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Virtual reality for showcasing sustainable engineering design

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Abstract. One of the goals of national parks is to promote sustainable development and environmental education. This paper presents a study to further the goal by demonstrating the value of virtual reality and augmented reality in the construction of a FRP (Fiber Reinforced Polymer or Plastics) pedestrian bridge in Taiwan’s national park. The purposes are three-fold. First, the bridge serves to educate visitors about the infrastructure of the park. Second, it attracts the attention of the public and raises interest in conservation and sustainability. Third, it allows to showcase sustainable engineering design with the latest virtual reality technology. The example described in this paper is based on the same principles of e-learning and mobile learning. The experience is valuable in encouraging and promoting tourism opportunities and sustainable resource use in national parks.

1. Introduction
National Parks of Taiwan have been in existence since 1984. Sharing the same vision as the conservationist John Muir, Taiwan established nine national parks throughout Taiwan and its affiliated islands, accounting for 8.63% of the total land area [1]. As indicated by the Construction and Planning Agency of the Ministry of the Interior (Taiwan), the goals of the national parks are [2]:

(i) to protect the natural environment,
(ii) to preserve species and genes,
(iii) to provide public recreation while developing the local economy, and
(iv) to promote academic research and environmental education.

To reach these objectives, construction activities in the national parks usually require an environmental impact assessment or special permits to protect environmentally sensitive areas. Man-made structures in the parks are required to perform multiple functions. Aside from their structural purposes, the structures need to be visually non-intrusive to the surrounding environment, and provide educational values. Construction materials should be specially selected and be compatible and harmonious with the surrounding areas. For example, the District of Columbia Water and Sewer Authority (DC Water) used fiber reinforced polymer (FRP) composite material to retrofit an eroding sewer pipe on US NPS land [3]. DC Water’s decision to select FRP not only solved the environmental issues, but also cut cost and construction time significantly.
2. Materials and Methods
Taijiang National Park is located on the southwest shoreline of Taiwan (in greater Tainan city). It consists of mainly coastal areas and wetlands filled with abundant wildlife resources and cultural significance. To no one’s surprise, four wetlands in the Taijiang National Park were decreed as protected areas of national and international importance to protect the wetland’s biodiversity: Zengwen Estuary Wetland, Sicao Wetland, Qigu Salt Pan Wetland, and Yanshui Estuary Wetland (using the standard English translations used by Taijiang National Park). Among them, the Zengwen Estuary Wetland and Qigu Salt Pan Wetland are famous as winter habitats of the globally endangered black-faced spoonbills (*Platalea minor*). In recent years, there has been a marked increase in interest in wildlife observation (such as bird watching) in national parks, and ecological tourism is on the rise. One famous location frequented by visitors is the Qigu lagoon in the Qigu Salt Pan wetland. The Qigu lagoon is an inland sea surrounded by sandbanks. It is the largest in Taiwan and is made famous for its oyster stands and the fixed fishing nets in the lagoon. Visitors can take a guided raft tour in the lagoon and visit the nearby saltponds. As pointed out by Zorrilla-Pujana and Rossi [4], it is important for national parks to use environmental education to move from the mere creation of protected areas to the effective management of the protected areas, at the same time satisfying the needs of both people and nature. To preserve the wetland ecosystems and promote environmental education, the Taijiang National Park Management Office established the Taijiang Wetland School in 2012, greatly enhancing their education outreach program [5].

2.1. Description of the Bridge
The Taijiang National Park has a total area of 39,310 hectares, among which 34,405 are shallow seas [6]. The FRP pedestrian bridge is located near the Liukong Service Station and Visitor Center, south of the Qigu lagoon. It is ideal for serving as an example to test environmental compatibility and public education. First, the material is unique. Unlike traditional construction materials, FRP is resistant to corrosion brought about by local high humidity and high chloride in the air. Second, the guidelines of national parks prohibit unwarranted construction, and structures in the parks should be long-lasting to avoid excessive repairs and renovation. In that regard, the long-lasting nature of FRP and its easy installation (usually by manual labor) suits the national parks very well. Therefore, the use of FRP to replace traditional construction materials such as reinforced concrete in national parks and environmentally sensitive areas should be encouraged.

Aside from the FRP material, the pedestrian bridge itself also serves multiple functions.

2.2. Construction of the Bridge
The FRP pedestrian bridge is located south of the Qigu lagoon dike. It was analyzed by a Finite Element software for allowable deflections and installed at the site in 2012 [7], but so far the bridge does not appear on Google Maps, which is used by the Taijiang National Park to show the general public how to arrive at the park. As can be seen from Google Maps, quite a few channels and waterways pass through the area. The pedestrian bridge is an essential crossing for people visiting the Liukong Visitor Center and the lagoon. It is conceivable that endemic amphibians and other small animals could use the bridge as a corridor to move between habitats during the night. How wildlife uses the bridge as a corridor necessitates a new study. One additional benefit from the introduction of the FRP bridge is that people learn more about FRP material and how it can be used to retrofit damaged buildings, a need exemplified by frequent earthquake occurrences in Taiwan. Since the pedestrian bridge was built with FRP, it avoided usage of heavy machinery and reduced the ecological footprint.

