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Characterizing the Digital Design Patterns Bio-Inspired by Mangrove Species

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Abstract

Forty different mangrove species found their home in Sungai Merbok, Sungai Petani, Kedah, the highest among other mangrove ecosystems in Malaysia. This region is notable for its magnificent landscape and also rich environment, which the United Nations have recognised as one of the world's few significant biospheres. However, several species, particularly in Merbok, are threatened. Therefore, the objective of this project is to identify the mangrove species as the main bio-inspiration for the digital design patterns and to provide awareness of mangrove preservation and environmental sustainability. This research used an approach of pragmatic qualitative analysis to achieve the research outcomes.

Keywords: Bio-inspired; Digital Design; Mangroves; Pattern

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1.0 Introduction

Sungai Merbok, Sungai Petani, Kedah is home to forty distinct mangrove species, the most of any mangrove ecosystem in Malaysia. The United Nations has recognised this region as one of the world's few significant biospheres, in addition to its magnificent landscape and rich environment. Nevertheless, a number of mangrove species, particularly in Merbok, are threatened; three of the mangrove species are currently considered to be critically endangered. With the present flood disaster that has afflicted Malaysia towards the end of 2021, this factor may be compelled to dig deeper and raise awareness about the importance of environmental preservation. It is critical to draw attention to this issue since it is a component of our responsibility to safeguard the environment. Therefore, the objective of this project is to identify the mangrove species as the main bio-inspiration for the digital design patterns. The identified design features of mangroves will be transformed into a digital design pattern. The methodology for this project is based on artistic design approaches that are derived into five phases begin with descriptive study through review of related studies as to paradigm with research strategy and framework; bioinspired study through observation and studies on mangroves species; design protocol into digital patterns development; and design analysis on categorisation and typology matrix documentation outputs of this project. This project discusses how typology matrixes and digital design patterns will be developed via various mangrove species' original sketches. It is estimated that hundreds of mangrove patterns will be constructed, and a chronicle of documentation of bioinspired patterns as well as a conceptual framework. The inspiration of mangrove species contributed impactful Malaysia's art and science avenue in bio-inspired approaches. This study will contribute to the fundamental knowledge in characterising methods for stakeholders to refer to sustainability and environmental preservation awareness.

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1.1 Problem Statement and Research Context

As reflected by the current scenario, several mangrove species, particularly in Merbok, are threatened, where three of the mangrove species are currently critically endangered (the species are: Sonneratia griffithii, Bruguiera hainesii, and Heritiera fomes). In the last decade, Malaysia's mangrove forest has shrunk due to excessive harvesting, natural wave action, and conversion of mangrove forest to other land uses, mainly for aquaculture and agriculture, which has estimated a loss of around 1.9 million ha since 1980 (Omar, Misman, and Linggok, 2018). It is crucial to draw attention to this issue since it is a crucial component of our responsibility to safeguard the environment. Moreover, this issue is essential in promoting public awareness since mangroves protect maritime environments' ecosystems (Latiff and Faridah-Hanum, 2014; Omar, Misman, and Linggok, 2018). Mangrove forests have a bad reputation due to perceived environmental disservices, such as being home to dangerous animal species and disease vectors (Friess et al., 2020). While this is meant as a rebuttal to initial unfavourable impressions of mangroves, such framing to capture the attention may have unforeseen repercussions for, or damage, future conservation efforts (Dahdouh-Guebas et al., 2020).

The current flood calamity afflicting Malaysia at the end of 2021 makes us obliged to dig deeper and raise awareness about the need for environmental preservation, protection, management, and restoration (Awang, 2021; FMT, 2021; Mamat, 2021). Indeed, it is vital to promote awareness about sustainability and the importance of environmental preservation. There is no detailed documentation or studies on the inspiration of mangrove species. There has been little innovative research in the art and design fields, particularly in bio-inspired design that depicts natural mangrove species and nature in depth. The vast collection of mangrove species in Sungai Merbok is mainly one of the grounds for investigation, research, and recommendation that the area is designated as one of the national heritage sites in Malaysia (and other mangrove reserves in Malaysia, as well). The vast species diversity of mangrove plants may contribute to the possible investigation and development of a more extensive range and variety of design patterns and motifs. Because of the unusual, various characteristics and the abundance of mangrove species, this plant was chosen as the primary source of inspiration. Indeed, the characteristic mangrove matrix species of bio-inspired digital design patterns will be established.

