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3D Printing for Kiswah Adornment to Replace Gold Thread Embroidery

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ABSTRACT

The Holy Kabah in Mecca is the most important artefact in the Islamic world and is deserving of beautification and glorification. Under the guidance of King Salman Bin Abdulaziz as part of the Vision 2030 development plan for the country to be a leader in the arts, culture and technology this study proposes a digital methodology for the adornment of the Kiswah, the cloth that covers the holy Kabah. The manufacture of this artefact is steeped in historic tradition, culture and craftsmanship and has to be able to withstand extreme environmental conditions and a feasibility study is proposed for using 3D printing technology to replace the traditional gold embroidered adornment of the Kiswah, while at the same time meeting the religious, traditional and practical requirements and therefore, material properties were a central concern. The feasibility study involves testing materials and 3D printing techniques out doors for the period of one year to test for adherence, warping, breakage and colour and textural changes as well as aesthetic considerations.

Keywords: Textiles, 3D Printing, Ceramics, Additive Manufacturing.

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1 INTRODUCTION

The Holy Kabah in Mecca Saudi Arabia is adorned with a black cloth known as the 'Kiswah' that is embroidered in real gold thread and silver with Arabic calligraphy and Islamic geometric patterns. The embroidery is so elaborate it takes 300 staff members one year to complete and uses 120 kg and 700 kg of raw silk at a cost of £3.3 million.

This paper proposes a new technological approach, specifically 3D printing, for embroidering the Arabic calligraphy on the Kabah. The aim is to find a cheaper more sustainable alternative that will also overcome the problems that are faced by the deterioration in appearance of the gold embroidery due to weathering.

Specifically, a feasibility study for this endeavour would include consideration of materials that need to fit particular criteria which include aesthetic appearance, maintaining appearance throughout year, does not deteriorate due to weathering, and is economically and environmentally sustainable and overall quality in addition to religious and traditional considerations. Consideration of the 3D production techniques should include these criteria. In reference to the manufacturing technique, the study also considers the technique of physical application to the Kiswah due to the fact that it is made from raw silk.

The work is towards achieving more economically and environmentally sustainable approaches to crafting the Arabic script.

The proposed project is essentially a feasibility study for new production techniques and material for the Quranic verses attached to the Kiswah. The main part of the proposed project is the testing of various production and material solutions and the outputs as results will inform the next stage which will be application of these approaches to the Kiswah.

Ultimately, the results will include aesthetic and functional attributes of the different tested materials and the different machine configurations. Therefore, the ultimate output of the project will be a new approach to decorating the Kiswah that is economically sustainable. Furthermore, the new approach should comply with all of the functional, aesthetic and religious requirements that are associated with the Kiswah. Specifically, the three-dimensional printed Quranic verses will be adhered to the existing Kiswah cloth and therefore, it is required to adhere properly without any warping to the writing or the cloth itself.

The main beneficiary of this proposed project is undoubtedly the Masjid Al Haram and all those that that have a stake in this mosque and the Holy Kabah. The Kabah is sacred to millions of Muslims globally and reducing costs and introducing the importance of sustainability, while at the same time maintaining the beauty and reverence of the Kabah sends an important message to the ummah about the importance of sustainability. The Kiswah factory at Mecca is also a beneficiary institution because the proposed project

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represents and evolution of craft practices and will bring this institution up to date with the times.

2 PRELIMINARIES

2.1 History of Kiswah

During the lifetime of the Prophet Muhammad (SAW) the first Islamic Kiswah was used in the 10th year Hijra and was put on the Kabah by the prophet himself (SAW) and it was made of Yemeni cloth, later the Kiswah was commissioned by the Caliph Omar ib Khattab to be made in Egypt (B). Other accounts of the Kabah being draped by a Kiswah come from the Yemeni King of Humayyur Tabu Karab in 400 AD, at that time the Kabah was draped in woven dried palm leaves (B). The colour of the Kiswah is not fixed, the colour has been red, green and later black, and there has even been a white Kiswah (B). The first kiswah factory was established by the Saudi King Abdul Aziz in 1926 in Mecca, the first Kiswah here took a year to weave and placed in 1927 (B).

2.2 Kiswah Calligraphy

In the Holy Quran embroidery has been mentioned four times, one example refers to the silk garments that will heavily embroidered worn by the pious in paradise (B). The calligraphic panels that are embroidered on the Kiswah first appeared in the 1340's. The verses of the Quran in calligraphy are embroidered into compartments which are supplemented with floral motifs (B). The woven words of the Holy Quran that are on the Kiswah of the Holy Kabah is testament to how important calligraphy is in the culture of Islam. It is important to note that the calligraphy is embroidered in a style known as 'thuluth' where it protrudes out from the surface a about 2cm depth (B).

