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SUSTAINABLE HERITAGE LIGHTING DESIGN WITH MODERN TECHNOLOGY

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Sustainable Heritage Lighting Design with Modern Technology

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1. Abstract

The research aims to explore the effective utilization of drone technology for visually narrating a story. By analyzing lighting techniques and design strategies, insights will be provided into lighting practices that address the current energy and climate crisis. Emphasis will be placed on sustainable lighting practices that seek to minimize energy consumption while maximizing visual impact. The proposed lighting design at Jatayu Earth Center (JEC) aligns with sustainable development goals, promoting sustainable tourism, job opportunities, and local culture. A combination of drone technology and solar-chargeable batteries addresses the need for affordable, reliable, and modern energy access. This research contributes to the discourse on sustainable approaches to illuminating heritage architecture, exploring the intersection of art, heritage, and responsible energy practices. The successful implementation and marketing of the lighting design at JEC can have a significant impact on the Indian tourism industry, serving as inspiration for similar eco-tourism projects in the region and stimulating the local economy.

2. Introduction

In a world grappling with an energy and climate crisis, the question arises as to why landscape and heritage architecture should be illuminated. The pressing need to conserve energy and reduce our carbon footprint may suggest that more immediate concerns should take precedence. However, a deeper exploration of the significance of illuminating these architectural marvels uncovers a tale of cultural preservation, community identity, and sustainable innovation. The rich history and collective memory of a community are embodied within these structures. They serve as custodians of our past, narrating stories of those who came before us—their triumphs, tribulations, dreams, and aspirations. By thoughtfully designing lighting solutions, we can bring these architectural gems to life, honoring the legacies of our ancestors and fostering a profound connection between generations. Approaching the lighting of heritage architecture with an eco-conscious mindset allows for innovative solutions to minimize energy consumption while maximizing visual impact. The benefits of illuminating these structures extend beyond aesthetics and historical reverence. Revitalizing neglected neighborhoods through well-designed lighting can transform them into vibrant spaces that attract visitors, boost tourism, and contribute to local economies. Well-lit public spaces enhance visibility and safety, encouraging social interactions and a sense of community among residents[1].

Within the realm of Jatayu Para(JP), the profound significance of illuminating heritage architecture becomes evident. This ancient masterpiece, a colossal rock sculpture located in Kerala, India, depicts the mythical bird Jatayu and represents a cultural and historical gem deeply rooted in local mythology and folklore[2]. Shining a spotlight on this extraordinary site pays tribute to its artistic and historical value while inviting a global audience to appreciate the richness of human creativity.
The integration of sustainable practices is key when considering the allocation of resources to illuminate JP. Utilizing drone lighting technology powered by solar-charged batteries offers the potential to minimize energy consumption by utilizing efficient LED technology and optimizing illumination control. This approach demonstrates a harmonious relationship between heritage preservation and responsible energy usage, aligning with a commitment to reducing environmental impact while showcasing the site's artistic significance.

The development and effective marketing of the center could result in increased tourist attraction, both domestically and internationally, thereby contributing to the Indian tourism industry. Furthermore, the success of the center could inspire the establishment of similar eco-tourism projects in the region, further stimulating the local economy. The objective of this project is to propose a dynamic lighting design that creates an enticing and captivating atmosphere at JEC, enticing visitors to experience the space and providing them with a memorable and extraordinary encounter. The proposed lighting design aims to achieve sustainability objectives aligned with SDG 8.9, which focuses on promoting sustainable tourism practices, job opportunities, and local culture and products. The research paper delves into the potential of combining drone technology with solar-chargeable batteries to promote energy conservation and sustainability. It addresses Goal 7 of the sustainable development goals, which emphasizes Affordable and Clean Energy and the need for affordable, reliable, sustainable, and modern energy access for all[3].

![Fig(1a) Targeted UN Sustainability goals](UN Sustainable development 2022)

By exploring lighting techniques, design strategies, and their impact on cultural heritage sites like JP, valuable insights can be gained into the effective use of lighting in times of energy and climate crisis. This research seeks to contribute to the broader conversation on sustainable approaches to illuminating heritage architecture and landscapes, fostering a deeper appreciation for the intersection of art, heritage, and responsible energy practices.
Research Question

How can we effectively utilize drone technology to visually narrate a story in the specific context of sculpture lighting, and what are the implications of using this technology in terms of sustainability?

Keywords: Drone lighting, Sculpture lighting, Renewable Energy, light pollution, light and shadow.