1.2 Research Aims

This research project aims to identify and select the significant features of mangrove species in the development of the bio-inspired digital design patterns and matrixes, analyse and design the mangrove matrix features into a digital design pattern, and finally construct the mangrove species conceptual framework and matrix categorisations.

2.0 Literature Reviews

It is important to situate the digital design patterns within the topics of bio-inspired design followed by the general background of mangrove species.

2.1 Background of Mangrove Species

Mangroves are the most impressive colonisers, referring to a diverse range of plants along the sea's edge (Spalding, Kainuma and Collins, 2010). Ong and Gong (2013) defined mangroves as a class of vascular plants that have evolved particular morphological, physiological, and other non-visible adaptations to thrive in a salty intertidal environment dominated by low dissolved oxygen or, in some cases, anoxic fine sediments. According to WWF (2018), a mangrove is a kind of plant that grows near rivers or beaches and has a distinguishing root. The mangrove ecosystem is made up of these plants and their accompanying microbes and animals. As a result, the name mangrove applies to both the plants and the environment. Mangroves serve a vital role in the maritime environment by providing habitat for a diverse range of animal species, including birds, fishes, reptiles, amphibians, and mammals. Spalding, Kainuma, and Collins (2010) discovered 73 species of pure and hybrid mangroves worldwide, categorising them as Indo-West Pacific species and Atlantic East Pacific species.

There are at least 20,533 hectares and 17,185 hectares of permanent forest reserves in the state of Kedah, including mangrove forests in the Kisap Forest Reserves, Air Hangat Forest Reserves, Langkawi's Pulau Dayang Bunting Forest Reserves, and Merbok Forest Reserves (Aldrie and Latiff, 2006). Merbok Forest Reserves is located in Kuala Muda and encompasses a total area of 3,085.9 hectares, making it the second-largest mangrove forest in West Malaysia after Larut Matang Forest Reserves in Perak. Aldrie and Latif (2006), Spalding, Kainuma, and Collins (2010), and Ong and Gong (2013) conducted scientific research on mangrove species from Sungai Merbok and all over the globe. Merbok Reserves have been identified as the only location in the world where 40 out of 48 mangrove species can be found. The Sungai Merbok in Sungai Petani, Kedah, which is renowned for its magnificent beauty and rich environment, has recently become a tourist attraction with the discovery of the ancient civilization of Sungai Batu (which is a part of Bujang Valley in Merbok region). Archaeologists claim that the Sungai Batu archipelago civilization is the oldest in Asia. Moreover, the Sungai Merbok Museum and Gallery were constructed as part of the attractions, providing knowledge on the natural ecology, including mangrove species and the ancient civilization (Kedah Forestry, 2015). Dahdouh-Guebas (2020) focuses on the public's perspective of mangrove ecosystems, whereas Kazemi, Castillo, and Curet (2021) propose an optimal porosity for minimising erosion in the model of mangrove roots. In addition, Natarajan et. al (2021) studied the genome of the mangrove species Avicennia marina.

Furthermore, according to Omar, Misman, and Linggok (2018), in the last decade, Malaysia's mangrove forest has shrunk due to excessive harvesting and natural wave action. Between 1980 and 2005, global mangroves decreased from 18.8 million ha to 15.6 million ha. Human activities provide six significant hazards to mangroves: conversion to other uses, overharvesting, overfishing, pollution, sedimentation, and changing flow regimes (this encompasses urban, industrial, aquaculture, and agricultural transformations). Additionally, the current flood calamity that afflicted Malaysia at the end of 2021 should make us dig deeper and raise awareness about the need for environmental preservation, protection, management, and restoration (Asrol Awang, 2021; Astro Awani,2021; Berita Harian, 2021; FMT,

2021; Mohd Rafi Mamat, 2021; Sinar Harian, 2021). The tragic tsunami on 24 December 2004 was also one factor contributing to the decreasing mangroves in Malaysia, Asia and globally.

