

Title: The design of an innovative automatic computational method for generating geometric Islamic visual art with aesthetic beauty

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THE DESIGN OF AN INNOVATIVE AUTOMATIC COMPUTATIONAL METHOD FOR GENERATING GEOMETRIC ISLAMIC VISUAL ART WITH AESTHETIC BEAUTY

BY:

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A THESIS SUBMITTED TO THE UNIVERSITY OF BEDFORDSHIRE IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

AUTHOR'S DECLARATION

I declare this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of Bedfordshire. It has not been submitted before for any degree or examination at any other University.

Name of candidate: Marwah Ibrahim

ABSTRACT

The demands for providing perfect and modern Islamic art patterns have increased, and Arab nations are unable to utilise Islamic art on the computer due to a lack of programs based on generating these patterns. Several studies address the topic of Islamic art from Arab regions and lack endeavoured to integrate computer software to develop or enhance Islamic art designs. With this gap in software to enhance and generate Islamic art, the Geometric Islamic Visual Art program (GIVA) package can support the development of innovative and automated algorithms for generating geometric Islamic patterns based upon pre-defined rules that guarantee the quality and involves key aesthetics metrics. Concurrently, the 'Triangulation' Mixed Methods Design is adapted by first developing a mathematical formula to generate Islamic art, determine a quantitative approach for a procedure of cross-sectional design, and follow a qualitative approach through semi-structured interviews. The software program development is based on a pre-existing mathematical algorithm and adjusted to create the Islamic art pattern of a star. The quantitative approach incorporated convenience sampling from 250 recruited Saudi adults categorised into groups of 50 from five locations. The response rate achieved for this study was 80%. The study adopts a pre-existing questionnaire from a previous study addressing the computerisation of Islamic art. A correlation is identified between previous use of graphical computer programs by the participants to create Islamic art and their intentions to use the new GIVA software. For the qualitative phase, nine experts from the College of Art, Design of King Abdul-Aziz University and Nawaf Company General Contracting were interviewed. They provided an evaluation of the patterns on several aesthetic themes including spaces between patterns, distances and sizes, colour grading, shape diversity, uniqueness, and complexity. The series of eight themes were obtained from qualitative data analysis using thematic analysis, by using Nvivo version 12 user requirements; spatial distance (in design), the eight themes are: distance and size; colour grading; shape diversity; uniqueness of pattern; complexity of pattern; and participant evaluation. With this quantitative and qualitative feedback, computerised generation of the perfect pattern is possible. This study can inform the Ministry of Culture, support the faculty of art and design throughout Saudi Arabia who work on the development of Islamic art using software and further enhance the Islamic art field to make it more popular. The study also suggests a variety of future studies including the use of an alternate formula to produce various Islamic art faster.

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- Ibrahim M, Wood J & Aggoun A (2019). “A Computational Approach for Delineating a Geometric Islamic Pattern.” *Hindawi Publishing Corporation Advances in Materials Science and Engineering*. Under review.

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DEDICATION

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Chapter I. INTRODUCTION

This chapter provides an introduction of the conducted study. This chapter starts by providing an overview of Islamic art patterns and discussing the intervention steps and utilisation of computer programmes to devolve these patterns using mathematical processes incorporated into a variety of computer software programmes. Subsequently, several themes of Islamic arts have been critically reviewed.

Next, the study aims and objectives are discussed. This will help to define the scope of the conducted study. After that, the research questions are defined which helps to provide clear, accurate, and measurable outcomes. Finally, the contributions to the body of the knowledge are put forward.

1.1 RESEARCH RATIONALE AND MOTIVATION

Islamic art has been represented throughout the centuries as having everlasting beauty. The patterns of Islamic art are distinctive in appearance as they involve multiple geometric shapes such as lines, points, surfaces, and polygons. However, Islamic art is not a random combination of shapes. It follows specific rules that are applied to create the patterns (Broug 2013). For instance, monuments throughout the world are decorated with Islamic art to epitomise the specific region and to record famous events or personalities by having Islamic art decorating the walls, doors, domes, and minarets of the buildings. Therefore, without the knowledge of the explicit application of this art, it is impossible to create perfect patterns. Researchers have dedicated their work to discovering the rules of Islamic geometric art for the purpose of exploring this subject matter further. Although a lack of research exists in this area, it continues to represent a unique subject for exploration through computer graphics.

It has been acknowledged that computer graphic design has supported and enhanced the development of complex shapes related to Islamic art patterns. (Kaplan 2002, Kaplan 2000, Crowe 2006, Ettinghausen, Grabar et al. 2001) argue that in this modern era of geometric design, new guidelines have been developed and enhanced through computer applications for the purpose of drawing Islamic art patterns in contrast to ancient times when the Islamic art designs were drawn manually. Consequently, Islamic geometric patterns, which is not limited to the development of the Islamic geometric *study* of patterns in turn, has also been extended through the invention of new patterns.

The visual language of Islamic geometric designs is vast and transcends borders and barriers alike. Therefore, in-depth research regarding Islamic geometric patterns and their use in Islamic culture and architecture is performed throughout this thesis. This study has explored historical architecture including Umayyad, Abbasid, Fatimid, Seljuk, Ottoman, Safavid, and Mughal architectures as well as Islamic architecture in Spain (Abdullahi, Embi 2013). Each of these architectural designs offers uniqueness and specific features. This is a key motivation

for exploring Islamic geometric patterns in detail. In addition, since this is an area of research consistently neglected despite an illustrious 800-year history, this contribution could be used in the development of innovative methods for the design of geometric art (Mantecón 2004).

Even though the integration and simulation of the mathematical process using a computerised technique can enhance the Islamic art patterns, other researchers still argue that such a line of research remains under-researched and underdeveloped. In connection with the development of Islamic arts using computerised techniques, (Rasouli, Bastanfard et al. 2008a) suggested that the current research can be categorised into both the development of an algorithm to draw the design and image processing related to how the geometric patterns are analysed and reconstructed. Therefore, this research has explored the historical and current Islamic geometric designs to support the innovation of computational designs to enhance the visual effects and to portray new images of Islamic design. Additionally, this research has assisted in the education of the Islamic culture to better define the identity of Islamic art.

Numerous Islamic art designs exist that are generated manually either worldwide or in Islamic sacred sites such as Saudi Arabia. These examples show a lack of applied technological techniques, including ineffectiveness when utilising diverse modern technology such as computer programs to create and improve the designs. Therefore, it is necessary to conduct this study to develop an automatic algorithm for the generation of geometric Islamic patterns. In addition, there is a lack of professionals and teachers nationally and internationally who cover the various aspects of Islamic arts through both manual and modern approaches for the improvement of the ancient art and discovery of new methods. As Saudi Arabia is where the religion was founded and as it remains the crucial geographical point for all Muslims at the sacred places of Mecca and Medina, most holy places in Saudi Arabia desperately need decorating with Islamic art. This deterioration of the Islamic art patterns drives the urgency to address this topic in order to develop and improve the existing manual arts (Al-Senan 2015).

According to the experts in Islamic art from the College of Art and Design at King Abdulaziz University, the Islamic arts as supported by the faculty are very rare and need to be expanded and further developed to enhance the knowledge and understanding of the art form to improve the Islamic arts overall. Therefore, the demand is increasing for the provision of perfect modern Islamic art patterns for sacred places as well as museums, houses, schools, and public places.

Several studies address the topic of Islamic art patterns formulated manually to modify the modern patterns and improve the ancient Islamic art design. Despite recent improvements in the techniques dedicated to computing Islamic art design, there is still a shortage of studies solely dedicated to the topic, especially in collectivist nations. There is also a lack of studies addressing this issue in developing Arab countries, including Saudi Arabia. This requires enhancing the old Islamic art patterns using existing or new software programmes. Therefore, this thesis first identifies the gap in the literature through a comprehensive review which supports a better understanding of the development of new software tools that provide a front-end for generating Islamic art patterns.

1.2 AIM AND OBJECTIVES

This study aims to develop an innovative and automatic approach for generating geometric Islamic patterns based upon the pre-defined rules that guarantee the quality of the produced pattern while considering aesthetic metrics in a manner that is easily implemented by individuals. The developed approach aims to save on costs in terms of the consumed time and resources while avoiding the need for experiences to produce geometric patterns that meet the required standards of aesthetic and quality. Moreover, enhancing the flexibility level is one of the core targets as the approach can be implemented over several platforms and delivered as an executable file to the end user.

To achieve the study aims, a set of objectives have been defined. These objectives have been grouped into three stages and defined as follows:

The objectives in the first stage aim to define the research gaps and end user requirements. The first stage helps to highlight the issues that need to be solved and the obstacles that must be overcome. In addition, it provides a clear expectation of the end user requirements and needs. The addressed objectives for this stage are:

- To investigate and evaluate the literature on the existing approaches for generating geometric patterns and to define the capabilities and limitations of each approach.
- To conduct a study that aims to define the end user needs and expectations from this approach.
- To conduct a literature review and to meet experts in order to define the metrics, features and rules that help to guarantee the quality and aesthetic of the geometric Islamic patterns.

The second stage aims to develop an approach that is capable of overcoming the defined limitations of the previous approaches and to generate the desired geometric Islamic patterns based on pre-defined rules in a manner that guarantees the quality of the produced pattern. It

also considers aesthetic metrics and can be implemented by individuals who are not experts in either the arts or IT. There are two objectives are addressed in this stage:

- Develop criteria to ensure that the aesthetic of the geometric Islamic patterns is preserved.
- Propose an approach that generates geometric Islamic patterns based on pre-defined rules that guarantee the quality of the produced pattern while considering the aesthetic metrics and how easily the approach is implemented by individuals.

The third stage aims to validate the developed approach and to provide reliable and accurate evidence that the developed approach is valid and capable of performing as expected. This stage has three objectives:

- To develop an application (prototype) for the purpose of generating geometric Islamic patterns based on the proposed approach.
- To test the developed prototype in order to provide evidence in terms of performance and to assess the prospective usefulness, behavioural intentions and ease of use of the developed prototype.
- To produce theoretical and practical implications to further advance the existing knowledge in the domain of computer science.

1.3 RESEARCH QUESTIONS

The following describes the key questions addressed throughout this research. Defining the research questions helps to provide clear and accurate answers which helps, in turn, to fulfil the aim and objectives of the conducted study.

- What are the existing approaches for generating geometric Islamic patterns?

This question aims to investigate and evaluate the existing algorithms proposed by other researchers for generating similar patterns, although the algorithm under review may not be restricted to Islamic art. In addition, the answer identifies the limitations, obstacles and challenges to support the attempt to overcome these limitations. The answer to this question was achieved by implementing a critical literature review.

- How can a computer be used for generating an accurate and aesthetic geometric Islamic pattern?

The answer to this question is approached via proposing, implementing, testing and improving a novel and efficient algorithm that can generate geometric Islamic patterns while also considering the Islamic art rules and aesthetic. However, multiple sub-questions must be answered first.

- What are the core features (metrics) of geometric Islamic patterns?

This question aims to provide a comprehensive evaluation of the features that distinguish geometric Islamic patterns as well as understanding the aesthetic aspects. The answer to this question was achieved via investigating the literature and asking various experts.

1.4 MAIN CONTRIBUTIONS TO THE BODY OF KNOWLEDGE

The conducted study provides a set of contributions to the body of knowledge:

- Developing a critical study that investigates the existing approaches that have been developed in order to produce geometric Islamic patterns. This study highlights the used methods, features, weaknesses, and limitations of the studied approaches. In addition, this study illustrates how these approaches can be improved.
- Developing a criterion that can be used to categorise and evaluate geometric Islamic Patterns in terms of aesthetic. This helps to guarantee the quality of the generated patterns.
- Highlighting the need for proposing an approach that is capable of overcoming the previous approaches' limitations while meeting the end user needs.
- Developing a new approach that generates the desired geometrics Islamic Patterns automatically while guaranteeing the aesthetic and quality of the produced patterns.
- Developing an application that applies the developed approach which helps to validate and verify the application in the real-world in addition to providing more knowledge in terms of performance, effectiveness, and efficiency.
- Defining the study limitations and providing a guide for the future work which will help to apply our contributions to the body of knowledge.

1.5 STRUCTURE OF THE THESIS

Chapter II: Research Methodology

This chapter outlines the entirety of the methodology that has been implemented to guide this study. The chapter concludes with a graphical research model that depicts the different phases of the research process applied. The protocol of the three studies is also presented separately.

Chapter III: Literature Review

This chapter displays an overview of the literature. It also provides a background that focuses on the history of Islamic visual art as well as the current knowledge of the existing approaches used for generating geometric patterns. This chapter also examines and critically assesses contemporary Islamic themes within a world-wide context and contextualises the present research within the previous literature.

Chapter IV: Quantitative study

This chapter outlines the quantitative data analysis used to analyse the numeric data from the univariate, bivariate multiple variants, in addition to the association and correlation approaches. In addition, this chapter also displays the descriptive statistics computed to describe the characteristics of the sample. In addition, the chapter presents other characteristics relevant to the developed software.

Chapter V: Qualitative study

This chapter presents the themes relevant to the hypotheses and categorises the priorities. It also outlines and categorises the themes that emerged that are significantly relevant to the Islamic arts. Furthermore, this chapter integrates the findings drawn from the quantitative and qualitative data analysis for discussion and interpretation in terms of the

literature and wider knowledge to produce the final software product for the study that is intended to be launched in the market.

Chapter VI: Developed Approach

This chapter combines the Chapter III outcomes (identified gap) and the findings from Chapters III, IV and V in order to define the specifications and design the developed artefact in detail. In addition, this chapter discusses the developed prototype in terms of the specifications, design, and its implementation.

Chapter VII: Results and Discussions

This chapter evaluates the implemented tests that have been conducted in order to measure the performance of the developed prototype in terms of the time and resources used. In addition, this chapter studies the end user experience experiments to prove that the developed prototype works as expected.

Chapter VIII: Conclusion and Future Work

This chapter highlights the findings from the research by addressing the strengths and limitations of the study and suggesting recommendations for future research, future research policies consideration and future research practices.

1.6 SUMMARY

This chapter has illustrated the main pillars of the conducted study. The chapter started with the research rationale and motivation which provides more knowledge and better perception of the subject and the investigated issues. Then the research aim, objectives and questions are stated in a clear and accurate way which facilitates achieving the study aims. It also provides clear, accurate and reliable findings. Finally, the main contributions to the body of the knowledge are presented. The next chapter is focussing on explain and discuss the applied research methodology in terms of the approach, types of data and tools used.

Chapter II. RESEARCH METHODOLOGY

This chapter mainly outlines the research design and methodological approach employed through the mixed methods design (MMD). The aim and objectives of this study are mentioned first before it presents outlines of the methodological strategies used through study starting with the epistemological stance and concluding with the data collection techniques. Next, the chapter depicts a flowchart of the different crucial procedures that helped to implement a simultaneous 'triangulation' mixed methods design.

This study surveyed all the constituent percentages of the procedures of three studies (I, II and III) beginning with the methodological approach through to the details of the methodological procedure of Study I. This was provided in the form of a cross-sectional design that is comprised of the eligibility criteria for the participants, the sample size, and the selected sampling methods. Adding, it has been further discussed that several data collection methods and ethical considerations were considered before describing the pilot study. Study II represents the application of a software programming technique for producing and enhancing the algorithmic equation used to generate a variety of Islamic art patterns. Lastly, the research design of the qualitative study (Study III) has been summarised along with all of the dissimilar components. These components were considered to be crucial to the entire semi-structured interview that comprised the target population, their motivation for choosing the eligibility criteria for the diverse participants, the justification for choosing a purposive sampling technique, the data collection methods and the ethical considerations.

2.1 STUDY AIM

As we discussed earlier, there exist numerous Islamic art designs that are generated manually. These examples show a lack of applied technological techniques including an ineffectiveness when utilising diverse modern technology such as computer programs to create and improve the designs. Therefore, it is necessary to conduct this study to develop an automatic algorithm for generating geometric Islamic patterns that guarantees the quality, reduces the operational cost and avoids dependency on experts. In addition, there are a lack of professionals and teachers nationally and internationally who cover the various aspects of Islamic arts in terms of both manual and modern approaches for the purpose of improving the ancient art and discovering new methods.

This study aims to develop an innovative and automatic approach for generating geometric Islamic patterns based on the pre-defined rules that guarantee the quality of the produced pattern and consider the aesthetic metrics in a manner that is easily implemented by individuals. The developed approach aims to save on costs in terms of the consumed time and resources while avoiding the need for experiences to produce geometric patterns that have an aesthetic and quality. Moreover, enhancing the flexibility level is one of the core targets as the approach can be implemented using several platforms and delivered as an executable file to the end user. In order to fulfil the defined aims, there are a set of objectives that have been defined in Chapter I which help to provide measurable milestones for the study completion.

2.2 OVERVIEW OF METHODOLOGICAL STRATEGIES

(Saunders, Lewis et al. 2009) previously defined the main research technique as the overall strategy of the way that this study has agreed on the research questions properly. (Saunders et al. 2009) highlighted a six-stage process for choosing the most suitable methodologies and

strategies for looking into inquiries, known as the ‘onion’ model. This is based on the concept of ‘layers’ and deciding on broader questions before addressing more detailed questions. The general advantages of implementing the research onion are that the model creates a succession of stages which will separate the strategies for the entire information gathering process which may then be comprehended and delineated by observing which methodological investigation can be characterised. The layers of the 'onion' model are utilised to structure the dialog of why every component was chosen and how these assists in responding to the research questions of this study. (Saunders. 2009) recommended that the specialist must characterise the phases while communicating a viable system. Firstly, the research philosophy requires a clear definition which then produces the beginning point of the suitable research method as defined within the second phase. Furthermore, the following phase mainly focuses on the research strategy while the fourth phase mainly classifies the time horizon. Finally, the data collection techniques are then acknowledged, as overviewed in Figure 2 - 1.

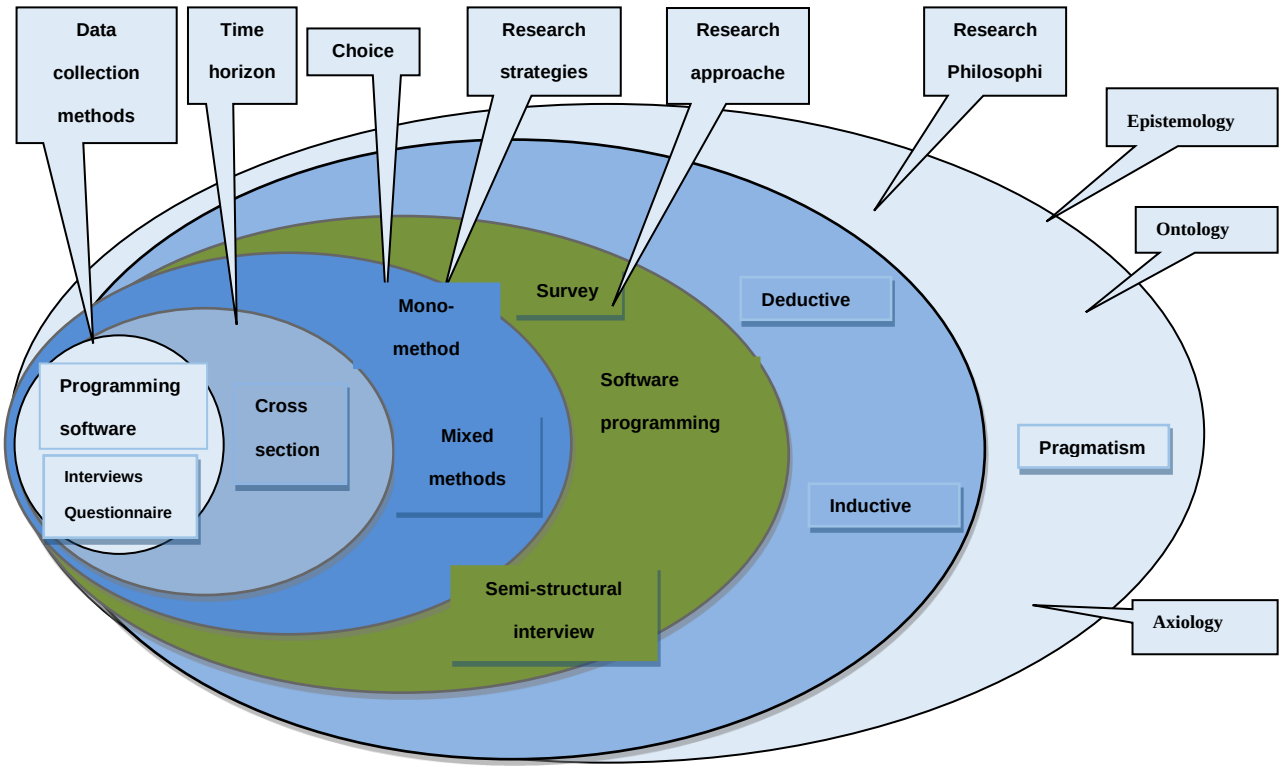


Figure 2 - 1 Research Onion Diagram (Saunders et al. 2009)

As depicted in Figure 2 - 1, the example for the mixed method design of epistemology, ontology and axiology is incorporated as three extra components outside of the principle Research Onion chart. Understanding and picking a theory is a basic advance when arranging and conducting this form of examination. The next section outlines these constituents in more detail.