3. Results and Discussion
As has been noted in previous sections, the role of national parks has shifted from establishment to management and education. To satisfy the shifting needs of the Taiwanese public, national parks should encourage and promote tourism opportunities and sustainable resource use. Putting part of the
parks online is a good first step. The process of placing the FRP bridge in virtual reality (VR) comprises several stages. First and foremost, a computer model of the bridge (and the surrounding area) needs to be built. Then the model needs to be imported into an immersive virtual environment. For visual display purposes, the model needed is not the same as the one previously used in the Finite Element analysis. We chose SketchUp for this task and created a replica of the FRP bridge in virtual space. The model bridge allows views of multiple perspectives. The purposes are twofold. First, the bridge serves to educate visitors about the infrastructure of the park. Second, it attracts the attention of the public and raises interest in conservation. In some circumstances there is even a third function, which is to showcase sustainable engineering design. Deformation diagrams obtained by the Finite Element analysis can be overlaid onto the surface of the model bridge to show the stress-strain relationship. Interested persons can view the model to examine the structural behavior from different perspectives, assuming the bridge is subjected to the specified loading condition.

3.1. Immersive Virtual Reality Display

Notice that the FRP bridge has a minimal design and non-intrusive profile. To assess the compatibility of the bridge with the environment, we examine the bridge model in virtual reality with its surrounding area (also with the Liukong Service Station and Visitor Center). The bridge model has excellent details, including posts, guardrails, balusters, edge beams, bridge decks, a wheelchair ramp, and an information board. To further enhance the appearance of the model bridge, which was essential as a tourist attraction and public education ([8], [9], [10], [11]), we added textures closely matching the real FRP to the model, and pasted high resolution photographs onto the information board at the entrance of the bridge. Viewers can read the text and see the figures on the information board without any difficulty. This was an important component of a successful 3D immersive exhibition. Finally, the bridge model was imported to Sketchfab for future 3D printing (if needed).

The FRP bridge was built to minimize its impact on the environment and to emphasize its adherence to the landscape ecological principle. For everyone to see the results and to deliver them in a timely manner, we put the bridge model on display in a 3D immersive virtual environment. This action highlights our emphasis on the material selection and bridge design. Compared to mere design drawings or photographs, the novelty in this contribution is the use of VR in the process of viewing, interpretation, and discussion. For this particular project, the FRP bridge has already been built. The VR model adds to the value of a real and functional bridge. For other projects, in which the structures have not been built, VR models could be used beforehand to assess whether the structures are environmentally compatible or not, and whether some of the placement and configurations are optimal or not. This increases the value returned by creating a virtual model.

To view VR models, computer screens are not the best choice. In the past few years, big tech companies such as Facebook, HTC and Samsung have all released VR helmets or goggles that can be worn to experience VR. The only problem is that these devices are too expensive. A low cost alternative solution for VR viewing is the Google Cardboard, the design for which was released by Google, and it has evolved into many derivative designs on the market. Users can acquire the material they need with little money and assemble a VR goggle. When the FRP bridge is viewed with a Google Cardboard, details of the bridge are preserved. Viewers can turn their heads to see different angles of the bridge or turn around to see their environment (figure 1). They may also pretend to visit the park and stand in front of the information board. The text and figures on the information board can be viewed clearly in virtual reality. It is as if they were at the national park, which is a true immersive experience that has high educational value and attracts tourist attention.

3.2. Augmented Reality and Mobile Display

Virtual reality is not the only thing that one can experience with the bridge model. Without wearing a VR goggle, users can still see the bridge and its surroundings on any surface using a mobile device such as a phone or a tablet. This is accomplished by augmented reality (AR). Using a specially designed AR tag for the bridge, the bridge will come to life and show up on the screen of the mobile
device when the device is pointed at the AR tag (figure 2). The viewer can rotate the bridge to see and examine different perspectives. They can also see more or less details of the bridge by pinch zooming in or out of the model. This AR viewing works on various surfaces such as the pages of a book, fliers, posters, and stickers. It is fun for education and a great supplement to courses such as those at the Wetland School.

![Figure 1](image1.png)

**Figure 1.** Conceptual illustration of viewing the virtual FRP bridge using a Google Cardboard.

![Figure 2](image2.png)

**Figure 2.** Conceptual illustration of augmented reality display using a mobile device.

### 4. Conclusions

In this study, a 3D model of the FRP bridge and its surroundings was built. Realistic details were preserved, including structure members of the bridge and an information board. Using VR goggles, visitors can tour the bridge in virtual reality. The experience is lifelike and the viewer can even read the text on the information board. In addition to 360 VR immersion, the FRP bridge model can also be displayed on any surface using AR. The viewer can rotate the bridge to see and examine different perspectives, or see more or less details of the bridge by pinch zooming in or out of the model. This is a great method of disseminating structural and material knowledge to a wider audience. It shows that
substantial educational value can be returned from creating a bridge model alone. Simply stated, placing a bridge in VR is every bit as important and useful as placing it in a national park. It should be considered by national park authorities.

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