2.2 Bio-inspired design

Bio-inspired design refers to a design genre that is affected by life and nature, the prefix bio alludes to living beings. Cross-domain links from scientific methodologies to engineering solutions are required for biologically inspired design, incorporating other relevant domains such as design studies (Vattam, Helms, and Goel, 2012). Nature refers to the green environment surrounding us, but it does not include artificial features. According to Yeler (2015), it will be feasible to improve humanity's quality of life by incorporating nature into design disciplines through observation of occurrences and processes. Inspiration was addressed by Gonçalves et al. (2014) and Chan et al. (2015) as a way of idea creation in which the active or passive design process is carried out by engaging with any alternative surrounding form of an object. It is one of the approaches that designers must use to produce ideas. A plethora of remarkable phenomena can be learned and benefited by embracing nature. More studies on bio-inspired design and biomimicry are by Kain (2017), Wang et al. (2019), Aamer (2021), Bianciardi and Cascini (2021), Sayuti et al. (2020), Vellwock and Yao (2021) among others.

2.3 Digital Design

Morales (2020) stated that 2D or 3D digital design involves movement, such as animation, where digital designers create images for computers, phones, dashboards, and other screens. Visual communication is often related to an idea, image, or brand to enlighten and inspire the audience by conveying a significant message and also help improve brand recognition and affinity. This digitisation approach will be used to design a communication tool to inform people in the community about the value of appreciating mangroves through bio-inspired design.

Objects, images, and texts were discussed in Gonçalves, Cardoso, Badke-Schaub (2014), and Versos and Caelho (2015) validated nature-inspired design techniques. Santulli and Langella (2016) researched the creation of auxetic structural principles in bio-inspired design. A study by Tavsan and Sonmez (2015) highlighted the direct use of nature in developing ideas in furniture design and biomimicry. Zhang et al. (2019) conducted research on a new approach for automatically generating a shrub branch type shell or hollow branch sculpture, the ornamental pattern for an arbitrary 3D model. Fu et al. (2016) concentrated on redesigning 3D designs influenced by natural lines taken from photos of natural items.

These four studies are likely the most similar in terms of depicting nature in design research. Other than that, this study also could help cultivate Malaysia as a world-class tourist and cultural destination and build the national identity based on arts, culture, and heritage, which might be relevant in promoting the abundance of mangrove species in Malaysia's maritime.

3.0 Methodology

3.1 Pragmatic Qualitative Analysis

This research uses an approach of pragmatic qualitative analysis to achieve the research outcomes, aiming to answer the research questions formulated based on the previous literature reviews and observation where the researchers choose the methods deemed appropriate for this study. In this context, pragmatic knowledge refers to established principles, heuristics, and guidelines that guide the researcher's actions and conclusions throughout the assessment process (Schilling, 2006).

Furthermore, the artistic research used to develop the engagement of representation selection during digital pattern design development from the context of bioinspired design, the allegorical illustration elements from the physical beings of the mangroves, and the synthesis of design exhibited through design activities. Qualitative, according to Creswell (2002), research is an inquiry-based technique that analyses and codes data for description and themes, interprets the meaning of the data using personal reflections and history, conducts research, and publishes the final report, which incorporates personal biases and a flexible framework.

3.1 Research Phases

This study consists of five phases, please refer to Fig. 1 below:

Phase 1: Descriptive Study Related Literature: Review and Framing Research Strategy

Related literature reviews were gathered in order to make this project clearer, including definitions of terms and the species of mangroves available in the Sungai Merbok and other mangrove reserves around Malaysia. The overall research framework will visually outline the theoretical and empirical activities carried out in this research project and will be used as a guideline for this study.

Phase 2: Bioinspired Study: Observation and Studies of Mangrove Species Observation

on the types of mangroves done through site visits (mangrove reserves around Malaysia) and reading the documentation by the government agencies, institutions, and NGOs involved in the research. All of the information will be gathered, analysed, and classified to produce design patterns from the visible physical beings of the mangrove species. The findings from this phase were documented and classified in detail in matrix typologies.

Phase 3: Design Protocol: Digital Patterns Development

The researchers designed the design patterns according to the physical features of the mangrove species manually and using design

software. Researchers employed a sketching or drawing tablet and software for efficient sketching data capture throughout the sketching process. With this in mind, the original sketches are studied and developed into digital patterns by exploring the structural pattern of the visible physical beings of the mangroves. Patterns will be proposed to be developed further in digital patterns. The patterns were originally based on the physical beings of the mangrove leaves, fruits, flowers, roots, and other parts of the mangrove, such as the skins of the tree trunk (please refer to Fig 2 below).