2.2.1 Mixed Methods Design Approaches

categorised mixed methods design into either the consecutive or concurrent categories. Inconsistent with their suggestion regarding the typology, Creswell and his colleagues further classified each of these two types into three subcategories (Creswell, Plano Clark et al. 2003). Furthermore, regarding all the sequential mixed method designs, the subcategories include sequential explanatory, sequential exploratory and sequential transformative. The three subcategories for the mixed method design also include concurrent nested, concurrent triangulation and concurrent transformative designs. Having reviewed and evaluated each type of sequential and concurrent mixed method designs, this study has adopted the concurrent 'triangulation' mixed methods design. The 'triangulation' mixed methods design is an applicable approach to guide this study and the justification for choosing this concurrent mixed method has been outlined in the next section.

2.2.2 Rationale for Adopting the Concurrent 'Triangulation' Mixed Methods Design

Through our research, a concurrent 'triangulation' mixed methods design is implemented because within this method, the quantitative and qualitative data is collected and then analysed in concurrent way. Likewise, two approaches were developed from the numerous epistemological positions followed by integrating quantitative and qualitative methods. These approaches must be commenced only if there are convincing reasons to carry out such an

approach. Furthermore, (Creswell, Plano Clark 2011) recommended that implementing a mixed methods approach may provide an improved understanding of the whole research problem rather than just the method. The rationalisations for merging quantitative and qualitative approaches in this research are categorised based on the researchers' and methodologist in the mixed methods designs (Bryman 2012, Greene 2007, Castera 1999). First, it improves the accuracy of the data by corroborating the results from different methods (triangulation). Second, relying on this approach helps to complete the picture (complementarily). Third, triangulation offers greater validity through completeness, which refers to the notion in this context that a more comprehensive account of the Islamic arts can be obtained if both quantitative and qualitative methods are utilised. This is related to complementarity, which refers to seeking "elaboration, enhancement, clarification and illustration of the results from one technique with the results from another" (Greene, Caracelli et al. 1989).

2.2.3 A graphical Model for Research Design

A complete graphical model for this research design is depicted in Figure 2 - 2. The reason for the production of this graphical model is to demonstrate the order of the quantitative and qualitative approaches in order to also show the different stages where the different research methods are mixed (Creswell et al. 2003). Having adopted the concurrent 'triangulation' mixed methods design, the two studies are concluded and the quantitative and qualitative approaches are employed to assure, cross-validate or validate the outcomes within a unique research (Creswell et al. 2003).

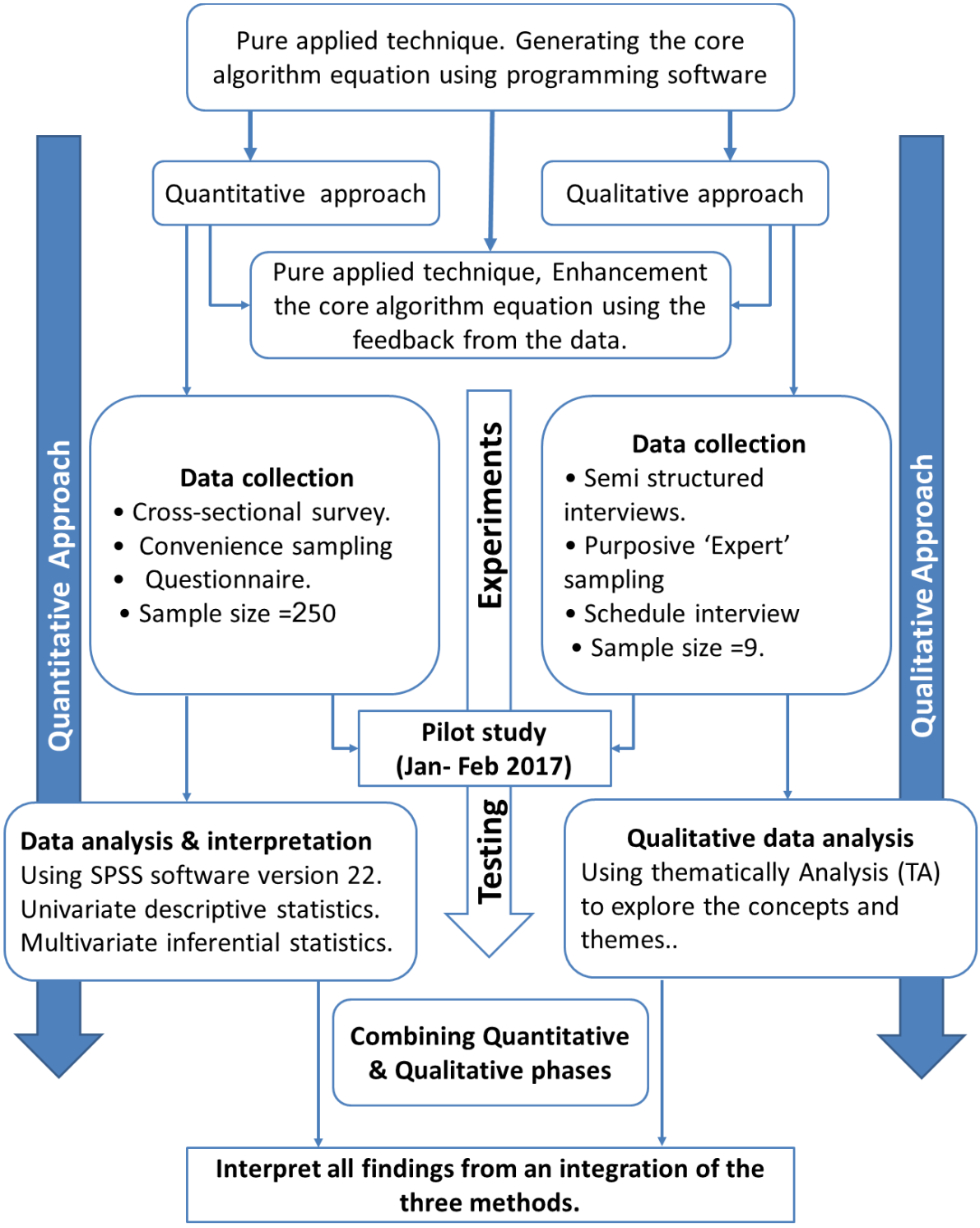


Figure 2 - 2 graphical research model for the concurrent 'Triangulation' technique adapted from (Creswell 2014)

2.3 QUANTITATIVE STUDY

This segment highlights the different characteristics of the quantitative study part of the research design performed using a cross-sectional survey method. This method is comprised of the eligibility criteria for the participants, the participant sample size, and the overall selecting phase of the sampling method. In addition, this part debates using the overall approaches regarding the pre-existing survey questionnaire. This approach is comprised of the back-translation process, the overall recruitment procedure of the participants and the response rate. Importantly, it describes the ethical approval and considerations when depicting the analysis of the statistics and the overall explanation of the quantitative findings within the research.

2.3.1 Population and sample

It is costly and labour intensive to study the entire population of the study in research (Abrams 2010, Thygesen, Ersbøll 2014). A brief explanation of the target population is required before the sample survey can be conducted so then the sampling is as representative as possible of the population under study (Thygesen, Ersbøll 2014). The target population for our research is determined according to the eligibility criteria overviewed in the following.

2.3.2 Eligibility criteria for participating in the survey questionnaire

The inclusion criteria for the participants are as follows:

- Has experience with Islamic art designs for at least three years.
- Has attained some scientific qualification(s) associated with an arts field or the computerisation of programs to develop Islamic arts.
- Employed as an academic staff member, interior designer, architectural designer, artist, or civil servant.

The criteria for excluding participants are as follows:

- Lack of relevant work experience.
- Has not attained any scientific qualification(s) related to the arts.
- Not affiliated with one of the five occupations listed in the inclusion criteria.

2.3.3 Rationale for selecting Jeddah as the data collection location

Jeddah is an extremely famous city within Saudi Arabia. It is one of the largest cities in the whole Saudi kingdom. Furthermore, Jeddah is also considered to be the commercial and banking capital of the kingdom of Saudi Arabia and overall, it is the wealthiest city in the Middle East. A map of the city is shown in Figure 2 - 4 (Al Deweik, Nayer 2016). Jeddah is ethnically diverse and multicultural with a total population of 3.9 million (Rabbat 2012). Furthermore, Jeddah is famous for the popular college of Design and Art at King Abdul-Aziz University. This is one of the teaching institutions that aim to graduate a highly qualified generation equipped with new skills to confront future challenges by providing a strong academic environment.

Since Jeddah possesses several advantageous attributes in comparison with other cities in Saudi Arabia, this study selected Jeddah as the location for carrying out the fieldwork of the pilot and primary study for the quantitative and qualitative phases. Sampling from this city enables the researcher to enhance the diversity of the collected data, which leads to the improved findings to support this research. In addition, no prior studies have addressed this issue in Jeddah. Finally, as the researcher lives in Jeddah, this offers familiarity with the place and people of the region and facilitates the recruitment of the target number of participants.



Figure 2 - 3 Map of Saudi Arabia showing the location of Jeddah

2.3.4 Cross-sectional design

Carlson & Morrison (2009), and Mann (2003) argue that there are three categories of observational study which are i) cross-sectional, ii) cohort, and iii) case-control, each with their own strengths and flaws. Furthermore, these studies can be flexible and moderately easy to implement. Observational studies are mostly used in different mixed method designs. The reason for this is that they can be further joined with other diverse methods such as semi-structured interviews in order to provide a more productive mindset related to the whole phenomenon that is being studied (Mann 2003). Given how cohort and case-control studies are relatively resource-intensive, most researchers select the cross-sectional design specifically because these studies are moderately efficient. These studies cost less for the reason that all of the data needs to be collected in one time frame from each individual group. Numerous outcomes may be studied from the collected data (Mann 2003). In the context of mixed methods designs, (Bryman 2012) suggested that cross-sectional designs primarily represent the quantitative viewpoint while semi-structured interviews commonly constitute the quantitative approach.

2.3.5 Sampling strategy

Sampling techniques are categorised into either random sampling methods (e.g., probability sampling) that are conventionally associated with the quantitative approach and non-random sampling methods which include non-probability sampling (mostly linked with the qualitative paradigm) (Onwuegbuzie, Collins 2007). Furthermore, probability sampling may be categorised as a systematic random sampling, basic random sampling, multi-stage sampling, stratified random sampling, and stratified cluster. However, our study has failed to employ any of these sampling techniques due to not recognising the requirement. This undermined the population target and the sampling frames. Therefore, while this study did not implement the probability sampling technique, the researcher has reviewed and evaluated the alternative sampling method of non-probability sampling in the following section.

2.3.5.1 Theoretical sampling

(Bryman 2012, Creswell 2013, Strauss, A. and Corbin, J. 1998) argue that theoretical sampling is a process that helps the selection of further participants based on the overall outcome of the previously obtained and analysed data. The participants are interviewed by the researcher to gain valuable information about the subject under study in a manner that might expand and refine the existing concepts gathered from the previous participants. It is applied in the grounded theory approach where it is adapted to collect data from interviewees for the purpose of formulating a theory (Thomson). (Bryman 2012, Altheide, Schneider 2013) indicated that in theoretical sampling, the first participant group is purposively selected while the subsequent participants are depending on the primary data analysis. The researchers continue to sample relevant cases until they reach a point where analysing the data no longer produces new information (Bryman 2012, Altheide, Schneider 2013, Creswell 2013). The sampling should conclude when theoretical saturation is reached. The key limitation of this sampling technique is the dearth of instructions that identify and explain how the researcher achieves the

theoretical saturation point. Experience and sophisticated research skills are therefore required for deploying this technique.

2.3.5.2 Convenience sampling

(Tuckett 2004, Bryman 2012) suggests that a convenience sample is appropriate for several pilot studies where the questions within the intended questionnaires are tested to evaluate the key findings of the earlier conducted work. Additionally, a convenience sample may be necessary when it is difficult to gather credible data using probability sampling techniques or when prohibitively complex procedures are required to access population lists (Bryman 2012, Tuckett 2004). This is because it enables novice researchers to collect as much data as possible within narrow time constraints (W. M. Trochim, Donnelly 2001).

The drawback of convenience sampling is that the participants selected are unlikely to be representative of the full population since the sampling frame is anonymous and the researcher may inadvertently exclude a proportion of the population (Bryman 2012, Tuckett 2004). There may be an under or over-representation of a population, resulting in sampling bias. This, in turn, makes it impossible to provide valid generalisations about the population under study leading to skewed findings and unsatisfactory results that lack external validity (Bryman 2012). Despite its drawbacks, convenience sampling remains useful in qualitative research provided that the researchers justify why they selected this method over others (Bryman 2012, Tuckett 2004). Therefore, the convenience sampling approach has been utilised here to recruit the participants for the quantitative study.

2.3.6 Sample size Calculation

Having the sampling frame not recognised and the target population remain undetermined coupled with the use of non-probability sampling for the convenience sampling approach, this study was no longer required to calculate the sample size using a formula inconsistent with

the experts, scholars and methodologists' perspectives (Bryman 2012). Consequently, according to this stance, the defined sample size (50) was selected according to the methodology experts (Bryman 2012, Creswell 2013). The current research recruited participants from different places and determined the sample size recruited from each place.

This study sought out and recruited 250 Saudi adults who were then categorised into one of the 5 recruited locations, including academic staff from the College of Art and Design of King Abdul-Aziz University, consultants who are Islamic interior designers, architecture designers from Nawaf's Company of General Contractors, artists from the Jameel House of Traditional Arts in Jeddah and civil servants from the Saudi Ministry of Culture and Information. Table 2 - 1 provides additional details on these populations.

Table 2 - 1 Participants distribution (organisations)

Organisation	The participants	Number of participants
1. College of Art and Design of King Abdul-Aziz University	Members of academic staff	50
2. Consulting offices for Islamic design	Interior designers	50
3. Nawaf's Company of General Contractor	Architecture designers	50
4. Jameel House of Traditional Arts in Jeddah	Artists	50
5. Ministry of Culture and Information	Civil servants	50
Total sample size		250

2.3.7 Survey Questionnaire Design

To compile the questionnaire for this study, a pre-existing instrument was adapted that measures the key variables of the study. (Segars, Grover 1993) conducted the only study found in the literature that used self-completion questionnaires on Islamic art patterns. There are benefits to using pre-existing questionnaires based on the fact that it is already well

authenticated and tested for reliability. Furthermore, by using a pre-developed instrument, this study is linked to the entire body of similar research which allows for a better comparison to other studies (Creswell 2013, Bryman 2012). Consequently, the current study contributes to its universal acquaintances based on Islamic art patterns by using the instruments developed by other researchers.

The adopted questionnaire used for this study begins conventionally by soliciting the personal and demographic information of the participants and their socio-economic characteristics. The following types of questions are included in the questionnaire: years of working in the Islamic art field, profession/position and whether the potential participants are currently using computer software to create Islamic art shapes. If the potential participants are already using a computer program to create Islamic art shapes, are they satisfied with the results? If the potential participants are using a computer program to create Islamic art, could the potential participants select the utilised software? Based on the potential participants' experience, what are the features and capabilities that need to be supported through the GIVA software? Based on the potential participants' experience, what are the principles that need to be considered through the GIVA software to guarantee the quality of the produced drawing? Based on the potential participant's current knowledge and opinion of Islamic art, what is the likelihood of the potential participant's prospective use of the GIVA program? Using a scale of 5 to 1, with 5 being strongly agree and 1 being strongly disagree, circle the appropriate number for each of the statements mentioned in the questionnaire. If we develop the GIVA software, please indicate the likelihood of your prospective usage of it. Using a scale of 5-1, with 5 being strongly agree and 1 being strongly disagree, please circle the appropriate number for each of the statements mentioned in the questionnaire? (see Appendix A).

The instructions for the participants were presented clearly and the pretested study in phase one of this research was intended to validate each question and to confirm that they were well-written with straightforward formatting.

2.3.8 Hypotheses

Based on the adopted questionnaire, the following 5 hypotheses were established as outlined in Figure 2 - 3.

A. Hypotheses on the previous use of computer programs by the participants

H1: There is a significant association between the participants' level of education and their previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art.

H2: There is a significant association between the participants' occupation and their previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art.

H3: There is a significant association between the years of experience of the participants in the Islamic art field and their previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art.

B. Hypotheses for the basic principles and features of the GIVA software.

H4: There is a significant association between the participants' level of education and their familiarity with the basic principles and features of the GIVA software.

H5: There is a significant association between the participants' occupation and their familiarity with the basic principles and features of the GIVA software.

H6: There is a significant association between the years of experience of the participants in the Islamic art field and their familiarity with the basic principles and features of the GIVA software.

C. Hypotheses on the perceived usefulness of the GIVA software.

H7: There is a significant association between the participants' level of education and the perceived usefulness of the GIVA software.

H8: There is a significant association between the participants' occupation and the perceived usefulness of the GIVA software.

H9: There is a significant association between the years of experience of the participants in the Islamic art field and the perceived usefulness of the GIVA software.

D. Hypotheses on the participants' behavioural intention to use the GIVA software.

H10: There is a significant association between the participants' level of education and their behavioural intention to use the GIVA software.

H11: There is a significant association between the participants' occupation and their behavioural intention to use the GIVA software.

H12: There is a significant association between the years of experience of the participants in the Islamic art field and their behavioural intention to use the GIVA software.

E. Hypotheses on the associations between the utilised computer programs.

H13: There is a significant association between the participants' previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art and their behavioural intention to use the GIVA software.

H14: There is a significant association between the participants' previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art and the perceived usefulness of the GIVA software.