3. Background research

3.1 Drone lighting technology: The use of unmanned aerial vehicles (UAVs), commonly known as drones, for lighting purposes is a relatively new application that has emerged in recent years as drone technology has advanced and become more accessible. The display, which typically involves flying several unmanned aerial vehicles (drones), frequently quadcopters, in a coordinated pattern while carrying light fixtures on board, is usually held at night and features many LEDs. The first drones to be used for this purpose were debuted in 2012 by the Ars Electronica Future lab in Linz, Austria, with their SPAXELS (short for "space elements")[4]. Initially, drones were primarily used for military and surveillance purposes, but as the technology has evolved, drones have found a wide range of commercial and recreational applications, including photography, videography, surveying, agriculture, and delivery services.
The use of drones for lighting purposes is considered an innovative application that has the potential to revolutionize the way lighting is utilized across various industries, including architecture, entertainment, and events. Drone lighting can be utilized in several fields, including theatre, architecture, and events, where it can create dynamic and immersive visual effects. In events such as concerts, festivals, and sporting events, drone lighting can enhance the audience's experience and create stunning aerial displays[23]. In architecture, the technology can highlight the unique features of a building, showcase its design, and create a memorable visual spectacle. The versatility of drone lighting makes it a technology with many potential applications across different industries.

**Fig(2) Examples of live drone performance :Intel-Disney ‘Starbright’ Holiday Drone Show 2016**

**Fig(3) Examples of live drone Spaxels over lenz Test flight in Mühlviertel 2016**
Possible developments that could shape the future of drone lighting include the potential for better integration with other technologies such as 5G networks, augmented reality, and artificial intelligence. As a result, it may become possible to create new applications in fields like smart cities and virtual events, as well as more immersive and interactive lighting displays. The technology is likely to become more automated and intelligent, which could result in easier operation and increased efficiency. This, in turn, could allow for more complex lighting displays, as well as the ability to program drones to fly specific patterns or formations. As drone technology advances, drones are expected to become safer, more reliable, and more robust, enabling them to be used in more challenging environments and for critical applications such as emergency response. With the growing emphasis on sustainability, the use of drones for lighting is likely to shift towards more environmentally friendly solutions, such as solar-powered drones or drones powered by renewable energy sources[5].

3.2 **Light pollution in rural areas**: Environmental degradation caused by excessive and misdirected artificial lighting in our surroundings is known as light pollution. Various aspects of our environment, including the natural habitat of animals, human health, and energy consumption, are negatively impacted by this growing problem. The natural world is affected by light pollution in numerous ways, as many studies have shown that it can disrupt the behavior and biological rhythms of various species, alter ecosystems, and cause changes in plant growth and reproduction, moreover, a range of human health issues, including sleep disorders, depression, and increased risk of certain types of cancer, have been linked to light pollution[6].
The impact of energy consumption due to light pollution is significant, as inefficient technology and unnecessary outdoor lighting contribute to increased greenhouse gas emissions and climate change. Rural areas are particularly affected by light pollution, despite their lower population density, as it can still have a detrimental impact on the natural environment, wildlife, and human health. The reduction of light pollution and preservation of dark skies is the focus of the International Dark-Sky Association (IDA), which notes that sculpture lighting in rural areas can contribute to light pollution and its negative impacts. The excessive or misdirected lighting of sculptures can cause skyglow, glare, and light trespass, leading to reduced visibility, discomfort, and interference with the natural behavior of animals and human activities, as well as alterations to ecosystems[7].

Fig(5) Stars can be seen amid the moon above metal sculptures in Borrego Springs(Hayne Palmour IV/The San Diego Union-Tribune file)

Fig(6) Milky Way Galaxy over Fountain Lake in Fountain Hills, Arizona
The IDA recommends responsible lighting practices for sculpture lighting in rural areas. This includes the use of properly designed and directed lighting fixtures, reducing unnecessary lighting, and using energy-efficient technology. The use of full cutoff fixtures that prevent upward light spillage and limit glare is especially important to reduce the negative impacts of sculpture lighting on the night sky.