Phase 4: Design Analysis: Categorisation and Typology/Matrix of Digital Design Patterns
A framework matrix summarises and analyses qualitative data in a table. It supports cross-case and theme sorting. Individual instances are sorted by row, while themes are arranged by column. Each intersecting cell summarises the source information related to the case and topic (Macfarlan, n.d).

In this study, the primary focus of our research is on mangrove species pattern developments. Despite the fact that the original idea is still in its early stages, each design should demonstrate promise and variants. The design patterns are created hastily (as a quick sketch) as the fundamental concept that simplifies the detailed elements of the physical entities of the mangroves. The designs that will be developed will be categorised according to species and physical traits identified in Phase 2. This discovery will promote future advances in bio-inspired designs.

Phase 5: New Models of Digital Design Patterns
This phase involves the development of a conceptual framework that arrives from the observational study, categorisation, design protocol/digitisation of motifs and patterns, and analysis of 40 prominent mangrove species. The validation of the model is based on the outputs being systematically recognised from the visual characterisation. Then, the new model of mangrove matrix species bioinspired will be structured into digital design patterns. Furthermore, final documentation for overall findings will also be executed in this final stage.

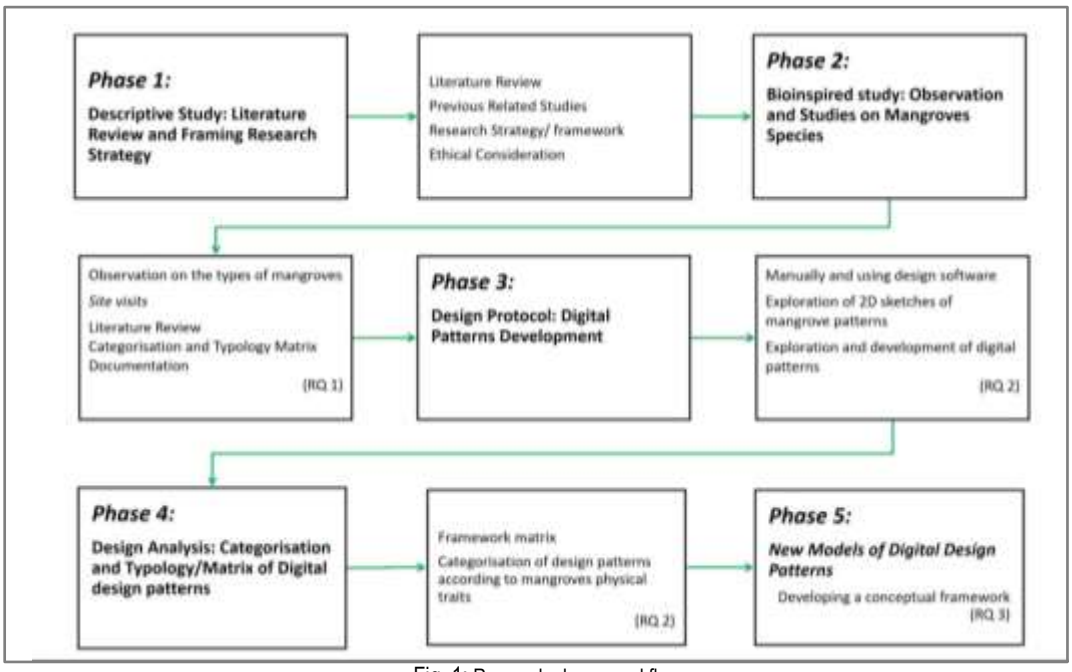

Fig. 1: Research phases and flows
(Source: Authors)

4.0 Results

Analogical design entails transferring information from one design scenario to another (Goel, 1997). An early idea-generating comparison and a key mechanism for developing ideas (Gonçalves et al., 2014). In this instance, mangrove species constitute the primary focus of our investigation. The mangroves' physical beings were translated and converted into a series of sketches. The physical creatures of the mangrove, such as the leaves, fruits, flowers, roots, and other components of the mangrove, such as the bark of the tree trunk, are considered in the concept studies. This study's analogy approach illustrated mangroves as the primary topic matter. Fig. 2 depicts an example of the developed design patterns from the early stage of original sketches on mangrove patterns development, while Fig 3. Shows the example of lighting design simulation of mangrove patterns in lighting design.