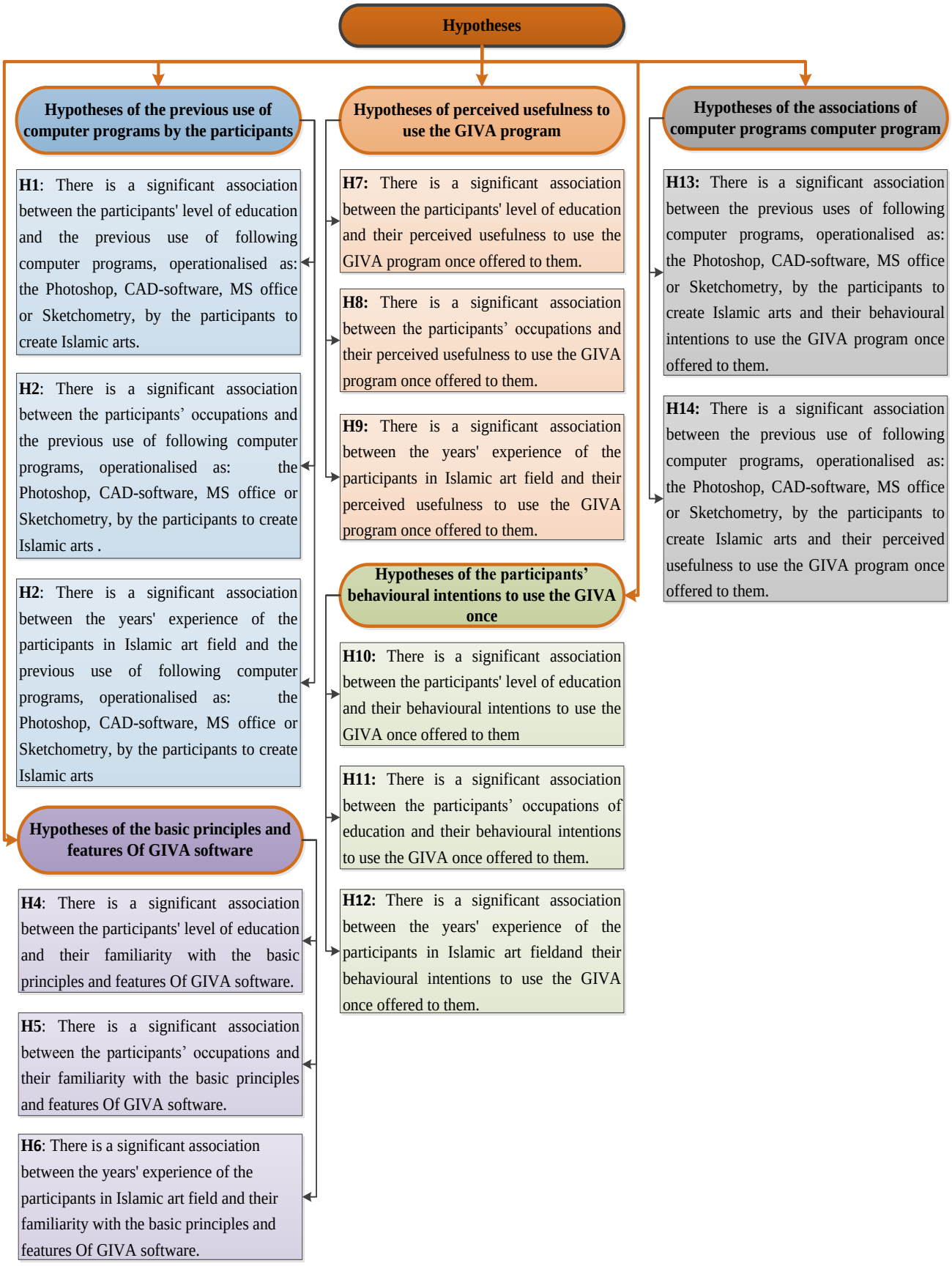


Figure 2 - 4 Outline of hypotheses model.

2.3.9 Administration of the questionnaire

Questionnaires are usually administered by post, email or online. Nevertheless, the postal service in Saudi is unproductive (Sawan, Jeon et al. 2016). While many cities in Saudi have an unreliable Internet service due to weak service providers (Phellas, Bloch et al. 2011), as Jeddah is one of the largest cities in Saudi in size, the government has provided a reliable and fast Internet service. However, despite the assumption that the email or website survey methods are the most practical methods for distributing questionnaires to the potential respondents of this study, some of the participants could not access the Internet. The distribution method was completed through personal supervision by providing the questionnaires directly to the participants through the officials of the selected institutions or organisations.

2.3.10 Pre-notification of participants

(Fowler Jr 2013, Salant, P., Dillman, I and Don A. 1994) suggest that the initial contact with a potential participant should include providing them with an informational notice explaining that they have been selected randomly for an upcoming study. Therefore, all the research participants were selected through the managers of their affiliated organisation with a pre-notification requiring their participation to fill out the questionnaire (see Appendix A).

2.3.11 Response Rate

A survey's response rate is the outcome of separating the number of participants taking part in the survey by the overall number of the potential participants estimated to participate. Furthermore, a smaller response rate may potentially lead to a sampling bias but only if the non-response is uneven among all the participants regarding the outcome. (Visser, Krosnick et al. 1996) suggested that although they have argued that higher response rates might produce accurate survey findings, a few rigorous studies have claimed and assumed that the surveys that have a lower expected response rate may yield more accurate outcomes than the studies with a significantly higher response rate. A response rate of more than 85% represents an overall excellent rate of returned surveys.

2.3.12 Response Rate Achieved for The Complete Study Covering Five Locations

Table 2 - 2 illustrates the response rate of the participants recruited at 5 locations which was 80% for the entire study. The range in the response rate from each recruited institution varied with a minimum of 71% at the Jameel House of Traditional Arts in Jeddah to a maximum of 91% at the College of Art and Design at King Abdul-Aziz University.

Table 2 - 2 Response rates of the participants recruited from five location.

SN	Location	Participant	Incomplete or opt out	Completed			Participants contacted	Response Rate %
				Male	Female	Total		
1	College of Art and Design/ King Abdul-Aziz University	Member of academic staff	5	20	30	50	55	91%
2	Consulting offices for Islamic design	Interior designer	10	30	20	50	60	83%
3	Nawaf ‘s Company of General Contractor	Architect designer	15	43	7	50	65	77%
4	Jameel House of Traditional Arts in Jeddah |	Artist	20	23	27	50	70	71%
5	Ministry of Culture and Information	A civil servant	10	30	20	50	60	83%
Total			60	146	104	250	310	80%

2.3.12.1 Statistical analysis for the quantitative study

The Statistical Package for Social Sciences (SPSS) version 21.0 was obtained in order to do all the data entry and related analysis. Furthermore, the first step mainly includes coding in all the data which is then followed by the data entry after the data collection. Furthermore, all the entered data was then validated by comparing it with the original questionnaires to confirm the accuracy. Likewise, descriptive numerical data was computed to then display the characteristics of the sample based on the demographic data. The frequency statistics were provided as percentage distributions, percentiles, standard deviations, and medians. Ultimately, following the univariate analyses, bi-variate and multivariate statistical tests were then completed using computing cross-tabulations.

2.3.12.2 Research reliability and validity

The questionnaires were reviewed to address issues in the queries that were not easily understood by the respondents during the pilot phase. Since the research participants reliably understood the pilot questionnaire, it was considered to be suitable to provide trustworthy answers across the whole set of questions. In addition, the questionnaire has also been thoroughly reviewed to determine its validity. Furthermore, in order to minimise the other concerns linked with the test's legitimacy, the whole questionnaire was then designed as close-ended in order to limit the responses to include only a progressive response, a negative response or no answer.

2.4 SOFTWARE PROGRAMMING

Islamic geometric patterns are considered to be an essential part of Islamic architecture (Gonzalez 2001, Kaplan 2000). Each geometric pattern is unique and engages with a specific methodology to develop its design (Kahera, Abdulmalik et al. 2009, Kaplan 2002). Some of the techniques have been industrialised to generate automated IGPs such as lines, stars and polygons. These geometric patterns portray the Islamic culture at historical sites and architecturally significant buildings (Ascott 2000, El-Said, El-Bouri et al. 1993, Broug 2008). Our approach aims to develop an innovative and automatic algorithm based on the identified Islamic geometric pattern aesthetics and pre-defined rules that guarantee the quality of the produced pattern while considering the aesthetic metrics.

Software development is the process used to structure all of the necessary steps to analyse, design, implement and test new software. The development of the application in this research follows the five phases of software engineering called the software development lifecycle (SDLC) as shown in Figure 2 - 5.

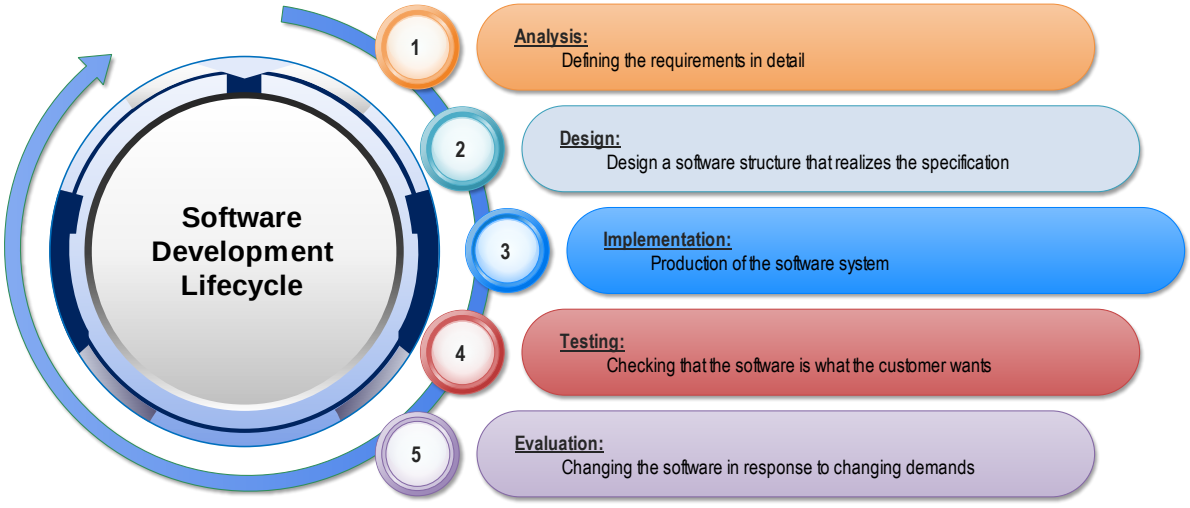


Figure 2 - 5 The software development lifecycle

The following steps were implemented to achieve the SDLC requirements as outlined in Figure 2 – 5:

1. Identify the deficiencies in the current system, interview the existing users, conduct questionnaires, and consult them to determine their requirements.
2. Identify the requirements of the new system by addressing the deficiencies in the existing system to determine the opportunities for improvement.
3. Design the new system according to the requirements and to determine which algorithm performs best.
4. Develop the new system and determine which programs must be installed to implement the proposed system.
5. Test the new system with the end users (public customers and companies) to ensure that the system meets their needs.

As we declared earlier, the literature review investigation and the conducted quantitative study will help to define the limitations of existing approach and the end user needs respectively. This will format the approach requirements. Figure 2 – 6 shows the research work that follows and presents how and when each research instrument will be utilised and for what.

The prototyping approach will be used in this study in to test the developed approach in terms of performance, usability from the end user perspective and functionality. The developed prototype will be used to collect the data from the experts who will evaluate and assess the quality of the geometric patterns produced in terms of quality and aesthetic. In addition, the developed prototype will be improved based on the collected feedback and recommendations.

Besides that, there are a number of experiments that will be conducted to investigate the performance of the developed prototype in the real world. The conducted semi-structured interviews have been explained in detail in Chapter V while the developed prototype and conducted experiments are discussed in Chapters VI and VII respectively.

Practically, the prototyping of the developed approach and the conducting of performance tests will help to discover unexpected errors that might occur and potentially prevent practices that might influence the quality and aesthetic of the produced Islamic geometric patterns. The conducted tests will help to measure the end user experience which reflects the satisfaction and usability of the tested software. By combining the performance measurements that have been collected from several experiments covered more than one configuration in terms of hardware and complexity pattern with the participant responses after the testing of the developed prototype, we will be able to prove that the developed approach and prototype have meet the defined requirements. Moreover, this will prove that the core objectives have been fulfilled and that the aims of the study have been achieved.

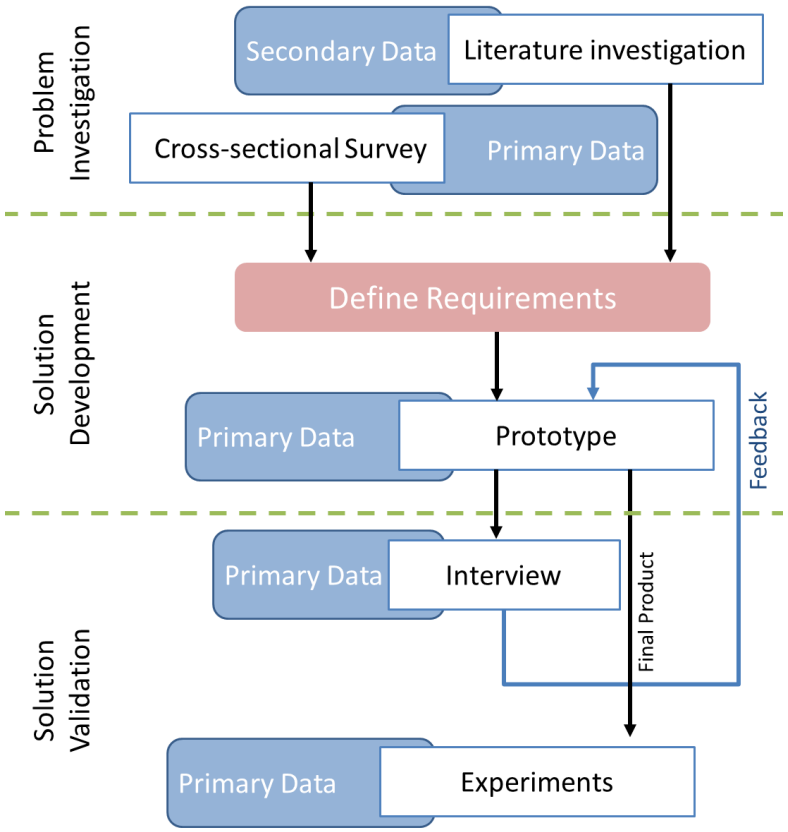


Figure 2 - 6 Research development and research instruments utilisation

2.5 QUALITATIVE STUDY

This section presents the research design and the methodological approach used within the qualitative study (Study III). In addition, it also highlights the components that are appropriate to semi-structured interviews comprising of an overview of the target population. It also highlights the entire rationale used for choosing the overall eligibility standards for the participants. In addition, it then discusses the sample size reflections along with the rationale for choosing the purposive sampling method. Furthermore, this chapter also demonstrates the following three processes: 1) the data gathering methods in the semi-structured interviews, 2) the recruitment process regarding the research participants and 3) the whole translation procedure within the qualitative protocol. Finally, this chapter also presents the ethical considerations which come before outlining the method of the qualitative data analysis used within applied research such as the social sciences, known as thematic analysis (TA).

2.5.1 Participants

The research participants in Study III included experts in Islamic art belonging to the University of King Abdul-Aziz and Nawaf's Company of General Contractors. The conducted interviews with nine participants took a place at the campus of the University of King Abdul-Aziz and done by the researcher.

2.5.2 Eligibility criteria for the participants taking semi-structured interviews

All the interviewees selected for this study must meet the following three criteria:

- Experience of more than three years in the field of Islamic art design. Three years was identified as a recognised period for an expert in any field (Bryman 2012).

- They hold a staff position as an Islamic art designer at King Abdul-Aziz University or in Nawaf's Company of General Contractors. These teams were selected as being experts in the field of Islamic art design.

A participant is disqualified from participating if they meet the following criteria:

- They have less than three years' experience in the field of Islamic art design.

2.5.3 Sampling strategy

Non-probability sampling techniques are classified into theoretical, convenience 'accidental' and purposive 'judgmental' sampling methods (Bryman 2012). (Creswell 2013) argues that sampling in qualitative research is not straightforward due to the numerous ambiguities and overlaps between theoretical and purposive sampling which are exchangeable approaches in the literature (W. Trochim 2006). As in Section 3.10.5 discussing the sampling strategy for Study II, this study has adopted purposive sampling which has been justified in the following section.

2.5.3.1 Purposive sampling

The final type of non-probability sampling technique is purposive sampling, also referred to as selective sampling. This technique is a widely used sampling technique within qualitative research because it refers to the overall selection of the participants centred on the main researcher's opinions rather than being indiscriminate. Furthermore, subjective sampling is a major characteristic of the population that is being studied regardless of the fact that the sampling is not randomised (Babbie 2010, Bryman 2012). Therefore this method of sampling is considered to be an extremely adequate technique that is important when obtaining different information on the participants who have retained knowledge about the issues that is being researched (Bryman 2012, Mack 2005, Onwuegbuzie, Collins 2007). Even though purposive

sampling may emerge as more scientifically applicable than convenience sampling, it remains dependent on a deep comprehension of the processes under investigation. Moreover, the selection of the sample set through purposive sampling is likely not related to bias because the findings from the studies cannot be applied in a widespread manner to other people.

Different types of purposive sampling approaches have been identified depending on the scope of the qualitative study, namely extreme case sampling, maximum variation sampling, homogeneous sampling, snowball sampling, criterion sampling, critical case sampling, total population sampling and expert sampling (Bryman 2012, Creswell 2013, Tuckett 2004). The maximum variation sampling (heterogeneous) enables the capture of a wide range of views, perceptions and thoughts from the participants which supports achieving a greater understanding of the topic that would otherwise be impossible to obtain through a random sample. The maximum variation sampling is relying on exploiting the greater insights into the phenomenon under investigation by an exploration from all angles. This can guide the researcher in the exploration of the common themes evident in the sample. However, while maximum variation sampling makes it difficult to achieve a high level of reliability, less bias and the generalisation of the research findings, the approach remains highly recommended by researchers and methodologists (Bryman 2012, Creswell 2013, Tuckett 2004). Therefore, purposive sampling in the context of the maximum variation sampling approach has been utilised here to recruit the participants of the qualitative study.

2.5.4 Sample size

Determining the sample size in qualitative research remains debatable amongst methodologists and researchers (Bryman 2012, Creswell 2013). (Morse 2000) suggested that the sample size is hugely dependent on the overall quality of the data, the investigated topic itself, the scopes of the study, the amount of valuable information that is received from each of the interviews, the number of interviews per interviewee and the qualitative method and

study design utilised. Likewise, (Bryman 2012) largely agreed with Morse when arguing that this approach is sometimes unsatisfactory for novice researchers due to the deficiency of consensus among the practitioners. Nevertheless, the guidelines for selecting the sample in a qualitative study exists based on the research design or method. This may be the only feasible approach for qualitative researchers (Onwuegbuzie, Collins 2007).

These guidelines for the sample size in qualitative research are recommended by (Bryman 2012) and (Creswell 2013). (Morse 2000, Morse 1994) suggests approximately 30 to 50 participants for ethnographic studies and 30-50 who will be part of interviews involved in grounded theory. (Creswell 1998) suggests that studies should have only 20-30 participants. For other phenomenological studies, the same study suggests there should be 5-25 interviews while on the other hand, (Morse 1994) recommends 6 or over. Furthermore, (Patton 1990) has argued that there are no clear rules that can be used to determine the adequate sample size within different qualitative research approaches. Additionally, it may be significant to determine this factor by looking at the other factors, for instance the resources available, the time allotted and the study objectives. Not at all like the potential computation technique used to decide on the example measure for quantitative research, there is no useful way to deal with the quantity of participants who ought to be enlisted for a qualitative report (Baker, Edwards et al. 2012). Taking these guidelines into consideration, the qualitative data was collected for this study from nine Islamic art experts all working at either King Abdul-Aziz University or Nawaf's Company of General Contractors. The interviews were face-to-face and lasted approximately one hour. A semi-structured interview schedule was devised specifically for this study.