**4. Methodology**

In this research paper, the realm of temporary dynamic lighting systems is delved into, with the aim of exploring their potential and proposing innovative concepts for their application. The paper is structured into three main parts: (1) Similar Case study (2) Analysis of present scenario (3) Propose a concept for temporary dynamic lighting system.
4.1 Similar Case Study

(1)The Dying of the light : The objective of this project was to create a short film that features a drone lighting rig, built by Daniel Riley[13] mounted it to an Alta 8 drone[14] with a motor max continuous power output of 350 W, illuminating a desert White Pocket in Arizona with a 150,000 lumen LED lighting system. The purpose of the shoot was to generate visual effects that would manipulate the viewer's sense of scale and perspective[15]. Due to battery life constraints, the duration of the lighting event was restricted to approximately 8 minutes per flight, and a single drone was utilized. The LED lighting system, which had a specification of 1000 watts, 5500K, and 75 CRI, was manually controlled using an on/off switch.
(2) LUX NOCTIS: The Lux Noctis is an ongoing photography series depicting landscapes of North America by Chicago-based artist Reuben Wu, which aims to portray a unique perspective of the planet by illuminating night landscapes with an aerial LED light, utilizes a prototype AL250 light by Fiilex that is mounted on a 3DR Solo UAV. The project is influenced by ideas of planetary exploration, chiaroscuro painting, and science fiction, and depicts landscapes that are unbound by time and space[19]. In this project, a fixture with a 30 Watt power, 5600K color temperature, and a 38-degree beam angle was used, which featured a GoPro mount[20].

Fig(11) Illuminating night landscapes with an aerial LED light view 1

Fig(12) Illuminating night landscapes with an aerial LED light view 2
(3) ΦΩΣ (LIGHT) upon Poseidon’s Temple: The temple of Poseidon, which is considered as one of the most renowned treasures of Greek civilization, was presented and filmed in a unique way with the use of drone lights during a summer full moon night. The temple was illuminated with real drone lights and was motivated by the Greek treasures. The filming was done by people who had a vision to share their different light perspective, and this special monument was filmed using this unique technique, without the use of CGI or VFX[21]. In this project, two drones were utilized. The led lights were carried by a heavy lifter drone, while the process was filmed by a quadcopter drone. The drones were controlled using a drone app, specifically the DJI app[24], enabling precise flights and the ability to follow a predetermined route. Notably, the drones were flown without any preprogrammed or automated plans. In addition to the filming drone, three more cameras were employed to capture the lighting effects from the ground. On the drone, six special LED lights were installed, with each light having a power output of 1KW, resulting in a total power of 6KW. No color temperature correction gels were used as the LED lights already had a color temperature of 5800 Kelvin. The batteries had a duration of 12-14 minutes for both drones, and battery changes were conducted whenever the voltage indicated insufficient capacity to complete the next frame.
<table>
<thead>
<tr>
<th>Aspects</th>
<th>Similarities</th>
<th>Differences</th>
</tr>
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<tbody>
<tr>
<td>Objective</td>
<td>Captivating visual effects through the use of drone lighting are aimed for in all three projects.</td>
<td>Each project has a unique objective.</td>
</tr>
<tr>
<td>Drone Type</td>
<td>Drones are utilized for lighting purposes in all projects.</td>
<td>Different drone models were used in each project.</td>
</tr>
<tr>
<td>Lighting system</td>
<td>LED lights are utilized in all projects.</td>
<td>The specifications of the LED lights vary in terms of power output, color temperature, and beam angle.</td>
</tr>
<tr>
<td>Lighting condition</td>
<td>The focus of the projects is on illuminating specific locations during unique lighting conditions.</td>
<td>The specific lighting conditions and locations differ in each project.</td>
</tr>
<tr>
<td>Duration</td>
<td>The duration of the lighting events in all projects is restricted due to battery life constraints.</td>
<td>The duration of the lighting events varies in each project.</td>
</tr>
<tr>
<td>Control method</td>
<td>In all projects, the drones are manually controlled using a drone app (DJI app).</td>
<td>The presence of pre programmed or automated plans differs among the projects.</td>
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Table(1) Comparative Analysis of Similar Project Case Studies

Similarities can be observed among these case studies in terms of the utilization of drones and LED lights for creative lighting purposes. The objective in all cases is to manipulate and enhance the visual experience in unique settings. However, distinctions arise regarding their specific objectives, locations, lighting conditions, equipment specifications, and sources of artistic inspiration. Valuable examples are provided by these case studies, showcasing the possibilities of artistic expression and innovative concepts achievable with drone lighting. They offer insights and ideas for the development of new concepts in the realm of temporary dynamic lighting systems, where boundaries of visual storytelling can be pushed, and captivating visual effects can be created.