The process of embroidering onto the Kiswah takes place in several stages, firstly, cotton cords are sewn onto the black silk, the reason for this is to form a curvature for the inscriptions as well as the decorations, thereafter, the gold and silver threads are embroidered over these cords.

2.3 Religion, Cultural and Tradition

The Arabic script that is embroidered onto the Kiswah are extracts of the Holy Quran as it decorates the Kabah which is the most important artefact in the Islamic faith. It is a requirement that the Kabah been kept clean and remain sanctified for worship, and such is the importance of this place that it is befitting to dedicate such time, expense and high quality craftmanship. Therefore, the requirements for such craft lie in the sanctity of the very religion and the words of God which require a befitting aesthetic beautification. This study asks the question of whether or not it is possible to maintain this sanctity and befitting beauty of this most important Islamic artefact through the application of 3D printing technology.

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This change from the traditional, which involves yearlong dedication of the finest craftmanship, to the digital, is required because of the need for economic sustainability and the need to overcome the problem of a dwindling recruitment to the traditional craft guild of the Kiswah.

Therefore, a measure of adherence to sanctity is the approval of those who are responsible for the maintenance and care of the Kabah and the manufacture of the Kiswah covering, as well as Muslims who visit the Kabah.

In addition to the requirement to maintain the religiosity, there are also a functional requirement that the embroidered script can be applied to the silk cloth, retain its structure in the intense heat and be aesthetically pleasing.

It is important to understand the significance and emotional value that he Kiswah has for Muslims around the world. The Kiswah adorns the most sacred site in Islam, the Holy Kabah which is a focal point for Muslims globally.

2.4 Traditional and Digital Craftmanship

The craftmanship is evident in the skill and exquisite art that reflects the magnificence of perfection and accuracy (http://factory.alharamain.gov.sa/index.html). There are over 200 men who work in the Kiswah for 8 months and it is a tradition that goes back centuries. With the proposed introduction of digital methods there is a need to understand the implications that the digital craftsmanship has for traditional craftsmanship and the relationship between the two. Almerbati et al. (2016) bring attention to the idea that the traditional knowledge and techniques can be achieved through digital methods, that in fact they are preserved. It is important that the digital craftsmanship harnesses knowledge that not only produce artefacts that are functional, but also maintain the cultural and traditional (Almerbati et al., 2016). Therefore, it is important in the proposed digitisation of the traditional craftsmanship of producing the Kiswah that the cultural can be replaced by the digital and that the cultural can be put into quantifiable parameters that drive the digital printing equipment (Almerbati et al., 2016).

2.5 3D Printing techniques

Almerbati et al. (2014) examines the affordability and design validity of AM (additive manufacturing) – produced Mashrabiyas using the SAFE values. Specifically, SAFE refers to the Social drivers for production, the Aesthetic and affordability factors, the Functionality, and Economic and Environmental considerations, such as the climate conditions (Almerbati et al., 2014).

Almerbati et al. (2014) say that AM is a more viable solution than traditional methods, especially, in terms of cost, however, they did stress that AM is not properly developed in the Middle East, but with time as materials and technologies develop it will become a more affordable solution (Almerbati et al., 2014).

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There are a number of different issues that are associated with the deposition of material onto fabrics. One of the main problems is the free movement of fabrics which make it difficult to deposit polymers (Brinks et al. 2013) and there is a need for the polymer to penetrate deeper into the fibres in order to achieve firm adhesion (Melnikova et al. 2014).

Researchers are investigating printing polymers directly which will allow hard surfaces while at the same time allowing free movement of the fabric itself (Pei, 2015). Pei (2015) review the Ultimaker 1which is a single-extruder FDM printer which is both quick and accurate. In Pei's (2015) study the key variables included the fabric and the polymer.

3 Methodology

3.1 Feasibility Study

A feasibility study is proposed that is comprised of two main parts, both concerned with establishing the feasibility of the proposed approach of using 3D printing as an alternative method for decorating the Holy Kabah.

Firstly, a comparative study is proposed to establish the differences between the traditional methods and those digital methods being proposed, this is based on the aforementioned ideas of traditional craftsmanship being upheld by digital craftsmanship (Almerbati, 2016) that the traditional craftmanship is something that can be maintained or further through the 'digital craftsman'

The researcher spent time at the *Masna Kiswah* (Kiswah Factory) in Mecca Saudi Arabia, to observe processes and speak with the craftsmen, and to establish numerical information which included the time taken, in terms of man hours, in order to complete one piece such as one *Ayat* (verse), and the size and number of the pieces, this in addition to cost and weight of materials. Moreover, the number of craftsmen, the age of the craftsmen and recruitment numbers of younger craftsmen, was investigated towards justifying the need for an alternative approach.