2.5.5 Semi-structured interviews

A semi-structured interview is a subjective method that consolidates some of the pre-decided arrangements of open-ended queries with a blend of different spontaneous inquiries that may empower the interviewer to then examine the point under clear investigation. Some of the pre-decided questions provide consistency and this empowers the interviewer to pick up control. The respondents at that point have the autonomy to voice their conclusions (Bryman 2012, Gill, Stewart et al. 2008). This type of interview enables an in-depth exploration of the participants' experiences and this can enhance the reliability of the collected and analysed qualitative data. Semi-structured interviews are the most common form of interview and they are frequently used in qualitative studies. This method can be used for sensitive topics as the audience is specifically targeted. This can allow for more personalised and comprehensive answers. The semi-structured interviews may perhaps be concentrated and very tedious, primarily in light of the fact that they require interviewing skills and a longer period for preparing and readying on the interviewers' side (Bryman 2012, Gill et al. 2008).

2.5.6 Semi-structured procedure and interview schedule

Nine semi-structured interviews were conducted from June through to July 2017 using the interviews questions below. The nine experts in the Islamic arts were interviewed from the two recruited locations (King Abdul-Aziz University and Nawaf's Company) at an agreement place, as mentioned in Chapter 6, Section 6.2. The questions were formulated from the assessment of the interview plans that were adopted in prior studies that lectured on the Islamic Arts (Abas, Salman 1992, Abas 2001, Kaplan, Salesin 2004, Marranci 2004, Lydon 2009). The previous interview questions exemplify the wider questions on Islamic art.

2.5.6.1 Semi-structured interview questions

1. What do you require of the GIVA software? What features would you like to be in the GIVA software?
    - Probe:
    i) What are the features that you would like in the GIVA software?
2. What do you think of the spaces between the patterns and shapes?
    - Probe:
    i) Are the spaces too wide, too thin or just right?
3. What are the distance and size differences between the shapes in this pattern?
    - Probe:
    i) Are there space and size differences? What is different about them?
4. What do you think of the colour grading of the patterns? Do they link in any way?
    - Probe:
    i) Do you like the colours used in the patterns? Do they match?
5. Is there shape diversity within the pattern?
    - Probes:
    i) Is there much diversity in this pattern?
    ii) Are there a lot of different shapes in the pattern?
6. Is the design of this pattern unique?
    - Probes:
    i) Have you seen this pattern before?
    ii) Does it have features that are found in other art?
7. Is this pattern complex? If so why?
    - Probes:
    i) Does this pattern look complicated?
    ii) Does it look like it is hard to make?
8. What are your overall perceptions of this pattern?
    - Probe:
    i) What do you think of this pattern? Is it good?

2.6 VALIDITY AND TRUSTWORTHINESS OF THE PRODUCT

The concluding step of this research was to present the feedback of the participants to the researcher on the final products based on their views and suggestions from the interview sessions.

The final products were sent to the participants via email in a zip file so then they could view all of the designs and provide their feedback. The researcher maintained all the participants' emails confidentially and in compliance with the ethical considerations and regulations. The intention of the final stage was to then identify the satisfaction of the designs as Islamic art based on the expert's opinion.

2.6.1 The back-translation process

The study allocated three Saudi professional bilingual certified translators (ST1, ST2 and ST3) to meet the requirements established by the WHO. The three points of consideration were: 1) having Arabic as their first language, 2) knowing something about English-speaking cultures and 3) knowing the terminologies used in both Arabic and English. The first two Saudi certified translators (ST1, ST2) were appointed to translate the pre-notification letter, the Participant Information Sheet (PIS) and the Informed Consent Form (ICF) for the quantitative study using the survey questionnaire and the qualitative study using the semi-structured interview questions. The same two also translated the survey and interview questionnaires from English into Arabic. A third professional translator (ST3) was allocated to translate the two new versions of the questionnaires for both the survey and interviews (Arabic version) into the source language (English version). The researcher and three translators held a meeting to review each translation to reconcile it into a single version. The final versions of both the questionnaire and interview questions were utilised during the last stage of pre-testing before completing a final edit in order for it to be used in the fieldwork.

For the processing of the nine Arabic interview transcripts, the researcher relied on ST1 to receive the five interview transcripts via email and the remaining four were sent to the ST2 for them to complete the translation to the English Language. After receiving the English-translated transcripts from ST1 and ST2, the researcher emailed the two translated interview transcripts to ST3 for translating the English version back into Arabic. Finally, the researcher compared the four back translated and non-translated versions of the interview to make sure the data was accurate.

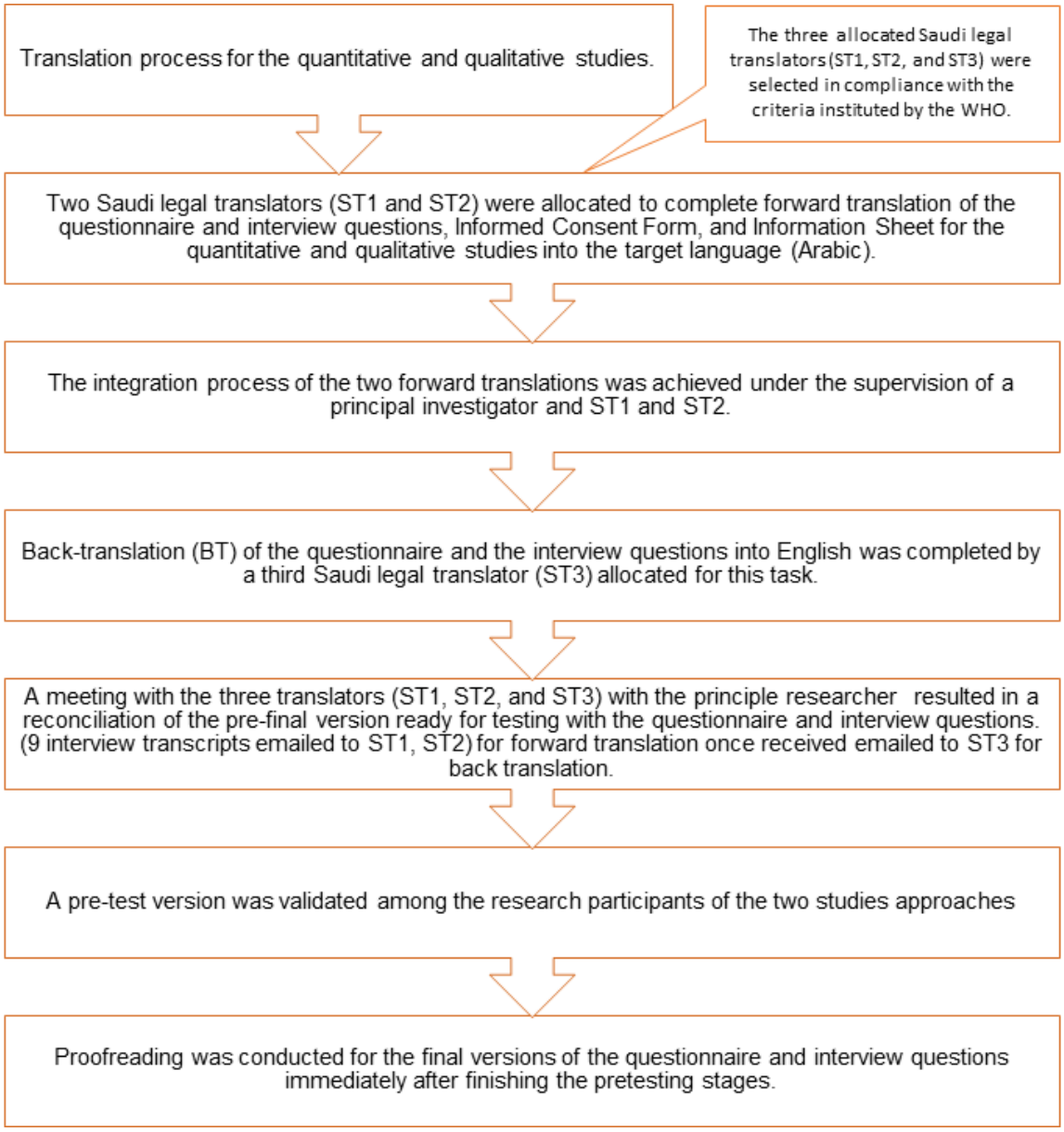


Figure 2 - 7 Back-translation (BT) process (adapted from (Epstein, Osborne et al. 2015).

2.6.2 Ethical considerations

Ethical approval for this research was granted from University of Bedfordshire in the UK (see Appendix D).

2.6.2.1 Consent form

All of the participants in Study II were provided with informed consent forms along with the survey and instructions for completing the responses (see Appendices F and H). The participants taking part in the Study III interviews were provided with information papers and fully detailed consent forms along with the instructions for the study (see Appendices E and G). The participants were asked to read the information sheet and asked to take part in the conducted study, and that by signing the consent form. This confirmed that their details would remain private and that they had the power to withdraw from the study at any time if they wished to. Furthermore, the nine experts who participated in the individual interviews were asked for consent for the interview being audio-recorded. They were then assured of confidentiality and the privacy of the provided data (see Appendices F and H).

2.6.2.2 Anonymity

All of the participants were given full anonymity and confidentiality when the information was collected about the participants. They were ensured that questionnaire responses and audio-recordings of the interviews will not be shared at all and that after the information has been put into the program and encoded, it will be permanently removed. The interviews were identified by case number and date instead of by name. Pseudonyms were used in the writing and transcripts while the participants were not identified in any report or publication.

The quantitative data that was collected was then analysed and afterwards stored confidentially using a password-secured SPSS format. Similarly, the qualitative data from the

individual interviews was transcribed and given the case numbers that are appended. The NVivo software was used to analyse the transcripts which were also password-secured. All of the documents were maintained in a locked cabinet at the University of Bedfordshire. Once the data collection was complete, all identifying information about the participants was destroyed.

2.6.3 Data analysis for the qualitative study

Before embarking on the data collection techniques in our research, the researcher minimised several technical concerns that aim to guarantee the quality of the overall data collection and data analysis. The issues considered were the procedures for recording the whole interview followed by the data transcribing, in addition to the use of qualitative data analysis software.

- For recording the dialogue of interviews, a high-quality voice recorder was implemented which made it simple when transcribing.

- The principal researcher transcribed all the interview recordings verbatim and verified the various transcripts that came up against the first recording in order to make sure that it was accurate.

- The help of the computer was needed when using the qualitative data analysis software package, NVivo. Version 12 was adopted to assist the data management and analysis process. This facilitated coding as well as the organisation and rapid retrieval of information.

In terms of qualitative data analysis technique, the Thematic analysis (TA) was selected as it is one of the many cluster methods that highlight the identification of patterns or ‘themes’ across a dataset. This approach is widely used throughout the social sciences, behavioural studies and applied sciences. One advantage of TA is that it is theoretically flexible and appropriate to the overall research questions which are linked with peoples’ experiences,

perceptions, and views. Furthermore, thematic analysis (TA) is mainly accomplished through the process of coding the data into six different phases in order to establish various meaningful patterns. Furthermore, these TA phases may also include familiarisation with some of the data, the overall generation of the original codes, the process of searching for various themes among the codes, reviewing all of the themes, defining and naming all of the themes and producing the final report. The researcher is tasked with identifying patterns through the difficult process of data familiarisation, data coding and the development and revision of the whole theme. Furthermore, the following discusses the six-phase process in detail as summarised by (Braun, Clarke 2006) and presented in Figure 2 - 8.

1) Familiarisation with the data is key to TA. To facilitate this task, the researcher may perform as the interviewer to then collect the qualitative data that is required. The researcher then transcribed the interviews from the recordings through the continuous re-reading of the data to then become familiar with its content.

2) Coding was achieved with the software program, NVivo 12. The researcher generated succinct label codes in order to then identify some of the key features within the data that may potentially be relevant to answering all of the research questions. Subsequently, the researcher may also code the whole of the dataset and collate all the codes and the relevant data extracts for use in a later stage of the analysis.

3) Searching for themes, the researcher can examine the codes and then collate the data to then identify the significant broader patterns to determine their meaning and the potential themes.

4) For reviewing the themes, the researcher refined the devised themes by collapsing some of the themes into others while other themes were broken down into smaller components. For this consolidation process, the researcher sequentially reviewed the data through two levels:

Level 1: Revise at the level of all the coded data to ensure that it fits each subject coherently.

Level 2: Review at the level of the themes in relation to the data corpus by using a thematic map to visualise the relationships.

The researcher reviewed how the patterns and themes helped to answer the research questions and explain any unclear findings which resulted from testing the hypotheses. If the analysis appeared to be imperfect, the researcher revisited the data and searched for new themes.

5) The researcher defined and named each theme based on which aspects of the data were captured and the theme's significance.

6) The last stage contains the final analysis and written report. The prepared document involved the themes that aim to provide a meaningful contribution to the understanding of the excerpt from the transcript of the interview within the data. This is in addition to contextualising the overall analysis in relation to the pre-existing literature. While these phases occur in chronological order with one building on the previous, the analysis process is recursive with a returning focus between the different phases.

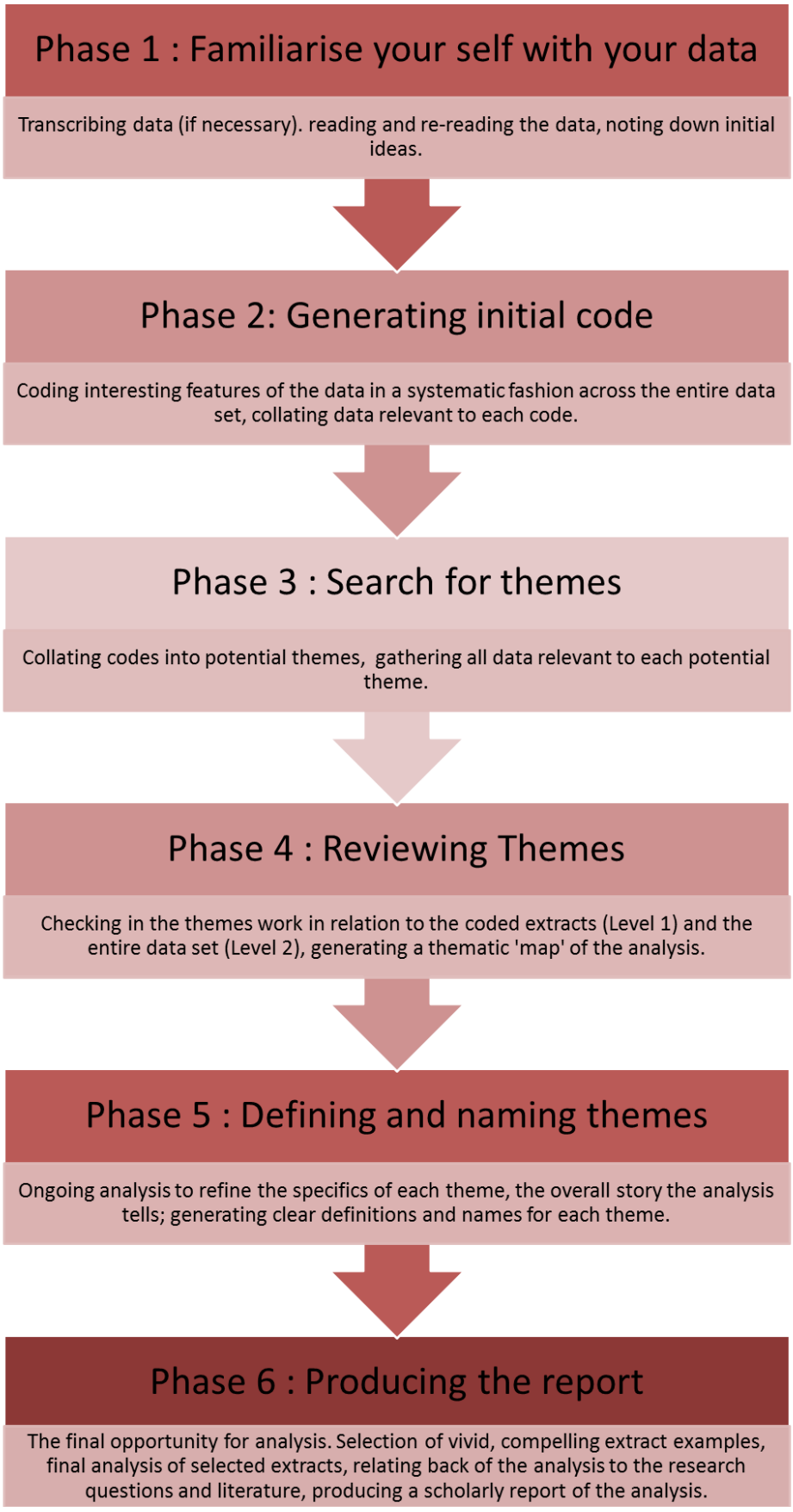


Figure 2 - 8 Summary of the six phases of thematic analysis (Braun, Clarke 2006)

2.7 SUMMARY

This chapter overviewed the research design and the methodological approach employed by the current study. It presented the aims of the study followed by a discussion of the concurrent 'triangulation' mixed methods research design that was utilised. In addition, the chapter discussed the conducted quantitative and qualitative studies in detail. In addition, the need for software programming was discussed in terms of importance and how it will be utilised through this research. Finally, the validity and trustworthiness have been discussed.

Chapter III. LITERATURE REVIEW

This chapter presents a review of the aesthetics of Islamic geometric patterns including the background on the current knowledge and the contemporary themes from the published literature both globally and regionally. This chapter also addresses the topic of Islamic aesthetics in terms of the understanding of the geometric patterns. The characteristics of *shape grammar* rules, which indicate the algorithmic systems, have been employed to analyse the present designs and to produce new patterns (Cenani, Cagdas 2006, Cenani, Cagdas 2007). Furthermore, the historical background of geometric ornaments in Islamic traditions is provided along with the possibilities made available through the mathematics of symmetry.

The literature review first includes the identification of literature on the aesthetics of geometric Islamic patterns and their examination while providing a critical evaluation of these studies. Second, it covers a review of previous computational approaches, which help to provide a critical evaluation and better understanding of the mechanisms, methods and targeted patterns and how to overcome their limitations. Finally, this chapter discusses some of the models in order to reach the point of a suitable theoretical approach that could guide this study to answering the research questions.

3.1 INITIAL COMPUTERISED LITERATURE SEARCH

This literature review collected studies published from the 1980s until 2017 using the University of Bedfordshire's search engines specifically the Key Databases available in Computer Science IEEE Xplore (IEE/IEEE). E-Journal Collections Springer Link and other databases including the Computer and Information Systems Abstracts (via ProQuest) and Computing Database (via ProQuest) were also used.

A keyword search was employed to obtain all of the relevant studies with a focus on computer-generated geometrical design, shape grammar rules, geometric Islamic ornaments, Islamic patterns and Islamic geometric patterns. Likewise, the key terms were grouped into "layers" and Boolean operators were used to combine up to three terms or phrases using AND, OR and NOT to filter the irrelevant results.

3.2 ISLAMIC ART DESIGNS

It is previously suggested that Islamic art is frequently unique and vibrant. In comparison to other religious art such as Christian art, Islamic art is considered to be comprehensive (very complex and advanced). In other words, it is considered impracticable to constrain it to spiritual and religious work (Kaplan 2005, Cromwell 2013, J. F. Bonner 2016). However, Islamic art is comprised of all of the artistic rituals and traditions in the Muslim culture (Cromwell 2013). It is arguable that the Islamic arts' aesthetic attractiveness transcends the differences of language and culture, as well as time and space. However, it is likely that this is the primary reason why the features of all noteworthy Islamic art are consistent despite the country or time in which the art was shaped and produced. The authors also argued that Islamic art is strongly influenced by the existing regional and global art derived from other cultures.