The next step in the design procedure of this study is to proceed with the *Design Protocol: Digital Patterns Development (as explained in the research methodology)* by selecting suitable mangrove patterns to be further developed digitally. This stage is the most crucial stage in this study, which will enhance and encourage more mangrove pattern development based on the early original sketches on mangroves (sample), as portrayed in Fig 2 below. Then, the *Design Analysis: Categorisation and Typology/Matrix of Digital Design Patterns* takes place.

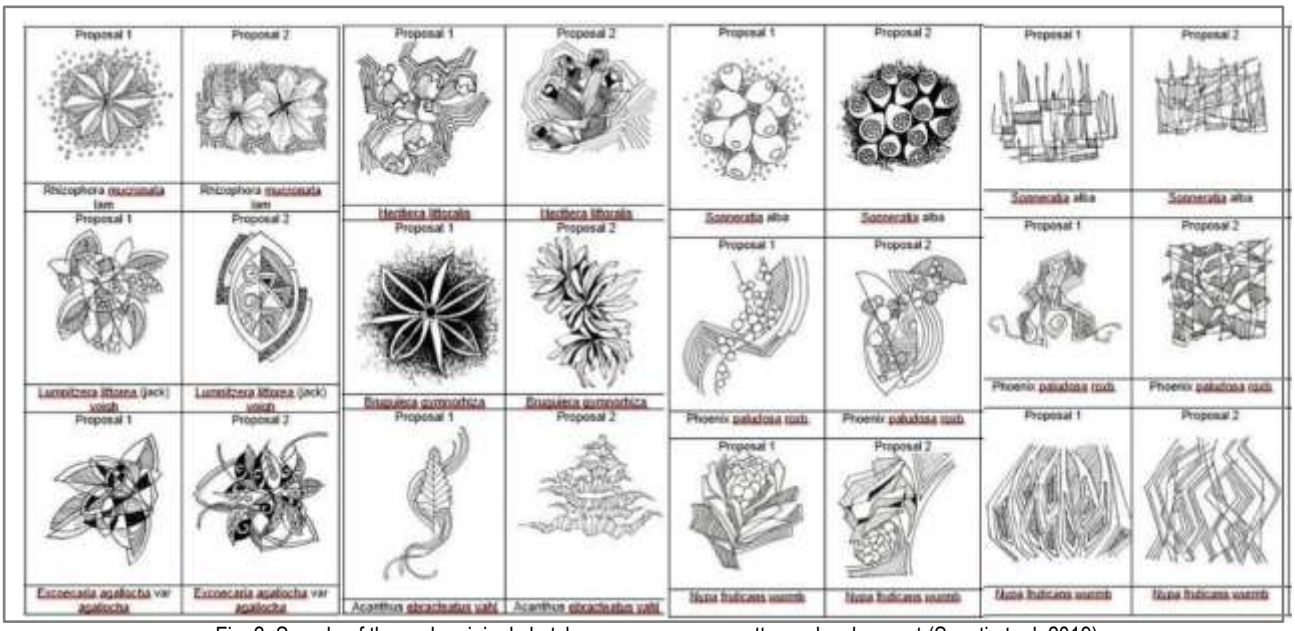

Fig. 2: Sample of the early original sketches on mangroves patterns development (Sayuti et. al, 2019)
(Source: Authors)

