picture and textual description of the species (Fig. 6). When clicking the “film” symbol, the video of the closest object can be watched in a window.

The panorama of Longfin Batfish School is demonstrated in Fig. 7. The disk body shape and dark bars of the batfish are apparent, and an interaction between a diver and a fish is presented. Information about the batfish was accessed by clicking the “i” button. Pictures and videos could be viewed by clicking “camera” and “film” icons.

## 2. Panoramic Video

In comparison to still images providing information and knowledge, panoramic video presentations have no interactive symbols but reveal lively wildlife and clear waters. They can generate a simulated sense of being at the spot (Fig. 4), as active creatures in panoramic videos present authentic situations (<http://120.105.97.242/greenisland/>).

## IV. DISCUSSION AND CONCLUSIONS

Tourism information often influences customer vacation plans. Content such as magnificent images or emotive words can emotionally connect customers to a destination’s story and then influence prospective customer purchasing decisions (Liburd, 2012). Panoramas employed to present land tourist attractions are becoming popular. Their information content can lure tourists and has been empirically evaluated (Guttentag, 2010). Panoramas are an alternative way to highlight the characteristics of a destination and allow viewers to virtually experience scenic spots. With the application of the Internet in combination with the rapid development of communication and information technology, the functions of panoramas are growing. In this study, the authors developed underwater panoramas to present two dive spots. Panoramic images transmitted local knowledge and contained the locations of service facilities and dive spots, and panoramic videos provided the virtual reality of the dive spots. The scenes of either the giant poritid colony or numerous fish on Big Mushroom dive spot were successfully captured. The batfish’s dark bars and interactions with a diver on Longfin Batfish School dive spot were also presented.

These presentations are expected to enhance the situational awareness of prospective customers and provide the highest level of functionality while viewing the essence of the attraction. The validity of underwater panoramas is waiting to be examined. In this study, the authors propose the practicality of using panoramic technology to introduce dive spots to prospective customers. If this is carried out in a formal marketing

promotion, we suggest that attractions be photographed in the order that visitors would encounter them when following the underwater trails prepared for commercial dive trips provided by dive centers. Photography at each dive spot should focus on the individual traits of that spot in order to show the variety of underwater scenes that a visitor could enjoy at that destination. These digital contents would be deployed in a destination’s website for tourist access and use.

The value of our work has been confirmed by the Google underwater street view project, released in September 2012 (Helmreich, 2011; Musil, 2012). Although Google’s project has affluent financial and technological resources, our solutions for developing underwater panorama websites have the strengths of (1) low cost hardware and software (< US\$30,000), which is obviously superior to Google’s expenditures; (2) fast deployment, needing only three persons and only 30 min to prepare for the field works; (3) modularized equipment has the advantage of easier and cheaper maintenance and repair; (4) our website offers panorama video to visitors in addition to still panorama images, and by sharing them through the internet we hope to generate interest and awareness that will encourage their motivation to visit; and (5) local knowledge hotspots can be added into the panorama, making our panoramic tours more informative and enjoyable.

The cylinder housing was an innovative piece of equipment for the six-lens camera. We were originally concerned that, because the spherical digital video camera was designed for terrestrial environments, flaws from distortion would occur when underwater scenes were captured through the “filters” of seawater, curved acrylic cylinder walls, and the water-air interface. Fortunately, images captured by the five vertical lenses were stitched together successfully, primarily because the site’s seawater was uniformly clear and blue. Colors blended very well during the stitching process because they were almost identical between adjacent images. Some interesting artifacts were shown on image-overlaps, however, when fish were at the edge of the field of view. In these events, a part of the fish’s image would be repeated on the flanking image by the stitching software (Fig. 6, the circle). The high mobility of the reef fish made such outputs very rare, however.

Some flaws in this system need improvement. The horizontal sky lens received direct sunlight that resulted in over-exposures, whereas images captured by the vertical lenses were consistently blue; therefore, stitching was unable to smoothly blend sky and water. A circular contour is apparent in the images (Figs. 6 and 7), and the hard light gives viewers an uncomfortable visual feel. To solve this problem, a graduated neutral density filter for reducing sunlight could be deployed on the sky-facing lens.

Recently, virtual tours simulating or shooting the reality of an existing destination through a sequence of video images has rapidly developed (Ray et al., 2011; Tussyadiah and Zach, 2012). It can be presented by photographic-based media or a panorama with an unbroken view. Such online tourism generates the experience of a virtual world and provides a

wider range of prospective customer choices. Therefore, panoramic content could become part of Green Island's virtual tour and be enjoyed remotely by distant customers through PCs, laptops, and Tablet PCs (Li et al., 2001; Hyun et al., 2009).

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