While there is a lack of studies addressing the topic of Islamic art, a few ascertained the significant role of mathematicians and geometricians who have qualified in relation to analytical geometric subjects in addition to architect engineers. These studies reveal that

mathematicians have played a substantial role in developing both ancient and new buildings (Kaplan 2005, Cromwell 2013, J. F. Bonner 2016). In this context, (Jan, Shaker 1994, J. Bonner 2017) suggested that the major source of the studies in the literature that address the associations between mathematics and architecture occurred during Medieval Islam. This body of literature concurs that geometric patterns consist of the amalgamation of basic figures, including tetragons, pentagons, triangles, octagons, and stars (Izadi, Rezaei et al. 2010, Kaplan 2005, J. Bonner 2017).

It is argued in another study that the methods that allow drawings to be generated by adding a set of algorithmic rules offer new ideas and solutions for patterns or shape grammar (Tepavčević, Stojaković 2012). Stiny and Gips in 1971 co-created the concept of shape grammar (Stiny, Gips 1971). Later, Gips in 1975 invented a set of clear rules (i.e. algorithms, which are a collection of rules applied through a finite number of steps to answer a problem) for the transformation used recursively on an initial form to generate a new form, such that A → B (Argamon, Burns et al. 2010, Gips 1975). Researchers have also reported that patterns can mainly be defined as a way to shows visual features (Özkar, Kotsopoulos 2008) . Furthermore, the phrase ‘shape grammar’ is based around the aspect of the overall design of the art. This is done through art that has a target meaning and a practical significance for that period (Tepavčević, Stojaković 2012). It was also suggested that there are various essential aspects that emphasise the crucial nature of the pattern grammar. It is vital for the implementation of modern architectural theories and designs (Tepavčević, Stojaković 2012). Furthermore, the application of the patterns within architectural theory and the overall design has a long history spanning four decades. Additionally, in architectural academic areas, aspects like shape grammar were put in place before conventional drafting methods that mainly use computer architectural design (CAAD).

The previous studies consider that in computational theory and pattern/shape grammar, there are mainly classes of clear rule-based expert systems within artificial intelligence which help to generate various geometric shapes (Tepavčević, Stojaković 2012). It has been argued that the underlying rules of geometric transformations and changes, for instance scale, translation, rotation, and finally reflection, all allow one shape to become a part of another (Fasoulaki 2008). It is correctly stated that a unique characteristic of shape grammar is that is has a finite number of rules and shapes which might form an indefinite number of design solutions. This approach may be used as an analytical tool for the overall breaking down of mixed shapes in order to generate complicated forms which began as simple shapes (Fasoulaki 2008).

Shape grammar signifies the algorithmic systems utilised and employed to analyse designs or to produce new and evolved patterns. However, despite utilising texts or symbols to express the essence of shape exemplification, shape grammar allows for the production of newer designs through the use of computational approaches that have different styles and rules. Therefore there are various possibilities concerning the selection and implementation of the rules and the type of principles which may also generate incipient design solutions or even new forms of objective (Fasoulaki 2008).

Similarly, another study argues that geometry is a significant and meaningful branch of mathematics, so it makes sense to separate geometry into a subtopic (Rønning 2009). It has also been described that the four strands in which geometry has been developed are building structures, art/pattern, motion/machines and navigation/stargazing (Taimina, Henderson 2005). The art/pattern strand concerns the study of patterns and symmetry that relies on measurements and calculations. These topics are vital in the navigation strand where issues arise in the processes of connecting shapes. The navigation strand is considered to be most valuable when discussing Islamic patterns as it is fundamental when considering perfect patterns.

3.2.1 Algorithm

Algorithms are defined as instructions, usually to solve a problem or complete a task. Algorithms usually involve math equations. For instance, the main example of an algorithm is computer code. In addition, the internet is based around algorithms and online searches typically utilise them. In other words, an algorithm is arguably a group of clear instructions with a finite number of steps that is utilised to complete a task or solve an issue. Algorithms are usually well-defined rules and commands in a finite number which allows individuals to solve a problem or even complete a task in a set amount of time (Yanofsky, 2011). As a result, an algorithm is a unit which utilises calculations to create more of a pattern. It is different from design as it is usually developed based on the inspiration. Technically, relying on a set of algorithms and combining these algorithms with complicated calculations to generate a pattern helps the design to be established through a calculation process. This is arguably more effective than the design being established by an architect as it provides the freedom of free structure (Choi and Kim, 2008). In fact, ancient populations have attempted to utilise mathematics to establish designs and simplify the involved processes. Correspondingly, through the utilisation of newly established tools, modern mathematical algorithms are typically utilised for the design of modes of transportation in addition to buildings and art. Likewise, mathematical algorithms typically create results that have variables that can be utilised in alternating scenarios. These are crucial as they allow for interchangeability (Yassine, 2012). According to Stavric and Marina (2011), it is important to study and explore the functionality of the mathematical formulas, as that helps to utilise them in expressing and implementing their processes.

3.2.2 Mathematical formula Algorithm

By moving to mathematical formula algorithm implementation, these methods are typically used to design a system and define it effectively through using of mathematics, which further simplifies the creation. In addition, Choi and Kim (2008) argue that the complexity level of the mathematical formula relies on the formulas that influence the parameters simplicity and complexity level. Technically, the complexity of the utilised mathematical formula will be increased if the involved parameters will be controlled in a separate way. However, in the case of the integration of the parameters, the mathematical formula becomes simpler. Correspondingly, mathematics and art are considered to be related. In addition, Stavric and Marina (2011) described mathematics as art motivated by beauty (art, design, and paintings, amongst others). Nevertheless, that study concentrates on mathematics in terms of the visual arts. Likewise, mathematics is directly influenced by art through conceptual tools, for instance, linear perspective along with mathematical objects.

A mathematical investigation, on the other hand, begins with summarising the relationship between mathematics and Islamic patterns. This should be both understood and explained in terms of mathematical equations. As a result, it is crucial to obtain reasonable questions in order to evaluate the findings and reflect on the findings in order to establish a valid investigation. Likewise, it is also crucial to propose assumptions. This is crucial as it allows these assumptions to be answered and more data be collected, which may even highlight other related assumptions.

Therefore, justifiable arguments and formal proof may allow for there to be further arguments that can confirm the hypotheses (Stavric and Marina, 2011). As a result, there were numerous reasons why the researcher chose to employ a research study focused on Islamic patterns. Firstly, the researcher has a personal belief that Islamic art patterns are the best combination of art and mathematics due to their interesting origin and value in today's society (Yanofsky, 2011). Secondly, Islamic art patterns are varied. Even though some shapes may be repeated,

the patterns and designs are still unique and interesting. Thirdly, culturally the researcher is highly familiar with Islamic patterns. This is as the researcher has always been interested in the aspect of Islamic geometric art as the researcher has studied Islamic art before.

In addition, the researcher believes that exploring mathematics and the visual arts is a simple process that brings in a whole new definition to modern art and design. In addition, through researching the area of Islamic geometric patterns, the researcher was amazed and inspired by the art and found it to be a way to express beauty, unlike other forms of art. As a result, this study was the perfect opportunity for the exploration of patterns as a mathematician. Furthermore, the researcher discovered that symmetries and mathematical principles were applied within the establishment of the patterns. As a result, the researcher is enthusiastic about incorporating basic Islamic patterns into their career and selecting art as a future career as well. Retrospectively, the study was based around the ways that mathematics and visual arts can be utilised together to create a suitable form of art that is both simple and effective. Correspondingly, the researcher has acknowledged that the ways that mathematics and the visual arts can be combined are endless. The attempts in this study show a small portion of these ways. Furthermore, my study has explored and acknowledged that the area of mathematics is required to fully discover the mathematical structure of patterns in order to be able to further develop them.

In all cultures, geometry is utilised in the design of items, and locations that reflects the identity of nations, and belief. Practically, geometry is typically relying on dimensions that vary between constants values, and proportional values that determine formulas; for instance, the golden mean (Pennick, 1980). Furthermore, the geometry representation might vary from representing beautiful painting, and arts into sacred belief's, and ideology. In addition, the beauty is crucial in order to maintain a suitable measure. Similarly, Islamic geometry is also crucial and relies on the ideology, and basis of Islam as part of the relationship between Islamic art and Islamic worship. As a result, Islamic art is sacred (Dabbour, 2012).

Similar to other types of art, there are a set of principles that provide characteristics of visual Islamic art that have been developed over the time (Nasr, 1987). Additionally, the unity of this art has been investigated in order to understand the purpose which allow the phenomenon of Islamic art to be effectively understood (Yanofsky, 2011).

3.3 THE ISLAMIC GEOMETRIC PATTERN

A large body of literature in Islamic art has tried to clarify that the creative aspects, practices, and traditions of Islam are noticeable in many systems as it is utilised in art, design and architecture (Kaplan 2005, Izadi et al. 2010, J. Bonner 2017, Jowers, Prats et al. 2010a).

Islamic art refers to artistic aspects that can be observed through the Islamic culture, as that art is not limited to beliefs or religious aspects. Furthermore, a standard characteristic of Islamic art is creating layers for surfaces within the geometric patterns. Therefore, the use of geometry is mainly stated to reflect the different style of the whole universe and to benefit the believer in order for them to reflect on life and the gift of creation. The integration of cultural arts, crafts and design into everyday life is the norm in the traditional Muslim world. Therefore, the essential idea is that as Islam is vital to each area of a Muslim's life, so should Islamic art be a mechanism that is utilised for establishing a sense of belonging in terms of everyone's day to day life as something that is attractive. Geometric patterns institute one of three non-figurative designs of decoration within Islamic art, which includes calligraphy motifs. Consequently, professional Islamic artists have suggested that Islamic ornamentation mainly consists of a group of these three types of decoration. Whether isolated or implemented within combinations that have non-figurative ornamentation or figurative representations, geometric patterns and shapes are mainly popular in relation to Islamic art largely due to their iconic quality (Kaplan 2005, J. Bonner 2017).

The perception of Islamic art is a contemporary idea which was not established and developed by the Islamic culture but by art historians from Europe and America (Flood, Necipoglu 2017). However, within the arts there was a Muslim integration, meaning that the integration was imbedded within Western cultures which resulted in complex and interesting art leading to a newly developed field in art antiquities. Some Islamic art scholars, specifically those located within Islamic countries, disagreed with the application of Islamic art and instead chose an alternative which utilises nationalistic names, for instance Turkish or Persian art (Blair, Bloom

2003). Furthermore, it is considered to be impossible to distinguish the contributions attained from other societies as Persian-speaking artists are similar to Turkish-speaking artists (Blair, Bloom 2003). There is an agreement in the literature that Islamic ornamentation includes different decoration, namely vegetal motifs, calligraphy, and geometric patterns. Nevertheless, there are also figurative forms of creatures (humans or animals) in this art. This is not typical. On the other hand, abstract process of decoration are considered to be implemented in order to establish visual statements in terms of a religious ideas and in order to express the logic and instruction that is essential within the Islamic idea of the universe (Lu, Steinhardt 2007, Cromwell 2010b).

The primary characteristic of the *Islamic geometric pattern (IGP)* is its use of salient and striking symmetric shapes such as complex polygons and multi-star shapes with the inclusion of various lines (Ebru 2009, J. Bonner 2017). Additionally, Islamic geometric patterns (IGPs) also have continuously interlacing and connecting lines as well as a certain flow and variety of shapes that portray the uniqueness and composition of the designs. There are many well-known Islamic geometric designs (IGPs) such as the Topkapi Scroll, 7-Fold system, decagonals and quasicrystalline (Cromwell 2010a, Cromwell 2009, Lu, Steinhardt 2007). However, (Cromwell 2010a) described the basic method of constructing a traditional IGP as the following. To begin polygonal tiling, afterwards put two lines in the location of an ‘X’ within the centre of each of the edges of the tiles. Next, extend all of the lines until they meet the other lines of similar origin in order to produce a pattern. Finally, get rid of the tilling in order to remove the construction lines to complete this method.

Geometric patterns can comprise of an amalgamation of fundamental diagrams including tetragons, pentagons, triangles, octagons, and stars (Izadi et al. 2010). The repetition, rotation and even the integration of these common shapes has the ability to create beautiful designs (Izadi et al. 2010). Furthermore, Islamic art focuses on the three key objectives of floral ornaments, Arabic calligraphy, and geometric ornaments. The combination of these elements

is mainly used within the same object (Cromwell 2010b, J. Bonner 2017). Star patterns within Islamic geometric patterns have stunning artistic geometric forms and they are widely known as one of the most eye-catching regular figures created by humans. This is why they are still incorporated into building designs. Overall, the current Islamic patterns are derived from natural elements and phenomena and they are chosen and categorised by emphasising these features (J. Bonner 2017, Cromwell 2010b).

Another study suggested that an entire program is employed in group theory in order to then study frequent star patterns (Grünbaum, Shephard 1992). Moreover, the researchers derived a number of mathematical devices in order to then analyse the patterns within both the symmetric and periodic groups while patterns are operated on the surface (Grünbaum, Shephard 1992). Likewise, the development of these patterns has been expanded to 17 wallpaper group patterns whose approach incorporates some of the shapes contributed by artists and designers to produce harmonic ornaments (Ostromoukhov 1998). Similarly, other studies generated sketches by filling in the tiles with star patterns on the external of the tile. This supplies a surface of different elements that have the ability to implement the parameters that are then drawn in various historical samples. Consequently, by implementing a deductive algorithm, another study provided sketches by filling in the irregular polygons (Kaplan, Salesin 2004). While the studies within developed and developing countries worldwide have extensively demonstrated IGPs, there remains a dearth of evidence from Arabic countries.

3.4 CULTURAL AND HISTORICAL RELATED LITERATURE

The next sections discuss the previous methods used in Islamic construction. This is as new methods need to be applied for the development of complex polygonal shapes which are considered to be an essential aspect of IGPs (Broug 2013).

Several studies have suggested that during the Umayyad period of the 7th century, patterns derived from the Byzantine and Sassanid eras became a part of Islamic design as Umayyad architecture (Rabbat 2012, Necipoglu 1992, Ben-Hamouche 2012). One of the most standard architectural designs from this time was the Dome of the Rock built in 688 - 692 Common Era (CE). This displays the patterns from the aforementioned eras as evidenced in its ornamental motifs and designs. Many of the designs are also seen in the construction of mosques and state buildings. Nearly all surviving tributes from the Umayyad period are located in Syria and Palestine.

The Abbasid architecture from 836 CE featured the rebuilding of the Great Mosque of Tunisia for which the interior was redesigned with unique patterns. The design of this building was primarily based upon geometrical, floral, and vegetal shapes and simple six-point polygonal geometric shapes were used for the first time. Moreover, examples of the most popular architecture in this era can be found on the Abbasid Palace in Baghdad and the Madrasa of Mustansiriyeh because these were both designed with detailed geometric patterns in terracotta (Yassin, Utaberta 2012).

The Fatimid dynasty built the Al-Azhar mosque in Cairo using geometric designs in its windows while displaying abstract panels with a six-point geometrical design. In addition, the Al-Juyushi mosque was built in 1085 with curved designs with floral and geometric patterns decorating the interior and exterior (Williams 2008). In general, Fatimid's architecture was based on calligraphic designs along with geometrical patterns to decorate the mosques, including Al-

Aqmar and Al-Salih Talai. Likewise, this era further developed IGPs using eight-point and twelve-point star shapes (J. M. Bloom 2008).

Seljuk architecture concentrated on figurative designs instead of floral but geometric patterns still intensely characterise the designs. Abstract six-point and eight-point star shapes commonly existed such as in the Tomb Tower of Kharaqan in Iran and Madrasa Al-Firdaws in Aleppo, Syria (Özkar, Lefford 2006). Geometrical patterns developed significantly during the Seljuk era as the six-point, eight-point and ten-point polygonal shapes were expressed in combination with multi-point stars.

Mamluk architecture was prominent in the Mosque of Baybar which features a twelve-point geometrical pattern. The Qalawun Complex is another example that incorporates ornate six-, eight-, ten- and twelve-point patterns. Furthermore, Mamluk architecture used sixteen-point and twenty-point geometric patterns for the first time with stars and curved designs to adorn the famous dome of the Hasan Sadaqah Mausoleum (Yeomans 2006).

By the end of the 14th-century, Ottoman architecture became less popular while decorative patterns were more common and well-known to scholars in terms of Islamic art. During the Ottoman era, buildings such as the Yesil Mosque of Iznik and Ulu-Cami displayed the characteristics of Ottoman architectural designs consisting of geometric patterns used as secondary patterns instead of decorative patterns. Similarly, the Suleymaniye complex, Haseki-Hurrem baths and Sokollu-Mehmet-Pasha in Istanbul were constructed during the rule of the Ottoman Empire in the 16th century for which eight-point and ten-point geometrical patterns were used to decorate the windows and doors while the walls included extensive decorative patterns (Bakeer 2009).

The Muslims of Spain inherited the local architectural designs with prime examples including the Great Mosque of Cordoba, Aljaferia Palace in Zaragoza and the Mosque of Seville. In addition, Alhambra Palace is considered to be an exceptional development by the Muslims of Spain. Typically, geometric shapes with floral designs were commonly used during this era for

buildings featuring multi-colour displays. Here, an odd number of geometric patterns were used in the architectural designs as well as many six-, seven-, eight-, and nine-point geometric patterns (Kaplan 2000, A. J. Lee 1987).

The emergence of Islamic geometric patterns and art has improved and modernised over time due to the advancements in technology (Jowers et al. 2010a). For instance, the concept of *emergence* in terms of geometric patterns can be defined as the development of shapes. This does not explicitly represent a specific generating method. The idea was explored that *emergence* plays a vibrant role in the exploration and generation of geometric pattern designs. In the structure of IGPs, these simple methods are employed recurrently as shown in Figure 3 -1 (Gross 2001a, Knight 2003).