4.2 Analysis of present scenario
4.2.1 Background & Regulation
Historical background

According to Hindu mythology, the rock is believed to be the location where Jatayu, a vulture in the Ramayana epic, fell after being injured by the demon king Ravana. Jatayu, an old friend of King Dasharath and a demi-god in vulture form, attempted to rescue Sita from Ravana's clutches. In the ensuing battle, Jatayu was injured and died. The sculpture at the site is dedicated to Women's Safety and Honour in remembrance of Jatayu's effort to protect Goddess Sita's honor[27].

The JP rock formation is recognized as a large bird-like structure, believed to represent Jatayu. It has become a renowned pilgrimage site for both Hindus and tourists. Over time, it has been developed into the prominent Jatayu Nature Park (JNP), covering 65 acres of land. The park features a monumental bird sculpture, designed by renowned film director Rajiv Anchal, which is considered the world's largest. Standing at 200 feet in length, 150 feet in width, and 70 feet in height, the sculpture showcases remarkable engineering and architectural prowess. The site, situated 1,000 feet above sea level, exhibits diverse geographical elements such as valleys, caves, hills, and rugged rocks[2].

Fig(15) Illustration: Ravana's Attack on Jatayu
➢ Lighting Regulation

Situated in the Kollam district of India, JP is found within the Western Ghats, which is designated as a UNESCO World Heritage Site and a biodiversity hotspot[16]. The Western Ghats, acknowledged as an ecologically sensitive area under the Environment Protection Act[17] of 1986 by the Ministry of Environment, Forest and Climate Change (MoEFCC)[18], are legally safeguarded due to their unique biodiversity and delicate ecosystem. It is recommended to utilize eco-friendly lighting sources, including LED, and avoid excessive lighting levels to mitigate environmental impact.

4.2.2 Analysis and observation of context

➢ Weather

JP in Kerala, India, belongs to the tropical climate zone, which is characterized by hot and humid conditions throughout the year [8]. Within the tropical zone, it falls under the subtropical region due to its elevation and proximity to the Western Ghats mountain range, with a distinct monsoon season from June to September. The average temperature in this area ranges from 23 to 32 °C (73 to 90 °F) and the annual rainfall is around 3000 to 3200 mm (118 to 126 inches) [9].

Fig(16) Chart representing annual temperature & rainfall of Kerala

➢ Location

The rock formation known as JP or Jatayu Rock is situated in the Kollam district of the southern Indian state of Kerala, specifically in Chadayamangalam village. The coordinates of Jatayu Rock are approximately 8.8215° N, 76.7927° E. The area of JNP, which encompasses the rock formation, is estimated to be around 65 acres.
Wind

The typical average wind current near JP, situated in the Western Ghats region, is variable and dependent on the time of year. It is observed that during the summer season, the winds are predominantly from the southwest, whereas in the winter season, the winds are from the northeast. The average wind speed ranges from 5 to 15 km/h, with occasional gusts up to 25 km/h during the monsoon season. The maximum wind speed allowed for drones is 25 miles per hour (40 kilometers per hour)[22].

Built environment of surrounding neighborhood

The surrounding neighborhood of JP is largely rural and comprises of hilly terrain covered with dense forests. The immediate surroundings of the JEC are also forested areas, with some small villages and farmlands scattered around. There are a few small shops and restaurants located near the entrance of the Earth Centre. The area is relatively less developed in terms of built environment, and the focus is primarily on preserving the natural beauty and ecology of the region.

Built environment around the statue

The built environment around the JP statue includes several amenities for visitors, such as visitor center that provides information about the statue and the surrounding area. The center also houses a souvenir shop and a restaurant, Cable Car, Adventure Activities, Amphitheatre, Nature Park[11].
➢ **User Activities**

The cable car ride is offered as a user activity in JP. Trekking, zip-lining, rock climbing, bird watching, and experiencing an Ayurvedic spa are also provided for users. Dining options are available as well.

➢ **Use of the place**

Next to the sculpture, a water body is believed to have formed from Jatayu's beak, sustaining the bird until Lord Rama's arrival. A preserved footprint of Lord Rama can be seen nearby. Inside the sculpture, a 6D Theatre presents the battle between Jatayu and Ravana. A temple dedicated to Lord Rama is also present, and a replica of King Janaka's palace showcases the Thretha Yuga era. An Open Air Performance Center allows for cultural events and offers a scenic viewpoint for sunset enjoyment.