Moreover, the field study is proposed to establish material and manufacturing requirements that would be relevant in consideration of a new approach. For example, currently the embroidered designs are embroidered onto material which is then fixed onto the silk Kiswah cloth, and a consideration for the feasibility study is what type of material is suitable for the 3D printing and whether it can be adhered effectively to the silk.

The total duration of the proposed feasibility study is 24 months and is divided into three phases. The first eight months are dedicated to research and development. This will involve developing the tests used to test the materials. At this preliminary stage there should be consideration of the material property requirements to be tested and the

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different options for attaching the 3D printed Quranic verses to the fabric. This stage will also involve development of the Arabic script itself in terms of font design, thicknesses, widths, depths, materials and colour.

The following 11 months should include testing the materials and processes in the natural environment that they would be normally on the Kabah. The materials will be attached to a cube-shaped frame and left outside to be tested against the extreme weather conditions that are found in Saudi Arabia.

The experiment variables include different ceramic compositions made with different techniques, different techniques for adhering the ceramic to the cloth, different cloths which in turn are adhered to the Kiswah, different colours and importantly different approaches to 3D printing. Therefore, there will be many different variables being tested at the same time against the constant variables which are the weather and time. In order to achieve this individual panels of samples representing the combinations of the aforementioned variables will be attached to the testing frame.

The feasibility study is a flexible, self-learning process because the results of the experiment will feed into further development during the experimental process. As the results emerge they will be fed back to the development process of the 3D printing and development of materials, which will then be further tested. Furthermore, any problems that are identified during the manufacturing of materials or 3D printing application will also be fed back to the development stage.

The final 4 months of the project will involve evaluation of the findings and recommendation for future development and implementation. At the end of this stage the materials and 3D printing approaches will be established and based on this implementation of the recommended 3D printing technology will be achieved.

3.1.1 Requirements and Test Variables

During the feasibility study which includes the aforementioned experimentation there are a number of requirements that are established as variables related to materials, 3D printing techniques, letter design and letter adherence methods as well as functional, cultural and aesthetic requirements related to materials and processes.

The functional requirements include durability and weather resistance, this especially a consideration because the Kabah is outside and exposed to the elements. The Kiswah cloth is changed once a year, therefore, the materials for its adornment need to durable for that time period. This is especially a consideration because of the weather extremes in Mecca where temperatures range from 30 to over 50 degrees Celsius.

Other functional requirements in relation to techniques and materials include the 3D printing technique used for the embroidered decorative effect on the silk which has to be easy to use, but importantly the technique has to allow the material to be easily applied as well as being strongly fixed to the material. Any considered materials should be light

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enough to remain adhered to the Kiswah cloth and light enough so that the Kiswah cloth can be applied to the Kabah manually.

As for the aesthetic requirements the designs that will be placed onto the Kiswah have to be aesthetically pleasing. The main idea behind the Kiswah is to beautify the Holy Kabah, and therefore, aesthetic beauty is important, something that is currently achieved through the use of gold. Aesthetics also includes the ability of the material to take on colour.

Other requirements include cost because one of them aim motivations is to save on the high costs of materials and labour through embroidering gold silk and therefore, the process of printing and application should also be cost effective, the time taken for 3D printing is another consideration as part of cost reduction. Finally, the materials and production processes have to be both sustainable and environmentally friendly

3.1.2 Material Properties and Application Technique Requirements

The chosen materials and application techniques will have to meet the aforementioned criteria to be considered suitable for adorning the Kiswah covering.

Pei (2015) examined printing materials onto fabrics, particularly 3D structures, and found there are two main factors that need to be considered are the fabric and the applied material. They found that PLA was more flexible than ABS as well as being more biodegradable, and importantly ABS was too brittle. Although there are number of advantages of ABS which include that it is lightweight, easy to machine, easy to colour through pigmentation it is not suitable for outdoor use. According to Pei (2015) ABS has good strength but it is very prone to warping.

Pei (2015) it was found that from three different polymers PLA was the most suitable when printed onto different types of fabrics, these fabrics included synthetic, man-made woven and knit fabrics. PLA was considered successful in terms of its adhesion, small amount of warping, high quality of print and good flexural strength (Pei, 2015). The results of their study also showed that woven cotton and woven polywool fabrics had better adhesion, although it is important to note the study does not address the properties of silk in term of material deposition.