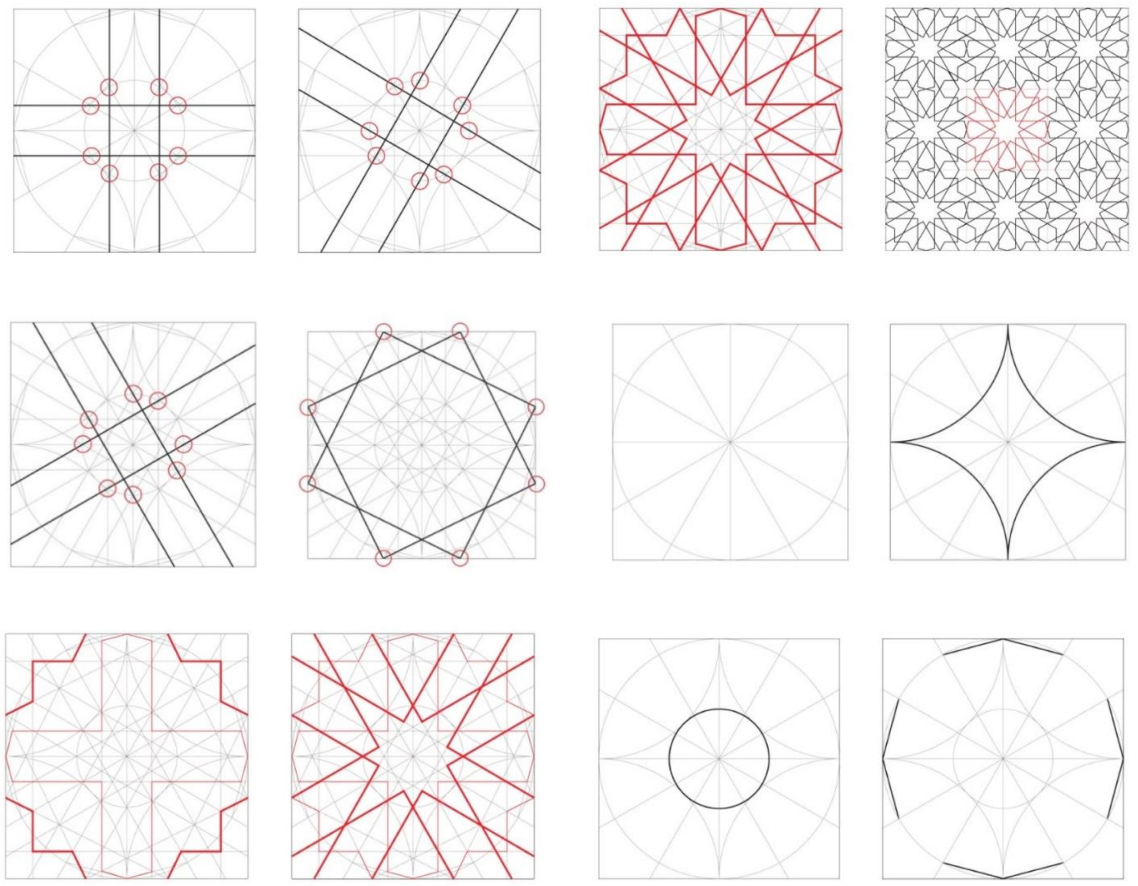


Figure 3 - 1 A variety of Islamic geometric patterns adopted (Jowers et al. 2010a, A. J. Lee 1987, J. Lee, Kim et al. 2015).

Multifaceted Islamic geometric patterns (IGPs) are assembled by the overlaying of forms which is considered by the authors to be a key distinguishing feature. According to (Jowers et al. 2010a), This evolution of the design elements might be described as the emergence of shapes were not in the core pattern, but these shapes have been emerged and developed during the pattern's generation process. The shapes 'emerge' automatically from the way in which the geometric shapes are overlaid through a well-ordered technique. IGPs also employ self-homogeneity which is typically perceived in a curve or geometric figure, that case presents identical shape. According to (Sayed et al. 2015), the scale operator performs a geometric transformation such as the scaling specific shape in order to generate a pattern that has self-similarity. For example, a previous study was conducted by (Kaplan 2005) which used a technique to produce IGPs with flexible or non-constrained surroundings with a polygonal network as a guide. Another study conducted by (Riether, Baerlecken 2012) developed a process to regenerate IGPs as a set of sectional tiles to create designs with no specific constrictions (Cromwell 2010b, J. Bonner 2017).

There is an agreement in the literature that *Islamic geometric patterns* reflect a set of elements that varies between tradition, civilization, and ideology. It is obvious that integrating pattern, and calligraphy are common in the Islamic art rather than figures because, as is comparable to other features of Islamic culture, Islamic art is the result of the accumulated knowledge of the superiority of the local environments (J. Bonner 2017, Cromwell 2009, Lu, Steinhardt 2007, Kaplan 2005). Likewise, IGPs integrate the motivations of a range of civilisations including the Persian, Arabic, African and Byzantine traditions. With Islamic art built on the foundation provided by these cultures while developing a unique style, it is prominently dominated by the previous cultures. (Lu, Steinhardt 2007, Kaplan 2005) stated that Western scholars of art allege that Islamic artists of the Muslim world often rely on previous cultures, especially Persian and Byzantine, from which the Islamic artists attempted to imitate or borrow the artistic

principles. They then reproduce or reform these styles consistently using Islamic principles and the structures of Arabesque design and calligraphy.

In summary, Islamic art is often vibrant and distinctive and it is no longer limited to religious work. However, it continues to include all artistic traditions of Muslim culture. Its powerful aesthetic appeal exceeds time and space as well as various languages and cultures (Cromwell 2009, J. Bonner 2017). There are noticeable local features and impacts from other cultures. The fundamentals of Islamic art comprise the whole of Muslim art and not only the spiritual aspects. Islamic art tends to depict a sense of belonging regarding what is otherwise just a corporeal form. On the other hand, Islamic art pays attention to the decorative arts while largely disregarding both painting and sculpture. Ultimately, researchers have admitted that calligraphy is a major art form in the Islamic arts (Cromwell 2009, J. Bonner 2017).

3.5 PROCEDURAL CONTENT GENERATION

3.5.1 Overview – components of computing

According to (J. Bonner 2017, Cromwell 2009, Lu, Steinhardt 2007), the Islamic art can be grouped into four groups: i) figural representations, ii) geometric patterns, iii) vegetal patterns, and iv) calligraphy. Calligraphy is considered to be the most essential element among them as it is used to represent the writings of the sacred Islamic books in an artistic manner. A calligraphic word presents the text using different types of brushstroke, in which a single letter can be written as an artistic stroke. Other essential components can also be combined with calligraphy in Islamic art.

One of the four components such as vegetal patterns have a variety of usages like on manuscripts, textiles, structures and different objects whether they are used on their own or combined with other elements. There is a unique difference between calligraphy and vegetal patterns. Vegetal patterns and their motifs come from Byzantine traditions belonging to the

Eastern Mediterranean and Sasanian Iran. Later, several Chinese patterns were used after the Mongol invasion. Furthermore, these designs were further spread to Turkey, India and all over Europe during 16th and 17th century. Their design includes several new versions such as natural flowers and blossoms which can be related to the various current regions of the Safavids, Ottoman and Mongol empires.

Later in the 16th and 17th century when geometric embellishment was at the highest level, the fundamental shapes and patterns that existed in ancient times from the Roman and Greeks were still present. Likewise, some of the unique patterns and shapes such as circles, and four-sided polygons. These shapes all result from squares and triangles and they are carved in either a circle or multisided polygon.

3.5.2 Classification of geometric patterns

Geometric designs have come to be one of three non-figurative shapes in Islamic art that contains calligraphy and vegetal patterns. Either alone or in correlation with figurative ornamentation or depiction, geometric forms are related to the Islamic arts due to their iconic superiority (J. Bonner 2017, Lu, Steinhardt 2007, Kaplan 2005). The designs not only decorate the surfaces of enormous Islamic constructions, but they also play a key role as the major decorative focus of a variety of objects. Despite the fact that geometric ornamentation has reached a high point in the Islamic world, the bases for both the figures and complex designs had already occurred by late antiquity among the Greek tribes, Roman tribes and Sasanians in Iran (Lu, Steinhardt 2007, Kaplan 2005). The Islamic artists acquired the fundamentals from these traditions to further develop them in order to generate new methods of artistic designs (Cromwell 2009). However, the significant guidance from different astronomers, mathematicians and scientists was vital to develop the exceptional styles possible (Kaplan 2005, Lu, Steinhardt 2007, J. Bonner 2017).

Vegetal designs exist alone or as part of a blend of other key types of ornaments, such as calligraphy, geometric forms and figurative symbols to decorate a wide range of structures, manuscripts and textiles. Most vegetal designs with subjects have been taken from several traditions of the current Byzantine ethics which are Eastern Mediterranean in origin. Calligraphy as an essential traditional Islamic Arab pattern is a significantly new development.

Calligraphy is the third ornamental technique of art development in the ancient Islamic culture. This technique uses artistic calligraphy that is comprised of geometrical and natural forms. Western scholars also refer to calligraphy as an added method of Islamic art but it is given the focus on the artistic use of letters inspired by countries such as China and Japan (Kaplan 2005, Lu, Steinhardt 2007, J. Bonner 2017). Additionally, other theories also suggest that the global growth of Islamic calligraphy is hugely influenced by the Chinese. Uncertainty is due to the pottery found in old Cairo (Al-Fustat) that seems to make this theory illogical (Christie 1922). The lack of proof offers clear enough evidence as there are inclusive changes between both of the languages, specifically in the way that they are written (J. Bonner 2017, Lu, Steinhardt 2007, Kaplan 2005).

As (Edmonds, Moran et al. 1998) mentioned in the catchphrase, "*emergence is in the eye of the beholder*," this phenomenon can be withdrawn once it is understood. (Gross 2001a) argued that an appreciation-driven approach emphasises the role that experience has on shape emergence. Further, the term *emergence* is primarily the guideline which acts as the unintended decoration in illustrations. "Emergent shapes" mostly define the anomaly of several interpretations of an illustration. Furthermore, three grounds in the previously mentioned several interpretations comprise the interconnecting figures where two or more values interconnect to generate recognisable subfigures. Different configuration parts might be classified in several ways as well as a figure-ground that reverses this as a novel symbol shaped by the boundaries of the numerous shapes. Gross also focused on perceiving the three types of development that help in computer illustrations including:

- Type One: a development that then results in interconnecting shapes.
- Type Two: a development that results in alternative configurations based on the different parts of the shapes used.
- Type Three: a development that is an outcome resulting from a figure-ground reversal.

The methods that help in the production of various Islamic geometric patterns have been presented in the next section which also provides the associated illustrations. On the other hand, before the exploring the different types in detail, it may be beneficial to introduce an additional distinction. (Knight 2003) suggested that there is a difference between the *emergence* of a process and *emergence* as a product. The emergence of the procedure is categorised by emergent formulas which are recognised and utilised. In contrast, emergence as a product is categorised by emergent shapes that are recognised but not employed, Flake (1998) described how cellular mechanisms are frequently used as instances of emergence since they are defined by simple rules.

(Djibril, Thami 2008) suggested that symmetry plays a crucial role in Islamic geometric patterns in terms of how they are created by integrating the patterns to provide stability and unity to the generated pattern. Furthermore, symmetry within IGP may be defined as being in a unique direction which refers to the repetition of the motifs. In addition, it can also be defined as being in two directions which denotes the tiling of motifs. It may also be defined as being radiated which refers to being symmetrical around a central point.

(Kaplan 2000) developed a system to generate the Islamic star pattern by using line analysis and they suggested that Islamic patterns should be considered as if they were puzzles that can be generated using line analysis and symmetrical techniques. Likewise, (Kaplan, Salesin 2004) used symmetrical motifs by tiling off the plane and creating different patterns. For this solution, a combination of triangles and circles were used with continuous symmetrical patterns in a system to generate a pattern automatically. Furthermore, (Kaplan 2005) filled *n*-

goal shapes to create patterns with the assistance of symmetrical lines to increase the aesthetic appeal. He highlighted that the tiling of the stars includes non-prime odd numbers that may produce various forms of symmetry. Similarly, new styles of tiling consisting of even-vertex stars are later mentioned by (Gangopadhyay 2013).

(Cenani, Cagdas 2006) and (Özkar, Lefford 2006) argued that the creation of geometric Islamic patterns uses only one of the underlying shapes in Islamic decorations. Diverse reproductive rule-sets apply to the figures which are created using *shape grammar* and *fractal geometries*. This is defined as a mathematical set or a natural phenomenon that exhibits a repeating shape at any scale. Drawing software has been employed to explore and produce elementary shapes within Islamic artistic decorations so then unique patterns can be formed along with numerous shapes. This is done using editing software. Furthermore, these patterns and shapes are usually seen today on modern buildings within the interior and sometimes the exterior. However, most of the patterns and shapes in this study have been created for the first time.

Conclusive evidence is present within the literature which proves that numerous geometrical Islamic art patterns can be implemented to create unique emergent shapes. For example, patterns derived from a rectangle, quadrilateral array and polar array are applied using drawing software to create an octagram, which is eight-pointed star shape (Özkar, Lefford 2006). The total number of pointed stars possible are 8, 16, 24 and 32. The angle to fill is 180° in some cases. For most of them, it is 360°. A pentagon is a significant form because it is considered to meet the golden ratio (the perfect ratio for a shape). Decagons and icosagons can be generated from a pentagon and the icosagon is the only form that can be closed in three dimensions (which gives the shape more significance in the art as it adds variety), which means a sphere can be generated using an icosagon (Özkar, Lefford 2006).

(Cenani, Cagdas 2006) suggested that a designated geometrical shape that comes from Islamic ornamental pattern design can then be created by first encoding it using computer programming language. Furthermore, according to the structure, all the scenarios are as follows. The computer must be equipped with the grammar application and the users are allowed to set only a minimal number of rules (as low of an amount as possible). Furthermore, numerous ornaments are generated randomly through the use of line weights, filling types and filling colours. In recent years, (J. Bonner, Pelletier 2012) focused on creating star shapes by using seven-fold polygonal elements which include seven-points or fourteen-points. This polygonal technique is well-documented throughout history as it was used by different empires to develop their desired geometric patterns. This approach systematically to create terra-polygons with intersections between the edges and edge lines, although it only offers the designing of specific types of polygonal pattern rather than circular and triangular shapes. This study focuses on polygonal patterns as well as circular and triangular shapes. Likewise, (Aljamali, Banissi 2004) also developed a solution to generating geometric Islamic patterns using the *Minimum Number of Grids* (MNG) and *Lowest Geometric Shapes* (LGS) algorithms. The LGS solution constructs the complex patterns in a systematic group and formulates the group by symmetrically using basic patterns to create the complex patterns. For instance, Friezes are two-dimensional patterns that repeat in one dimension. (Radaelli 2011) alleged that scholars in the Islamic arts have been employed by all human cultures and traditions to make the ornamentation for architecture, textiles, metalwork and ceramics. These shapes can be classified into seven different ‘frieze groups' depending on their symmetry-related properties. The *7-Frieze Group* creates complex patterns by grouping hexagonal and octagonal patterns together to generate a series of more complicated patterns. As this approach is utilised based on the existing geometrical shapes systematically in order to generate the patterns, it does not develop geometric patterns from the beginning (J. Bonner 2017). Although there is a lack of studies from developing countries, a recent study conducted in the Middle East region reported that it is possible that further studies in the Arab region,

particularly in Saudi Arabia, could result in generating more diversity in Islamic Art patterns using computer programmes. This effort would be instead of using manual techniques to reduce the time taken and to produce more accurate work which may then be compared to other non-Arab regions.

On the other hand, the grid method can be useful for generating a series of patterns that can be used on walls and pillars while not being considered suitable for tombs (J. Bonner 2017). This research was not limited to mixing the basic geometrical shapes together for the generation of patterns (J. Bonner 2017). In this regard, it is essential to recognise that the Topkapi Scroll is a vital documentary basis for the study of Islamic geometric ornamental patterns and designs. (Necipoğlu 1992) reported that the scroll is made up of 114 geometric patterns and shapes drawn in ink and dye. A group of discovered structures were built between the 10th and 16th centuries shows some patterns on the walls and domes that were utilised in order to decorate those structures. The discovered decoration does not show the mechanism that was used to produce the patterns, and the designer identity, and production data are missing. The two-dimensional figures make it unclear how they can be made into three-dimensional ornamental objects (Saliba 1999, Hoeven, Veen 2011). (Cromwell 2010a) used the random arrangement of the stars to generate geometric patterns by employing mathematical analysis and the Topkapi Scroll focuses on the randomisation of lines at specific angles to create a series of patterns, such as three-fold patterns, tiling patterns and a twelve-pointed rose motif arrangement based on triangular and square lattices.

(Cromwell 2010a) also developed an approach using the “polygon in contact” method. In a hybrid system, tiles with one-point motifs and tiles with two-point motifs are used to create a geometric pattern. Similar designs were generated during the Mongol Empire as seen on Humayun’s Tomb. In particular, (Cromwell 2010a) also described penrose tiling as being intricate in design because they are non-periodic and the structure of this type of tiling is called quasi-periodicity. (Cromwell 2009) described quasi-periodicity as a distinctive way to

subdivide the projection into a slice of a cubic lattice and tiles with matching rules. Additionally, in this tiling model, there are unusual five-fold and ten-fold rotational symmetries that use a limited number of periodic designs with a repetition of stars. It is used in relation to the number of points, which is based on edge-to-edge tiles containing convex polygons. Star and kite patterns are developed using this technique, and these kinds of patterns are typically seen on walls such as at Karatay Madrasa, Iran designs, Maragha, Konya, and Gunbad-i-Kabud which are all based on quasi-periodicity.

Interestingly, recently published articles have discussed the field using computerisation to create Islamic art partners (Taimina 2018, Park 2018). Over the years, as Islamic art develops and becomes more complex, the star shape has changed the most because it is of key importance in Islamic art (Park 2018). The star has improved greatly over the last decade. It started with a basic five-pointed shape with no colour and no internal patterns. Next, it evolved into the eight-pointed star of Islamic art, which was believed to be developed through the integration of mathematics, religion, and art. This is why this star is the key to the development of Islamic art (Taimina 2018). Today, the Islamic star features many colours and patterns with the most famous star being the sixteen-pointed star which is mostly used in architecture and jewellery. This pattern has attracted architects from around the globe and it is used in some of the world's most popular buildings and structures (Park 2018, Taimina 2018).

Another important Islamic art shape is the hexagon, as seen in many different types of architecture. It starts from a six-pointed shape with only an outline (Thalal, Aboufadil et al. 2018). In modern days, hexagons can include many internal colours and meaningful patterns to make them very intricate (Taimina 2018). A powerful and well-made shape within Islamic art is called the saft. This is made by combining the Islamic star and hexagon patterns (Zhang, Zhang et al. 2017). This shape is used by many Arab nations for architectural structures including malls, mosques and other public places. This shape has been thoroughly studied by

(Castera, Peuriot 1996) and it is now being further studied by art professionals around the world (Taimina 2018).

Compared with the existing efforts, this research focuses on the generation of multiple Islamic geometric patterns through the use of circles and triangles. The proposed system here generates geometric pattern shapes automatically by providing simple commands which offer several advantages. First, the solution is not limited to a single pattern. Second, the end user can determine the type, size and dimension of the generated pattern. Third is the accuracy of the generated pattern. The pattern dimensions do not affect the pattern resolution/accuracy. Finally, the end user can test the aesthetic of the produced pattern by applying the existing theories.

3.6 DISCUSSION

Through the utilisation of digital technology, the improvement of the surfaces in terms of buildings is considered to lead to the unprecedented independence of expression (Yanofsky 2011, J. Lee et al. 2015). The rapid expansion of computer technology lead to develop new designs through algorithms outside of the control of the creator (Stavric, Marina 2011, Choi, Kim 2008, Yassine 2012). The improvement of manufacturing technology also allows for the creation of several investigational shapes that deliver expressive structural work (Kaplan 2005, Abdullahi, Embi 2013, Yassine 2012). These phenomena are differentiated in the principles of traditional geometry, and that by employing new terminology like “Digital Geometry”, and “Digital Materiality.” Practically, some designers strictly restrict the role of the computer and decline designs created by computer software, instead constructing designs relying on their foundational knowledge of geometry (J. Lee et al. 2015, Abdullahi, Embi 2013, Choi, Kim 2008). This study has considered the difference in terms of these extremes in relation to the use of computer software and algorithms in design (J. Lee et al. 2015, Yanofsky 2011, Kaplan 2005).

The purpose of this study is to find an assembly point (where all of the shapes connect) for use in both foundational geometric and algorithmic designs. Technically, this study details the star (in terms of the assembly point and the shape overall) in combination with the patterns created by designers while overcoming the issues within the designs that are created through the use of digital technology (J. Lee et al. 2015, Kaplan 2005, Abdullahi, Embi 2013, Choi, Kim 2008, Yassine 2012). (Yanofsky 2011) defined an algorithm as a collection of clear rules where a finite number of steps used to answer a mathematical problem. In other words, it is a group of well-defined rules and commands in a finite number that can provide a solution relying on these rules. Here, the algorithm generates a unit in order to produce a symmetric pattern that completes the wanted shape, which is relying on the inspiration and provided guidance.