➢ **Architectural elements of statue**

The stunning work of architecture that is the Jatayu statue combines traditional mythological elements with modern engineering and design. The statue is constructed in a reclining position, with one of its wings deliberately fragmented and the other wing positioned flat. The head, talon, and claws of the sculpture are elevated towards the sky. Its wings are spread out, covering an area of 150 feet and are made of copper sheets designed to resemble feathers. The statue's beak, which is 20 feet long and 5 feet wide, is made of steel and designed to be sharp and pointed. The statue's talons, which are 15 feet long, are made of roller compacted concrete (RCC) and designed to resemble sharp claws. The overall design of the statue is intended to resemble a bird in flight. The statue is perched on a large rock formation, which provides a natural and stunning backdrop.
Visibility from short and long distance

The Jatayu statue at JEC possesses high visibility from both short and long distances due to its unique design and impressive size. From several kilometers away, the statue is easily visible as it stands tall on a large rock formation when approaching the nearby town of Chadayamangalam. Additionally, on a clear day, the statue can be seen from certain elevated locations up to a distance of about 30-40 kilometers away. However, the statue's visibility can be affected by individual factors and surroundings.
➢ Light situation from surrounding neighborhood & the statue

The lighting situation around the Jatayu statue at JEC is predominantly determined by the installation of artificial lights in the surrounding area, as the statue is encircled by a natural landscape of trees and rocks.

➢ Light situation from surrounding neighborhood & The statue

The lighting situation around the JP statue at JEC is dependent on the artificial lights installed in the surrounding area, as it is surrounded by a natural landscape. The statue and its immediate surroundings are illuminated by strategically placed artificial lights in the surrounding neighborhood, which ensure ample visibility for visitors during nighttime and enhance the overall viewing experience. The lights also serve as a safety measure to ensure that the area is well-lit and secure for visitors.
4.3 Design Proposal

4.3.1 Vision

The creation of an alluring and captivating atmosphere at JEC through the use of sustainable sculpture lighting design that utilizes drone technology to reduce light pollution is envisioned.

The goal is to attract people to visit the space at least once in their lifetime, provide them with a memorable and extraordinary experience, and promote sustainable tourism.

4.3.2 Mood board

[Images of mood board with labels: Reflection, Connection, Courage, Melancholy, Pain]
4.3.3 Image board

*Fig(27)*

**Dynamic lighting**

*Fig(28)*

**Drone lighting**

*Fig(29)*

**Drone facilitated façade lighting**

*Fig(30)*

**Drone based Sculpture lighting**
The proposed vision for illuminating the JP rock formation involves the use of dynamic lighting technology in the form of a theatrical show with four different light scenes. These scenes will symbolically represent the story of Jatayu's heroic effort to retrieve Sita from Ravana, as described in the Hindu mythological literature Ramayana. The use of different colors and dynamic effects will enhance the visual experience for the audience.

The aim of this vision is to attract tourists to the site while minimizing the negative impacts of light pollution. The concept of dynamic lighting provides a unique opportunity to showcase the cultural significance of the JP rock formation in a visually appealing manner. The use of theatrical lighting techniques will add an element of drama to the presentation, making it more engaging for the audience.

The four light scenes will be designed to convey different themes and emotions, ranging from the initial confrontation between Jatayu and Ravana, to Jatayu's valiant attempt to save Sita, and finally, his tragic demise. The colors and dynamic effects used in each scene will be carefully selected to enhance the narrative and create an immersive experience for the audience.

Transferring Jatayu’s story to four light scenes.

**Scene 1: Kidnapping Sita**
Start with a warm and serene yellow lighting using drones for the first 20 seconds, with a medium intensity level(50%). Transition to intense red lighting for the next 20 seconds to signify danger and distress, with a high intensity level(80%). Conclude the scene with a combination of yellow and red lights for the remaining 20 seconds, gradually decreasing the intensity to create a transitioning effect.

**Scene 2: Fighting with Jatayu**
Begin with a combination of red and yellow lights, allocating the first 15 seconds for this mix, with a medium intensity level (50%). Increase the intensity to maximum(80%) for the next 15 seconds to enhance the energy and intensity of the fight, maintaining the red and yellow color combination. Gradually reduce the intensity and introduce brief bursts of white light for the remaining 30 seconds to highlight key actions and create dynamic effects.

**Scene 3: Jatayu Got Injured and Falling Down**
Shift to cool tones such as blue and purple lights for the first 30 seconds using drones, with a medium intensity level(50%). Gradually decrease the intensity over the next 15 seconds to represent Jatayu's declining strength, while maintaining the blue and purple color combination. Conclude the scene with a gentle fade-out of the lights for the final 15 seconds to symbolize Jatayu's descent, gradually reducing the intensity to a low level(20%).
Scene 4: Jatayu's Death with Pain
Use black (shadow) and low-intensity lighting (20%) (white) to create a somber atmosphere for the first 30 seconds, symbolizing pain and sorrow. Gradually introduce red lights with increasing intensity for the next 15 seconds to represent the intensifying pain. Conclude the scene with a final 15 seconds of dimmed white light, signifying the end of Jatayu's life.