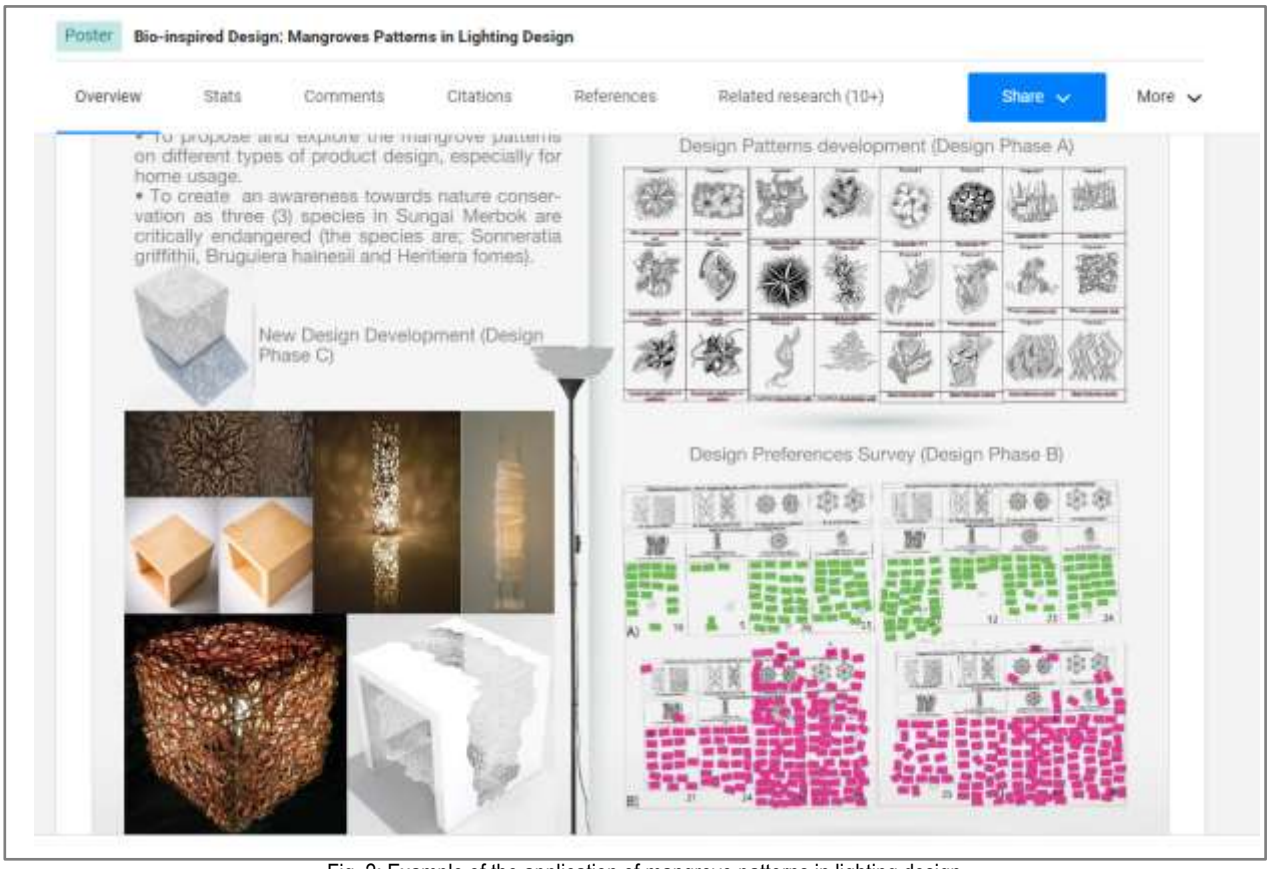

Fig. 2: Example of the application of mangrove patterns in lighting design.
(Source: Authors)

6.0 Conclusion

The mangrove was chosen as the main bio-inspired element of this study because of its richness of species, distinctive traits, different roles, and endemic to the coastal areas around Malaysia. The further development of typology matrixes and digital patterns according to the visible physical being of mangroves will be a novel contribution as bio-inspired by mangroves research/ study has never been further explored in detail and documented previously. This study focuses on the concept of idea creation that supports the utilisation of natural materials by drawing analogies between nature and creative designs. It is a modification of the visible physical characteristics (visually or based on surface research) and how the sources of inspiration for idea generation were objects, images, and texts.

This project also documented the literature review and the patterns generated in an effort to educate and attract individuals interested in learning more about mangrove species and advocate the preservation of mangroves in Sungai Merbok and other reserves in Malaysia. Moreover, this research is pertinent to Malaysia's National Creative Industry Policy (DIKN 2011), especially in Creative Multimedia, Creative Cultural Arts, and Creative Cultural Heritage. The study's findings could also help to support the Ministry of Tourism and Culture's policy objectives which focus on strengthening arts heritage, promoting Malaysia's uniqueness, and developing knowledge, skills, creative, and innovative human capital in the arts, culture, and heritage to achieve the ministry's vision of building national identity and the SPV 2030 for strategic ecotourism and heritage tourism.

Additionally, the relevant SDGs which support this research are Goal 8 to regain maximum and productive employment for all and promote good work for all, Goal 14 for conservation and sustainably utilise maritime resources, and finally, Goal 15 to protect, restore, and promote sustainable use of terrestrial ecosystems, forests, and biodiversity.

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Paper Contribution to Related Field of Study

The contribution of this paper in relation to the field of study of Industrial Design, Product Design, Bio-inspired Design, and Graphic Design.

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