Likewise, (Choi, Kim 2008) debated that while advanced algorithms, and calculations are utilised in generating a shape, the design developed through a calculation is more efficient. One may therefore be randomly developed by designer in order to proceed new designs separate from the actual structure. Designs developed based on mathematical algorithms are not to unique to the modern era. In fact, (Yassine 2012) has suggested that for hundreds of years, architects have attempted to create designs by making use of calculations as part of the attempt to combine with architecture. Relying on the computer algorithms, the facilitating will not be limited to the buildings, and decorative aspects, as these algorithms might be applied in order to design various items, such as airplanes, ships, and motorcycle. Furthermore, the developed algorithms help to produce shapes according to the pre-defined rules, and formulas (Stavric, Marina 2011).

Accordingly, the application utilised for the mathematical formulas in the context of building planning can be efficiently applied to control the design by utilising computational algorithms in tune with today's society. The study can then implement changes through algorithmic steps. The Islamic star pattern can be formed using geometric statistics. According to Abdullahi, and Embi (2013), the ornament design can include architectural applications, as it is a meaningful

advancement in the Middle East and Central Asia. Dabbour (2012) argued that the Islamic star shape represents the proportionality, alteration, distinctiveness, and steadiness of mathematics.

Experiments on geometric pattern designs using computational algorithms were performed to discover an operation control method to adjust the geometric decorations via Grasshopper. This is a program that was developed based on mathematical algorithms in order to control the used values. The aim was to enhance the understanding of the generation methods needed by Islamic star patterns. According to (J. Lee et al. 2015), the polygons-in-interaction of Hankin's technique from 1905 and 1925 set a milestone for designs inspired by Islamic star. Hankin's work was vitally important for Islamic art due to it producing a real establishment for a program to producing Islamic star designs, providing wide range of pattern formation (Kaplan 2005). (Cromwell 2009) argued that diverse shapes, such as stars and kite patterns, were developed using this technique yet these kinds of patterns typically exist on walls such as Karatay Madrasa, Iranian designs, Maragha, Konya and Gunbad-Kabud. They are based on quasi-periodicity.

The next section summarises the previous studies that address Islamic art patterns in chronological order. Table 1 includes the details about the approaches, methods and analysis used in these studies. In addition, the table may be used to observe the effect of the various approaches and methods when establishing Islamic art. In particular, through observing the approaches and methods, this study is able to select a method effectively.

Table 3 - 1 Summary of the previous studies addressing Islamic art patterns.

Research	Approach	Method
(Kaplan 2000)	"*Utilising the star pattern as a basis for the complex shapes through a range of methods*".	"*Using Radially Symmetric motifs by tiling of the plane and symmetrical lines around polygons, the results are calculated with a software implementation of the technique"*.
(Aljamali, Banissi 2004)	"*Coordination of IGP based on the Minimum Number of Grids and Lowest Geometric Shape, in order to calculate the minimum requirement for shapes in order to construct the star pattern in various forms*".	*"The construction is through the symmetric elements with a description and demonstration of the procedures for constructing the Star/Rosette unit patterns based on our proposed classification in a grid formation".*
(Cromwell 2009)	*"The tiling is unique for their many centres of local five-fold and ten-fold rotational symmetry, and some Islamic geometric shapes/patterns share features".*	*"Using quasi-periodicity, the tiles are developed with corresponding rules and a projection of a cubic lattice in R5".*
(Cromwell 2010a)	*"A technique for combining the one-point and two-point applications of the 'polygons-in-contact' method for creating Islamic geometric patterns".*	*"This technique along with hybrid buildings are shown to underlie some cultural Turkish patterns and forms".*
(Cromwell 2010b)	*"A mathematical analysis of typical star patterns/shapes shows a range of methods for creation, including a design/pattern combining nine-pointed and eleven-pointed stars and another with thirteen-pointed and sixteen-pointed stars".*	*"The Topkapi Scroll is a vital documented source for the study of Islamic geometric ornaments. This study shows that the practice of constructing a design by copying a template using reflections along its sides halt the range of symmetry types produced".*
(J. Bonner, Pelletier 2012)	"*A far-reaching set of seven-fold polygonal sub-grid elements produces stunning Islamic geometric patterns/designs characterised by distinctive fourteen- and seven-pointed stars*".	"*Using a polygonal method as well as other polygonal systems, the 7/14 System offers tremendous design potential for the creation of new geometric patterns*".

Compared to the existing research, the current study highlights the development and enhancing of various Islamic geometric patterns by incorporating circles and triangles. The system (GIVA) generates geometric shapes and patterns automatically by inserting simple commands which offers several advantages. First, the program is not limited to a single pattern but it can generate multiple aesthetic patterns. Second, the number of pattern heads (e.g., 4, 6, 8 and 10), the number of patterns to be generated, the size of the sketch and the type of generated pattern can be collectively determined using the GIVA program. Third, there is the accuracy of the generated pattern. The pattern dimensions do not affect the pattern resolution/accuracy. Finally, the end user can select the colours according to their preference.

3.7 SUMMARY

This chapter has reviewed a broad range of aspects on the existing knowledge and contemporary themes covered in the published literature on the aesthetics of geometric Islamic art based on an understanding of the geometric features. These include the various features, diverse shape grammar guidelines and historical background on geometric ornaments within the Islamic culture to then discuss the different possibilities related to the mathematics of symmetry.

Chapter IV. QUANTITATIVE STUDY

This chapter presents the statistical analysis of the numeric data collected from the questionnaire. Through uni-, bi-, and multivariate analyses as well as inferential statistical analysis, the data is reviewed following cleaning, grouping, regrouping (recording) and computing. The findings are presented in the form of descriptive data in addition to the demographic characteristics. All of the relevant variables mentioned in the questionnaires are related to the participants' perception and knowledge about the Islamic pattern designs and how the programs are incorporated. In addition, the discussion considers the results belonging to the descriptive data and each hypothesis is compared with the existing literature.

4.1 WHY QUANTITATIVE STUDY?

The purpose of utilising a quantitative study is the need to investigate the defined hypotheses that have been developed to study the end user in relation to various aspects such as the requirements and programs used. The outcomes of this study are used to provide a clear view about the end user's needs and to help format the features that must be supported by the developed approach. In addition, the collected data helps to develop a concept about the behaviour that the proposed approach must follow.

The defined hypotheses clarify how other aspects might influence the end user such as years of experience or field of interest. By investigating the expected end user, this will help to provide another point of view that illustrates what features they need and the aesthetic aspects that must be preserved. Besides that, relying on quantitative and qualitative data will improve the quality of the arguments and enhance the accuracy and reliability of the study findings.

The quantitative study outcomes will be combined with the literature review outcomes to define the developed approach requirements. Practically, defining the user needs is an essential step that shapes the whole approach. The quantitative study findings help to determine what must be supported and what should be avoided. This reflects the requirements in terms of the end user. The literature review outcomes represent the limitations and obstacles that have been defined by other researchers.

4.2 STATISTICAL ANALYSIS METHODS

4.2.1 Data analysis steps

The Statistical Package for Social Sciences (SPSS, version 22.0) was utilised to perform the overall data entrance and data analysis. In addition, all the data was cleaned, and data entry took place after portions of the data were collected. Likewise, the data analysis was implemented, and that was done for the univariate data as well. This process includes examine one variable at a time. Next, the descriptive statistics were calculated with frequency distributions in order to illustrate the numbers and percentages presented and to describe the overall characteristics of the sample when it comes to the demographic data. In addition, most of the time, statistics show percentage distributions. Following the univariate analyses, the bi- and multivariate numerical tests were established with the help of the computed cross-tabulations of the selected variables in order to then produce various contingency tables. Furthermore, a p-value of 0.05 or under is considered to be statistically significant because it allows the Chi-square tests (X^2) to be performed in order to identify a link between the predictor and overall outcome variables.

4.2.2 Inferential Statistics

- Cross-tabulation analysis is an influential method used to describe the associations between the various variables simultaneously. Here, cross-tabulation is used to compute the frequencies and percentages of the participants' observations as well as to calculate the Chi-square statistic.
- Associations are identified through the Chi-square (X^2) statistic test which helps to determine the relationship between two categorical variables.
- Correlations are part of the bivariate analysis which is applied to examine the overall strength of the association between two different variables. Likewise, this correlation involves coefficients ranging from -1 to +1.

4.3 RESULTS OF THE QUANTITATIVE STUDY

4.3.1 Descriptive and demographic characteristics

Table 4 - 1 includes the socio-demographic features of the 250 research participants recruited for this study. The participant's age ranged from 20 to greater than 60 years old. In addition, 104 were female (41.6%) and 146 were male (58.4%). Of all the participants, the peak quantity were aged either 40-49 years old (24.8%) or 50-59 years old (24.8%) while the lowest proportion of participants were above 60 years old (4.4%). The majority of the participants were married (92.4%). Concerning the level of education of the participants, 8% had a doctorate, 16% had a Master's degree, 34% had a Bachelor's degree, 28% had a diploma certificate and 14% had a high school certificate. The participants in this study were affiliated with one of the following five jobs, each with a population percentage of 20%: artist, interior designer, architectural designer, academic or civil servant. Most of the respondents reported that they received a moderate income (60%) with the lowest proportion (12%) of respondents receiving a low income while 28% received a high income. Regarding the level of education, most of the participants had 11-15 and 16-20 years of experience (24.8% each). The second highest had 1-5 years of experience (23.2%) followed by 6-10 years (22.8%). The minority had over 20 years of experience (4.4%).

Table 4 - 1 Demographic characteristics for all participants (*N*=250).

Socio-demographic data	Male (M) N (%)	Female (F) N (%)	Total N (%)
Gender	146 (58.4)	104 (41.6)	250 (100)
Age			
20 – 29	33 (22.6)	25 (24.0)	58 (23.2)
30 – 39	31 (21.2)	26 (25.0)	57 (22.8)
40 – 49	34 (23.3)	28 (26.9)	62 (24.8)
50 – 59	40 (27.4)	22 (21.2)	62 (24.8)
Above 60 years	8 (5.5)	3 (2.9)	11 (4.4)
Marital Status			
Single	7 (4.8)	12 (11.5)	19 (7.6)
Married	139 (95.2)	92 (88.5)	231 (92.4)
Level of education			
Doctorate Degree	9 (6.2)	11 (10.6)	20 (8.0)
Master's Degree	21 (14.4)	19 (18.3)	40 (16.0)
Bachelor's Degree	51 (34.9)	34 (32.7)	85 (34.0)
Diploma Certificate	42 (28.8)	28 (26.9)	70 (28.0)
High School Certificate	23 (15.8)	12 (11.5)	35 (14.0)
Occupation			
Artist	30 (20.5)	20 (19.2)	50 (20)
Interior designer	31 (21.2)	19 (18.3)	50 (20)
Architecture designer	29 (19.9)	21 (20.2)	50 (20)
Academic	28 (19.2)	22 (21.2)	50 (20)
Civil servant	28 (19.2)	22 (21.2)	50 (20)
Income			
Low income	17 (11.6)	13 (12.5)	30 (12.0)
Moderate income	90 (61.6)	60 (57.7)	150 (60.0)
High income	39 (26.7)	31 (29.8)	70 (28.0)
Years of experience			
1-5	33 (22.6)	25 (24.0)	58 (23.2)
6-10	31 (21.2)	26 (25.0)	57 (22.8)
11-15	34 (23.3)	28 (26.9)	62 (24.8)
16-20	40 (27.4)	22 (21.2)	62 (24.8)
Over 20	8 (5.5)	3 (2.9)	11 (4.4)

4.2.2 Experience using computer software and the satisfaction of the results

Table 4 - 2 shows whether the participants had used computer software before this study to create Islamic art shapes and if they were satisfied with the information gained. Most of the men (93.8%) and woman (94.2%) had used computer software before to make Islamic art shapes and patterns. This suggests that 6% (9 males and 6 females) have not used design software prior to this study. However, most of the participants who had used the software were not satisfied with the information gained (83.6% male and 87.5% female) with a total of 213 (85.2%) of the respondents not satisfied.

Table 4 - 2 The prior use of computer software to create Islamic art patterns.

Computers software use and results gained	Male (M) N (%)	Female (F) N (%)	Total N (%)
Use of any computer software to create Islamic art shapes			
Yes	137 (93.8)	98 (94.2)	235 (94.0)
No	9 (6.2)	6 (5.8)	15 (6.0)
Are you satisfied with the results gained?			
Yes	15 (10.3)	7 (6.7)	22(8.8)
No	122 (83.6)	91 (87.5)	213 (85.2)
I do not use	9 (6.2)	6 (5.8)	15 (6.0)

4.2.3 Different programs use to make Islamic are

Table 4 - 3 shows that 235 out of 250 respondents answered the multiple-choice questions. Of these, 588 boxes were ticked with an average of 2.5-ticked boxes per respondent. On average, each male chose 2.58 answers, and each female chose 2.40 answers. These averages were calculated from:

- Male: (146 – 9) / 353 = 2.58 (9 did not choose an answer for this question).
- Female: (104 – 6) / 235 = 2.40 (6 did not choose an answer for this question).

Table 4 - 3 also describes the programs used by the participants to create Islamic art patterns. The percentages of the participants who used Photoshop, a CAD software programme, MS Office and Sketchometry to create Islamic art patterns were 24.8%, 29.1%, 23.3% and 22.8% respectively. In addition, Table 5.3 shows that most males (28.3%) and females (30.2%) chose CAD software. The minority of male participants chose Sketchometry (22.1%) and the minority of females chose Photoshop (21.7%). Overall, most of the respondents of both genders chose CAD software (29.1%).

Table 4 - 3 Four programs used prior to the study by the participants to create Islamic art.

Program	Male (M) N (%)	Female (F) N (%)	Total N (%)
Are you using the Photoshop programme to create Islamic art patterns?	95 (26.9)	51 (21.7)	146 (24.8)
Are you using a CAD-software programme to create Islamic art patterns?	100 (28.3)	71 (30.2)	171 (29.1)
Are you using the MS Office programme to create Islamic art patterns?	80 (22.7)	57 (24.3)	137 (23.3)
Are you using the Sketchometry programme to create Islamic art patterns?	78 (22.1)	56 (23.8)	134 (22.8)
Total N (%)	353 (100.0)	235 (100.0)	588 (100.0)

4.2.4 Features of the GIVA software

Table 4 - 4 shows that overall, 235 out of 250 respondents answered the multiple-choice questions and ticked 723 boxes with average 3.07-ticked boxes per respondent. Table 4 - 4 also describes all of the features of the GIVA software with the participant's responses showing the percentages for what was of most importance in terms of accuracy, repetition, scalability, colour and size control at 20.9%, 24.3%, 20.3%, 18.7% and 15.8% respectively. The majority of males (25.1%) and females (23.3%) chose repetition while the minority of males chose size control (13.7%), and the minority of females chose colour (15.9%). The majority of all respondents chose repetition (24.3%) as the most important feature. On average, each male chose 3.08 answers and each female chose 3.071 answers.

Table 4 - 4 Five key features of the GIVA software with preferences of importance rated by the participants.

Features of the GIVA software	Male (M) N (%)	Female (F) N (%)	Total N (%)
Accuracy is an important feature of the GIVA software.	89 (21.1)	62 (20.6)	151 (20.9)
Repetition is an important feature of the GIVA software.	106 (25.1)	70 (23.3)	176 (24.3)
Scalability is an important feature of the GIVA software.	82 (19.4)	65 (21.6)	147 (20.3)
Colour is an important feature of the GIVA software.	87 (20.6)	48 (15.9)	135 (18.7)
Size control is an important feature of the GIVA software.	58 (13.7)	56 (18.6)	114 (15.8)
Total N(%)	422 (100)	301 (100)	723 (100)

4.2.5 Important principles of the GIVA software

Table 4 - 5 shows that overall, 235 out of 250 respondents answered this question with 1171 ticked boxes at 4.98 boxes per respondent. Table 4 - 5 also describes the key principles of the GIVA software with the importance having been rated by each by the participants for repetition, contrast, symmetry, balance, shape diversity, interlocking shapes and proportionality at 11.4%, 12.6%, 14.3%, 16.7%, 12.6, 15.6% and 16.7% respectively. The majority of males (16.3%) and females (17.3%) chose proportionality, the minority of male participants chose repetition and contrast (11.9%) and the minority of females chose repetition (10.6%). Overall, the majority of respondents chose proportionality (224.3%) with each male choosing 4.96 answers on average and each female choosing 5.02 answers.

Table 4 - 5 Seven important principles of the GIVA software rated as popularly preferred among the participants.

Important principles of the GIVA software	Male (M) N (%)	Female (F) N (%)	Total N (%)
Repetition is an important principle of GIVA software.	81 (11.9)	52 (10.6)	133 (11.4)
Contrast is an important principle of GIVA software.	81 (11.9)	67 (13.6)	148 (12.6)
Symmetry is an important principle of GIVA software.	100 (14.7)	68 (13.8)	168 (14.3)
Balance is an important principle of GIVA software.	111 (16.3)	84 (17.1)	195 (16.7)
Shape diversity is an important principle of GIVA software.	87 (12.8)	61 (12.4)	148 (12.6)
Interlocking shapes is an important principle of GIVA software.	108 (15.9)	75 (15.2)	183 (15.6)
Proportionality is an important principle of GIVA software.	111 (16.3)	85 (17.3)	196 (16.7)
Total N (%)	679(100)	492(100)	1171(100)

4.2.6 Participants' perceptions about the uses and features of the GIVA software

Table 4 - 6 illustrates responses to the Likert scale of five points ranging from "strongly agree" to "strongly disagree." This was used to collect the views of the participants on whether they would utilise the features of the GIVA software created to develop and enhance Islamic art patterns. In terms of applying the GIVA program features to improve Islamic art, 52.0% and 39.0% of participants reported strongly agree and agree respectively whereas 2.4% reported strongly disagree. Moreover, for the GIVA program being quick at finalising the tasks within

making Islamic art, 52.0% and 34.0% of participants responded with strongly agree and agree respectively while 3.2% reported that they strongly disagreed. Regarding the notion that using the GIVA program to form Islamic art would increase productivity, 53.2% and 35.2% of the participants reported strongly agree and agree respectively and 3.2% reported strongly disagree. In terms of agreeing to create Islamic art using the GIVA program in the future, 50% and 39.6% of the participants reported strongly agree and agree respectively and 2.8% reported strongly disagree. On the likelihood of using the GIVA program to improve the existing work, 51.6% and 36.8% of the participants reported strongly agree and agree respectively and 3.6% reported strongly disagree. Finally, concerning the option of planning to use the GIVA program for creating Islamic art frequently, 53.6% and 34.8% of the participants reported strongly agree and agree respectively, and 2.0% reported strongly disagree.

Table 4 - 6 The participants' perception about the features of the GIVA software.