The total duration of the four light scenes will be 4 minutes, drawing inspiration from one of our outdoor projects in Alingsås. The choice of colors was driven by the intention to portray the emotions of Jatayu effectively. The selected colors were carefully chosen to align with the desired emotional responses.

The decision to maintain the intensity of the lights between 20 to 80 percent was made in order to strike a balance and avoid extremes of brightness or darkness. This range of lighting intensity ensures that the visual impact is optimal, while also preventing any excessive brightness or discomfort for the viewers.
Storyboard

Scene-1

Kidnapping Sita

- Warm and serene yellow lighting for the first 20 seconds using drones at a medium intensity level (50%)
- Transition to intense red lighting for the next 20 seconds, indicating danger and distress, at a high intensity level (80%)
- Conclude the scene with a combination of yellow and red lights for the remaining 20 seconds, gradually decreasing the intensity to create a transitioning effect.

Fig(31) Sketch representing the Kidnapping scene of sita by Ravana by the author

Scene-2

Fighting with Jatayu

- Start with a 15-second mix of red and yellow lights at a medium intensity level (50%)
- Increase intensity to maximum (80%) for the next 15 seconds to enhance energy and intensity
- Gradually reduce intensity and introduce brief bursts of white light for the remaining 30 seconds to highlight key actions and create dynamic effects

Fig(32) Sketch representing the fighting between Ravan and Jatayu by the author
Scene-3

Jatayu Got Injured and Falling Down

- Use drones to shift to cool tones (blue and purple lights) for the first 30 seconds at a medium intensity level (50%)
- Gradually decrease intensity over the next 15 seconds to depict Jatayu's declining strength, maintaining the blue and purple color combination
- Conclude with a gentle fade-out of the lights for the final 15 seconds, symbolizing Jatayu's descent, with gradually reduced intensity to a low level (20%)

Fig(33 ) Sketch representing the depicting Jatayu's Injury and Descent by the author

Scene-4

Jatayu's Death with Pain

- Use black (shadow) and low-intensity lighting (20%) (white) for the first 30 seconds to create a somber atmosphere of pain and sorrow
- Gradually introduce increasing intensity red lights for the next 15 seconds to depict intensifying pain
- Conclude with a final 15 seconds of dimmed white light to symbolize the end of Jatayu's life

Fig(34 ) Sketch representing the Jatayu’s death and funeral
By the author
4.3.5 Testing & Simulation

The testing and process began by selecting luminaires with three different beam angles to analyze the light distribution and formation of shadows. The aim was to examine how the light was distributed and how shadows were formed. The luminaires were tested in the Dialux software to analyze the distribution with narrow beam angle (10 degree), medium beam angle (18 degree), and wide beam angle (26 degree).

Fig(35a) & Fig (35b) Front and Top View Software Simulation of Jatayu Statue with Narrow Beam Angle Fixture

Fig(36a) & Fig (36b) Front and Top View Software Simulation of Jatayu Statue with Medium Beam Angle Fixture