Another material that should be considered Nylon 645, which was deemed by Pei (2015) to have the flexibility and strengths found in PLA and ABS. Importantly, in reference to the application to the Kiswah, nylon is a hard-wearing material and can be dyed. The latter point is important because of the aesthetic requirements of the Arabic scripts. Furthermore, the properties of the fabric depend on the structure of the weave, the fibre, yarn crimp, thread packing and stitch density.

Finally, ceramics is serious consideration as a material for the 3D printing. The 3D printing of ceramics started as a prototype in 2000 to become a reliable production technique over a period of 15 years (Chaput, 2015). Ceramics are now used in a number

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of applications which is testament to their durability. Hwa et al. (2017) looked at the recent advances in 3D printing of porous ceramics and research and development in the area of ceramics is moving towards meeting new needs which includes the need for more colours and new material formulations (Chaput, 2015).

It is important to remember that in the proposed project will involve the ceramic being exposed to the elements, particularly extreme temperatures and the fact that the printed ceramic are fired more than once means they have potential in the hot climate. This idea has been suggested by Chaput (2015) who says that the development of new formulations which include loaded resins which comprise of 20 percent resin and 80 percent ceramic which leads the way for the development of new materials for customers who want the ceramic properties that are resistant to heat, but at the same time want different mechanical properties. This is relevant to the proposed research project as not only is there a need for heat resistance but also mechanical properties which will include adherence and flexibility. Further evidence that using ceramics is suitable for the proposed project is that dense ceramics are now being developed for the aerospace industry (Chaput, 2015). Bechthold (2016) brings attention to the fact that research in ceramic materials have brought new applications from new performative qualities which can be used in today's construction culture. Although there has been much work related to printing small pieces with intricate geometries by artists, there has been little research into printing ceramic architectural components (Bechthold, 2016).

3.2 Design Prototyping

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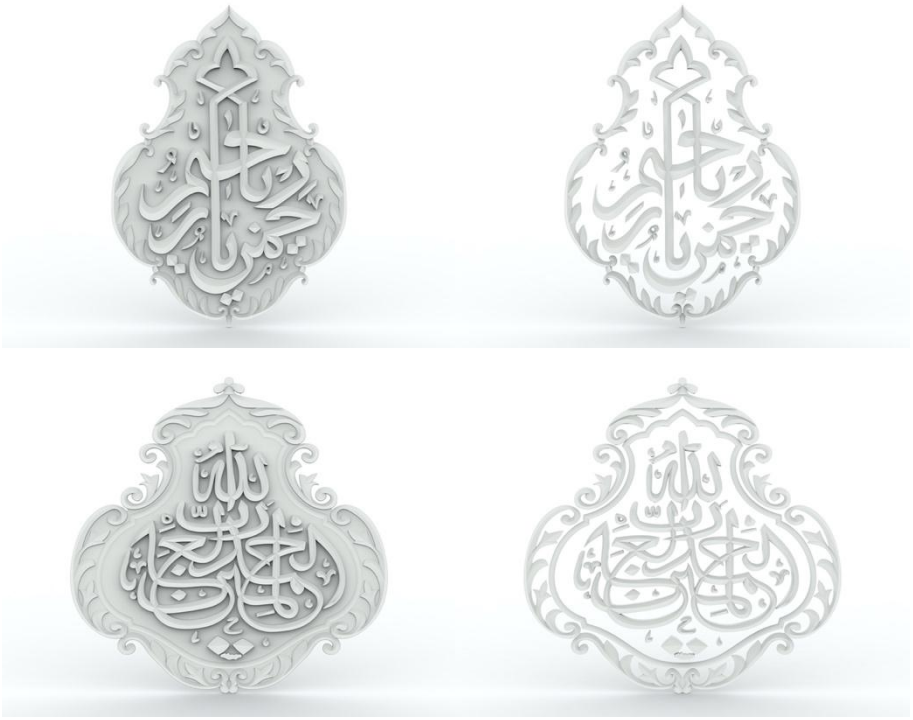

4 CONCLUSION

The paper has addressed the possibility of using digital technology to adorn the Kiswah with Quranic verses retaining the traditional and religious requirements, as well as the functional requirements, especially to withstand extreme environmental pressures. The paper has highlighted the important considerations that need to be taken in relation to craftsmanship, religion and importantly, technique and material considerations. To take a great leap in the use of technology for a traditional and established practice has been shown to require a feasibility study and what that study should involve. This represents a major shift from traditional methods for such an important artefact, but this study has shown how it can be possible and how it should be pursued.

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