Fig(37a) & Fig (37b) Front and Top View Software Simulation of Jatayu Statue with Wide Beam Angle Fixture
<table>
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<tr>
<th>Type of Beam Angle</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tr>
<td>Narrow</td>
<td>• Precise highlighting of desired features is enabled by the use of a luminaire with a narrow beam angle, resulting in increased focus on specific areas of the sculpture. &lt;br&gt; • The visual impact of the sculpture is enhanced through the formation of shadows, resulting from the narrow beam angle, which provides a sense of depth and accentuates its texture and intricacies.</td>
<td>• Variations in brightness and diminished lighting uniformity can potentially occur due to the concentrated beam angle, resulting in uneven illumination across the sculpture, with lower levels of illumination in areas outside the beam angle. &lt;br&gt; • The visibility and appreciation of the artwork as a whole may be affected by the limitation of the narrow beam angle, which restricts the coverage area of the luminaire and potentially leaves certain parts of the sculpture less illuminated or in shadow.</td>
</tr>
<tr>
<td>Medium</td>
<td>• A comprehensive and balanced distribution of light across the entire sculpture is ensured by employing a luminaire with a medium beam angle, effectively highlighting its features and form.  &lt;br&gt; • Relatively consistent light intensity throughout the sculpture is ensured by the chosen medium beam angle, resulting in an even illumination without significant variations in brightness.</td>
<td>• The visibility and appreciation of specific details or sections of the artwork may be affected by the limitation of the medium beam angle, which potentially leaves certain parts of the sculpture less illuminated or with reduced lighting intensity. &lt;br&gt; • The dramatic impact that more defined shadows might provide can be diminished by the softer and less pronounced shadows produced by the medium beam angle, potentially resulting in a reduced sense of depth and contrast on the sculpture.</td>
</tr>
<tr>
<td>Wide</td>
<td>• Enhanced overall visibility is achieved by effectively covering a larger area of the sculpture through the use of a luminaire with a wide beam angle, resulting in an extensive lighting distribution. &lt;br&gt; • Relatively consistent light intensity across the sculpture is achieved by the chosen wide beam angle, resulting in an even illumination without significant variations in brightness.</td>
<td>• The dramatic impact that more defined shadows can provide may be diminished by the softer and less pronounced shadows produced by the wide beam angle, potentially reducing the emphasis on the sculpture’s form and details. &lt;br&gt; • A potential loss of contrast and depth perception in specific regions may be caused by the wide beam angle, which can result in over-illumination in certain areas of the sculpture.</td>
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*Table(2) Advantages & disadvantages of different beam angled fixtures*

From the above conclusions the design proposal includes the utilization of two medium beam angle luminaires and one wide beam angle luminaire, which are chosen to emphasize the head portion of the sculpture with greater detail because the head portion is visible from a long distance. Enhanced highlighting and visual intricacies are enabled by the specifically chosen wide beam luminaire for the head, while balanced illumination throughout other areas of the sculpture is provided by the medium beam angle luminaires.
4.3.6 Final Design Proposal

Fig(38) Illustration represent light scene from scene1

Fig(39) Illustration represent light scene from scene2
4.3.6 Final Design Proposal

Fig(40) Illustration represent light scene from scene3

Fig(41) Illustration represent light scene from scene4
The design proposal aims to implement dynamic lighting using three separate drones, each equipped with luminaires (RGB+W) that have a power rating of 26 watts and an output of 25,100 lumens. These luminaires will be strategically positioned at a height of approximately 9 meters above the sculpture, the drones themselves will remain stationary throughout the lighting display, while the luminaires will have the capability to adjust their position vertically by 90 degrees (up and down). The concentration of the observer will be directed towards the sculptures, rather than the drones. The proposed design allows for the creation of captivating light shows with a duration of approximately 4 minutes. The event is scheduled to take place between evening 6.45pm and 7.45pm, after sunset, and can be conducted four times a week on a weekly basis.

5. Results & Analysis

- The case study summarized and analyzed similar lighting projects that utilized drone technology, identifying successful design elements. These elements were then considered for application in the JP sculpture lighting project. The findings suggest that incorporating drone lighting rigs can offer unique perspectives and manipulate viewers' perception of scale and perspective. The use of high-intensity LED lighting systems, controlled manually or through drone apps, enables precise lighting control and the ability to follow predetermined routes. Additionally, selecting LED lights with specific power outputs and color temperatures can enhance the desired visual effects. The successful integration of drone technology in these projects showcases the potential for innovative and captivating lighting solutions for the JP sculpture.

- The proposed lighting design for JP aligns with sustainability objectives, including promoting sustainable tourism practices and preserving cultural heritage. By incorporating energy-efficient lighting systems and minimizing light pollution, the design aims to attract visitors while respecting the natural environment. The four light scenes, representing different themes and emotions from the Ramayana, will be carefully designed light scenes enhance the narrative and highlight the cultural significance of JP.

- The examination of how a story can be visualized through drone technology in the specific phase of JP sculpture lighting reveals insights into effective storytelling techniques. The implications of utilizing drone technology for storytelling purposes in this context are explored, providing a comprehensive assessment of its impact. Considerations regarding the long-term sustainability of drone technology in sculpture lighting are investigated, shedding light on the environmental and practical aspects of its usage. The results contribute to a better understanding of the potential and challenges associated with utilizing drone technology for visual storytelling and provide valuable insights for future applications in similar contexts.
Based on the comprehensive analysis, the eco-friendly lighting thresholds and values for the JP project were established. The lighting design incorporates LED luminaires with high energy efficiency and low carbon emissions. The maximum allowable light pollution levels were determined to minimize the impact on the surrounding environment and preserve the natural darkness of the site. Furthermore, the use of renewable energy sources, such as solar-charged batteries for the drone lighting system, significantly reduces the project's carbon footprint.

Several factors need to be considered when selecting a drone, including payload capacity, flight duration, battery life, compliance with regulations, and safety features. The maximum payload capacity of the drone ranges from 25 to 36 KG (MTOM). For this project, drone models such as Freely Alta[29], DJI M600[30], and Gryphon X8[31] are proposed as heavy lifters, capable of handling up to 25 KG in total weight. The required batteries depend on the drone type. For this project, the drone should be equipped with a pair of 2x16000 mah batteries for flight and a minimum of 6s 6000mah batteries for the drone lights, providing continuous lighting for up to 10 minutes. The flight duration of the drone can vary from 10 to 25 minutes depending on factors such as drone type, weight of the rigged LED lights, and flight conditions. When the battery power is depleted, the drone needs to be landed, turned off, and the battery set replaced. Similarly, the batteries for the LED lights also need to be replaced.

The lighting control for drone lighting at JP was achieved through the use of the Sky Panel app. The app allowed for easy access and adjustment of brightness, color temperature, and color effects. It demonstrated the capability to create dynamic lighting effects, synchronize multiple lights, and control individual fixtures or groups. The wireless connectivity utilized by the app facilitated seamless control over the lights, eliminating the requirement for manual adjustments or physical access to the fixtures. This lighting control system effectively enhanced the drone lighting experience at JP, offering convenient and efficient control over the lights.

6. Discussion

The effective utilization of drone technology in visually narrating a story within the context of sculpture lighting is a topic of significant discussion. Drones offer unique perspectives, dynamic visuals, and creative storytelling possibilities. However, the implications of using drones in terms of sustainability should be carefully considered, including energy consumption, carbon emissions, noise pollution, and proper waste management. Balancing captivating storytelling with sustainable practices requires exploring alternative energy sources, optimizing flight routes, and implementing responsible regulations and guidelines.
• Drone technology offers distinct advantages compared to traditional lighting methods. Unique angles and perspectives can be captured, providing a fresh visual experience. The flexibility to adjust lighting intensity and direction enhances creative possibilities. Furthermore, the use of drones reduces the reliance on scaffolding or other equipment that may pose risks to the sculpture. Additionally, drone technology contributes to reducing light pollution through precise lighting control. These advantages highlight the potential of drones for enhancing the aesthetic appeal and minimizing environmental impact in sculpture lighting projects.

• The technical challenges associated with using drone technology for sculpture lighting are addressed. Despite the numerous benefits, certain limitations must be considered. These include factors like battery life, weather conditions, and regulatory requirements for operating drones in public spaces. This research examines how these challenges were successfully tackled in the lighting setup for the JP sculpture. Strategies implemented to address battery life issues, adapt to various weather conditions, and comply with regulatory frameworks are discussed. By analyzing these experiences, insights are gained for future projects to overcome technical challenges and maximize the potential of drone technology in sculpture lighting endeavors.

• In this research paper, the potential for future applications of drone technology in sculpture lighting is explored. The focus is on the possibilities of utilizing this technology in other sculpture lighting projects, not only in India but also globally. This includes an examination of the technical and regulatory considerations that need to be taken into account when implementing drone technology for lighting purposes. Additionally, the creative and artistic possibilities that can be explored through the use of drones in sculpture lighting are discussed, emphasizing the potential for innovative and visually captivating lighting designs. This analysis provides insights into the promising future of drone technology in the field of sculpture lighting.

• The integration of drone technology, solar-chargeable batteries, and sustainable tourism practices in the proposed lighting design supports the sustainability objectives outlined in SDG 8.9 and Goal 7 of the sustainable development goals. By prioritizing energy conservation, renewable energy sources, and the preservation of local culture, the lighting design contributes to a more sustainable and environmentally responsible approach to lighting in JP.

Limitations

• This project also has certain limitations that should be acknowledged. Firstly, regulatory restrictions and permissions may impose challenges in obtaining necessary permits and adhering to airspace regulations when utilizing drone technology for sculpture lighting. Additionally, limitations arise from the reliance on drone-mounted lighting rigs, including constraints associated with battery life and flight time, necessitating careful planning and coordination for uninterrupted lighting. Furthermore, adverse weather conditions, such as strong winds or rain, can impact the feasibility and safety of operating drones for lighting purposes. These limitations necessitate consideration and mitigation when implementing drone technology in sculpture lighting projects.
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