Uses and features of the GIVA software	Male (M) N (%)	Female (F) N (%)	Total N (%)
Applying the GIVA program features to improve on Islamic art.			
Strongly agree	75 (51.4)	55 (52.9)	130 (52.0)
Agree	57 (39.0)	33 (31.7)	90 (36.0)
Undecided	9 (6.2)	6 (5.8)	15 (6.0)
Disagree	3 (2.1)	6 (5.8)	9 (3.6)
Strongly disagree	2 (1.4)	4 (3.8)	6 (2.4)
The GIVA program is quick at finalising tasks of Islamic art.			
Strongly agree	72 (49.3)	58 (55.8)	130 (52.0)
Agree	54 (37.0)	31 (29.8)	85 (34.0)
Undecided	11 (7.5)	6 (5.8)	17 (6.8)
Disagree	5 (3.4)	5 (4.8)	10 (4.0)
Strongly disagree	4 (2.7)	4 (3.8)	8 (3.2)
Using the GIVA program to form Islamic art would increase my productivity.			
Strongly agree	77 (52.7)	56 (53.8)	133 (53.2)
Agree	51 (34.9)	37 (35.6)	88 (35.2)
Undecided	9 (6.2)	4 (3.8)	13 (5.2)
Disagree	5 (3.4)	3 (2.9)	8 (3.2)
Strongly disagree	4 (2.7)	4 (3.8)	8 (3.2)
Agreeing to create Islamic art using GIVA program in the future.			
Strongly agree	70 (47.9)	55 (52.9)	125 (50.0)
Agree	59 (40.4)	40 (38.5)	99 (39.6)
Undecided	8 (5.5)	2 (1.9)	10 (4.0)
Disagree	5 (3.4)	4 (3.8)	9 (3.6)
Strongly disagree	4 (2.7)	3 (2.9)	7 (2.8)
Likely to use the GIVA program in my work to improve on it.			
Strongly agree	86 (58.9)	43 (41.3)	129 (51.6)
Agree	45 (30.8)	47 (45.2)	92 (36.8)
Undecided	8 (5.5)	4 (3.8)	12 (4.8)
Disagree	2 (1.4)	6 (5.8)	8 (3.2)
Strongly disagree	5 (3.4)	4 (3.8)	9 (3.6)
Planning to frequently use the GIVA program to make Islamic art.			
Strongly agree	87 (59.6)	47 (45.2)	134 (53.6)
Agree	45 (30.8)	42 (40.4)	87 (34.8)
Undecided	6 (4.1)	8 (7.7)	14 (5.6)
Disagree	6 (4.1)	4 (3.8)	10 (4.0)
Strongly disagree	2 (1.4)	3 (2.9)	5 (2.0)

4.3 Statistical Analyses for Testing The Hypotheses

4.3.1 Hypotheses of the previous use of computer programs by the participants

H1: There is a significant link between the participants' education level and their previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art.

Table 4 - 7 illustrates the connection between the participants' education level and using the following software. A statistically significant association was found with using Photoshop to create Islamic art (X^2 (8) = 16.01, p = .042) as well as using CAD software (X^2 (8) = 30.13, p = .000). In addition, a statistically significant association was found for using MS office (X^2 (8) = 14.48, p = .040). Furthermore, a statistically significant association was found for using Sketchometry to create Islamic art (X^2 (8) = 13.04, p = .037).

Table 4 - 7 Association between the participants' level of education and existing computer programs.

Variable	Chi-square (X^2)	Df	Sig P-Value
Photoshop	16.01	8	.042
CAD-software	30.13	8	.000
MS Office	14.48	8	.040
Sketchometry	13.04	8	.037

*** p value of < .05 is statistically significant. **p value of < .001 is highly significant.**

H2: There is a significant association between the years of experience of the participants in the Islamic art field and their previous use of operationalised computer programs such as Photoshop, CAD-software, MS Office and Sketchometry to create Islamic art.

Table 4 - 8 shows the associations between the participants' occupation and using the following software. A numerically significant link was found between the participants' occupation and using Photoshop to create Islamic art (X^2 (8) = 33.99, p = .000), in addition to

CAD software (X^2 (8) = 33.89, p = .000), MS Office (X^2 (8) = 33.56, p = .000) and Sketchometry (X^2 (8) = 35.34, p = .000).

Table 4 - 8 Association between the participants' occupations and computer programs

Variable	Chi-square (X^2)	Df	Sig P-Value
Photoshop	33.99	8	.000
CAD-software	33.89	8	.000
MS Office	33.56	8	.000
Sketchometry	35.34	8	.000

*** p value of < .05 is statistically significant. **p value of < .001 is highly significant.**

H3: There is a significant association between the years of experience of the participants in the Islamic art field and their previous use of the following computer programs -Photoshop, CAD-software, MS office or Sketchometry - to create Islamic art.

Table 4 - 9 lists the associations between the years of experience of the participants and their use of the following software. A statistically significant association was found when using Photoshop to create Islamic art (X^2 (8) = 9.01, p = .032) as well as CAD software (X^2 (8) = 20.13, p = .011). However, a lack of an association was found between the years of experience of the participants and using MS Office (X^2 (8) = 4.33, p = .070) as well as Sketchometry (X^2 (8) = 7.15, p = .110).

Table 4 - 9 Association between the years' experience of the participants and computer programs

Variable	Chi-square (X^2)	Df	Sig P-Value
Photoshop	9.01	8	.032
CAD-software	20.13	8	.011
MS Office	4.33	8	.070
Sketchometry	7.15	8	.110

*** p value of < .05 is statistically significant. **p value of < .001 is highly significant.**

4.3.2 Hypotheses of the basic principles and features in the GIVA software

H4: There is a significant association between the participants' level of education and their familiarity with the basic principles and features of the GIVA software.

Table 4 - 10 outlines the associations between the participants' level of education and the features required of the GIVA software, which the participants prefer to use when creating Islamic art. A statistically significant association was found for the features of accuracy (X^2 (4) = 6.34, p = .043), repetition (X^2 (4) = 4.23, p = .050), scalability (X^2 (4) = 8.33, p = .038), colour (X^2 (4) = 10.32, p = .025) and size control (X^2 (4) = 6.22, p = .044).

Table 4 - 10 Association between the participants' level of education and features required in the GIVA software

Variable	Chi-square (X^2)	Df	Sig P-Value
Accuracy	6.34	4	.043
Repetition	4.23	4	.050
Scalability	8.33	4	.038
Colour	10.32	4	.025
Size control	6.22	4	.044

H5: There is a significant association between the participants' occupation and their familiarity with the basic principles and features of the GIVA software.

Table 4 - 11 details the associations between the participants' occupation and the features required of the GIVA software. A statistically significant association was found for the features of accuracy (X^2 (4) = 27.13, p = .012), repetition (X^2 (4) = 28.21, p = .012), scalability (X^2 (4) = 26.28, p = .012), colour (X^2 (4) = 25.13, p = .012) and size control (X^2 (4) = 26.56, p = .012).

Table 4 - 11 Association between the participants' occupations and features required in the GIVA software

Variable	Chi-square (X^2)	Df	Sig P-Value
Accuracy	27.13	4	.012
Repetition	28.21	4	.012
Scalability	26.28	4	.012
Colour	25.13	4	.012
Size control	26.56	4	.012

H6: There is a significant association between the years of experience of the participants in the Islamic art field and their familiarity with the basic principles and features of the GIVA software.

Table 4 - 12 lists the associations between the years of experience of the participants and the features required of the GIVA software. A statistically significant association was found for all of the features used create Islamic art in terms of accuracy (X^2 (4) = 5.28, p = .028), repetition (X^2 (4) = 6.34, p =.036), scalability (X^2 (4) = 8.23, p = .041), colour (X^2 (4) = 11.12, p = .058) and size control (X^2 (4) = 12.23, p = .062).

Table 4 - 12 Association between the years' experience of the participants and features required in the GIVA software

Variable	Chi-square (X^2)	Df	Sig P-Value
Accuracy	5.28	4	.028
Repetition	6.34	4	.036
Scalability	8.23	4	.041
Colour	11.12	4	.058
Size control	12.23	4	.062

4.3.3 Hypotheses of perceived usefulness of the GIVA software

H7: There is a significant association between the participants' level of education and the perceived usefulness of the GIVA software.

Table 4 - 13 outlines the associations between the participants' level of education and their familiarity with the basic principles and features of the GIVA software including repetition, contrast, symmetry, balance, shape diversity, interlocking shapes and proportionality which the participants prefer to use when creating Islamic art. A statistically significant association was found for the features of repetition (X^2 (4) = 18.44, p = .028), contrast (X^2 (4) = 17.36, p = .033), symmetry (X^2 (4) = 16.01, p = .036), balance (X^2 (4) = 12.23, p = .044), shape diversity (X^2 (4) = 14.62, p = .039), interlocking shapes (X^2 (4) = 18.49, p = .026) and proportionality (X^2 (4) = 12.88, p = .042).

Table 4 - 13 Association between the participants' level of education and the principles of the GIVA software

Variable	Chi-square (X^2)	D f	Sig P-Value
Repetition	18.44	4	.028
Contrast	17.36	4	.033
Symmetry	16.01	4	.036
Balance	12.23	4	.044
Shape diversity	14.62	4	.039
Interlocking shapes	18.49	4	.026
Proportionality	12.88	4	.042

*** p value of < .05 is statistically significant. **p value of < .001 is highly significant.**

H8: There is a significant association between the participants' occupation and the perceived usefulness of the GIVA software.

Table 4 - 14 includes the associations between the participants' occupations and their familiarity with the basic principles and features of the GIVA software. A statistically significant association was found for the features of repetition (X^2 (4) = 14.91, p = .015), contrast (X^2 (4) = 14.75, p = .015), symmetry (X^2 (4) = 13.74, p = .015), balance (X^2 (4) = 15.61, p = .015),

shape diversity (X^2 (4) = 15.73, p =.015), interlocking shapes (X^2 (4) = 15.83, p = .015) and proportionality (X^2 (4) = 14.16, p = .015).

Table 4 - 14 Association between the participants' occupations and the principles of the GIVA software

Variables	Chi-square (X^2)	Df	Sig P-Value
Repetition	14.91	4	.015
Contrast	14.75	4	.015
Symmetry	13.74	4	.015
Balance	15.61	4	.015
Shape diversity	15.73	4	.015
Interlocking shapes	15.83	4	.015
Proportionality	14.16	4	.015

*** p value of < .05 is statistically significant. **p value of < .001 is highly significant.**

H9: There is a significant association between the years of experience of the participants in the Islamic art field and the perceived usefulness of the GIVA software.

Table 4 - 15 lists the associations between the participants' level of education and their familiarity with the basic principles and features of the GIVA software. A statistically significant association was found for the features of repetition (X^2 (4)= 16.55, p = .031), contrast (X^2 (4) = 16.89, p = .041), symmetry (X^2 (4) = 14.46, p = .026), balance (X^2 (4) = 18.52, p = .037), shape diversity (X^2 (4) = 13.23, p = .042), interlocking shapes (X^2 (4) = 15.22, p = .035) and proportionality (X^2 (4) = 12.64, p = .048).

Table 4 - 15 Association between the years' experience of the participants and the principles of GIVA software

Variable	Chi-square (X^2)	Df	Sig P-Value
Repetition	16.55	4	.031
Contrast	16.89	4	.041
Symmetry	14.46	4	.026
Balance	18.52	4	.037
Shape diversity	13.23	4	.042
Interlocking shapes	15.22	4	.035
Proportionality	12.64	4	.048

*** p value of < .05 is statistically significant. **p value of < .001 is highly significant.**

4.3.4 Hypotheses of participants' behavioural intentions to use the GIVA program

H10: There is a significant link between the participants' education level and their behavioural intention to use the GIVA software.

H11: There is a significant link between the participants' job and their behavioural intention to use the GIVA software.

H12: There is a significant association between the years of experience of the participants in the Islamic art field and their behavioural intention to use the GIVA software.

Table 4 - 16 shows the correlations between the participants' behavioural intention to use the GIVA program and their level of education (rho = .952, p = .004), occupation (rho = .125, p =.048) and years of experience in the Islamic art field (rho = .123, p = .035).

Table 4 - 16 Correlation between the participants' level of education, occupation, and years of experience and their behavioural intentions to use the GIVA program

Variable	The behavioural intentions to use the GIVA program	
	Spearman's rank test value (rho)	Sig P-Value
Participants' level of education	.952*	.004
Participants' occupation	.125*	.048
Years of experience of the participants	.123*	.035

*** Correlation is significant at the 0.05 level.**

4.3.5 Hypotheses of the participants' behavioural intentions to use the GIVA once

H13: There is a correlation between the participants' level of education and their behavioural intention to use GIVA once it is offered to them.

H14: There is a correlation between the participants' occupation and education and their behavioural intention to use GIVA once it is offered to them.

H15: There is a correlation between the years of experience of the participants in the Islamic art field and their behavioural intention to use GIVA once it is offered to them.

Table 4 – 17shows the correlations between the participant's behavioural intension to use the GIVA program and the participants' level of education (rho = .731, p = .022), occupation (rho = .215, p= .001) and years of experience in the Islamic art field (rho = .648, p = .032).

Table 4 - 17 Correlation between the participants' level of education, occupation, and years of experience and their perceived usefulness to use the GIVA program

Variable	The perceived usefulness to use the GIVA program	
	Spearman's rank test value (rho)	Sig P-Value
Participants' level of education	.731	.022
Participants' occupation	.215**	.001
Years of experience of the participants	.648	.032

**** Correlation is significant at the 0.01 level.**

4.3.6 Hypotheses of the associations of computer programs

H16: operationalised as: the Photoshop, CAD-software, MS office or Sketchometry, by the participants to create Islamic arts and their perceived intentions to use the GIVA program once offered to them.

Table 4 – 18 shows the correlations between the perception of the participants about the usefulness of the GIVA program and the familiar computer programs of Photoshop (rho = .157, p = .013), CAD software (rho = .133, p=.035), MS Office (rho = .227, p = .037) and Sketchometry (rho = .317, p = .012).

Table 4 - 18 Correlation between familiar computer programs and the participants' perceived usefulness of the GIVA software

Variables	The perceived usefulness to use the GIVA program	
	Spearman's rank test value (rho)	Sig. P-Value
Photoshop	.157*	.013
CAD-software,	.133*	.035
MS office	.227*	.037
Sketchometry,	.317*	.012

*** Correlation is significant at the 0.05 level.**

H17: There is a significant association between the participants' previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic arts and their behavioural intention to use the GIVA software.

Table 4 - 19 outlines the correlations between the behavioural intention to use the GIVA software and their use of familiar computer programs such as Photoshop (rho = .861, p = .035), CAD software (rho = .519, p = .042), MS Office (rho = .648, p = .034) and Sketchometry (rho = .859, p= .044).

Table 4 - 19 Correlation between familiar computer programs and the participants' behavioural intentions to use the GIVA software

Variable	The behavioural intentions to use GIVA	
	Spearman's rank test value (rho)	Sig P-Value
Photoshop	.861*	.035
CAD-software	.519*	.042
MS Office	. 648*	.034
Sketchometry	.859*	.044

*** Correlation is significant at the 0.05 level.**

4.4 DISCUSSION

4.4.1 Socio-demographic characteristics

Regarding the socio-demographic characteristics, the majority of the participants were married. This is because in Arabic nations, it is favourable that people are married by the age of 30. Overall, there were only 19 participants (7.6%) who were single. In terms of the participants' level of education, it is shown that most of the participants only needed a Bachelor's degree to have the job they ideally want while it is more likely for people who are performing an academic job to have a doctorate or a Master's degree. The respondents with a low income most commonly have a high school or a diploma certificate and this study has revealed that the participants who have a low income are those with a high school certificate, making up one of the lowest proportions. Furthermore, regarding the income of the participants, it can be seen that most of the participants receive a moderate income because most of the participants' occupations are related to art, design and architecture. On the other hand, people with academic and some civil servant occupations reported as having a high income, although this is not the case for all civil jobs. Therefore, people in some civil service occupations receive a low income. Finally, the last question asks how many years of experience the participants have. The majority answered 11 - 15 years or 16 – 20 years. This is highly impacted by the age of the respondents.

4.4.2 Using computers software and the satisfaction of the results gained

Regarding 'Using computers software or not and the satisfaction with the results gained', the first question asks if the participant have used any computer software previously to create Islamic art patterns. The majority responded positively. This is likely due to it being relevant for their job considering that most of the participants worked as artists, designers or architects. The second question asks whether the participants are satisfied with the results obtained with the highest proportion reporting in the negative. This is likely due to the software not providing

them with the information that they want. They may also not know how to use it fully or it is not necessary for their job.

4.4.3 Different programs used by the participants to create Islamic art patterns

The software programs previously used included Photoshop, CAD software, MS Office and Sketchometry. The participants had to report which programs they used to make Islamic art. The Turbo CAD designer software was selected by many participants which could be because it is a self-explanatory program that performs the tasks quickly without having too many complex settings. Therefore, while it may be easily used, some of the participants may not select it because they do not like the layout and the settings or tools may be limited. The second most popular program was Photoshop. The participants may have selected this because it offers many complex tools as well as introductory features. Unlike the other programs, Photoshop offers the most tools which is likely to provide everything that the participants want as a result. The least selected program was Sketchometry, possibly because it is a complicated tool that is not easy to work with without experience. This software also takes longer to complete tasks.

4.4.4 The main features of the GIVA software

The five most important features of the GIVA software used by the participants include accuracy, repetition, scalability, colour and size control (Stiny, Gips 1971). The majority of the participants reported that repetition is the most important feature of the GIVA program. This feedback may be because repetition is a key feature when making Islamic art patterns as there tends to be a theme running through Islamic art through the repetition of sizes and shapes. This can only be made possible through repetition and scalability. The second most popular feature is accuracy. This is because the users cannot create Islamic art if it is not accurate at all corners and sides in order to follow a certain pattern or structure (Rasouli, Bastanfard et al.

2008b, Abas, Salman 1992). The third most popular feature is scalability. This may be due to its importance when merging more than one shape as it allows for various sizes of said shapes. Other participants may not have selected this because it is a common feature in many programs. Few of the participants chose size control. This could be because it is not important when creating Islamic art and it is a common feature in other software.

4.4.5 The important principles of the GIVA software

For the key principles of the GIVA software, seven were favoured by the participants in particular including repetition, contrast, symmetry, balance, shape diversity, interlocking shapes and proportionality. The most favoured was proportionality which could be because it allows you to change the size of a shape so then consistent patterns and sizes can be achieved (Nasr 1990). However, some of the participants might not have selected it because of the way it works, or they do not require it for the type of art that they create. The second most important principle according to the respondents is balance. This may have been reported because to make Islamic art, everything must be in balance and even, especially along the sides and corners of the shapes and patterns. Together with proportionality and balance, the principle of interlocking shapes is important because it allows for the linking together of the shapes (Ettinghausen et al. 2001) quickly and easily. Some of the participants might not have selected this feature because when creating Islamic art with other tools, they may instead only repeat the shapes to develop the pattern without the need to interlock. The least important principle according to the results is repetition. This is likely because many other software programs also have this principle as it is considered to be the most common principle found within Islamic art software (Critchlow 1976).

Other features within the GIVA software include contrast and shape diversity (Blair, Bloom 2003, Sayed et al. 2015). These are useful when starting a new art project as they provide the base for the entire design. Without these features as a starting point, the resulting art will not

have a unique shape. This reason is likely why some of the participants reported these features as important even though they are principles also found in competing software.

4.4.6 The perceptions of the participants about the uses and features of the GIVA software

Connected to the perception of the participants regarding the specific uses and features of the GIVA software are six statements to which the participants stated strongly agree, agree, undecided, disagree or strongly disagree in response. In the questionnaire, these six statements were separated into two questions with three statements each. For example, those who reported “strongly agree” to the statement ‘Planning to frequently use the GIVA program to make Islamic art’ indicate that they find the GIVA software to be very useful in it makes their design efforts straightforward (Gonzalez 2001). On the other hand, someone who reports “strongly disagree” to the question suggests that they are not used to creating art and that the software is not relevant to them as they have no use for it.

The statement of ‘Likely to use the GIVA program in my work to improve on it’ resulted in the participants strongly agreeing that the GIVA program will improve quality of work due to its many features enabling the desired effects and patterns (Ascott 2000, Riether, Baerlecken 2012). Others who strongly disagreed may have done so because there are many other Islamic art programs. As a final example, the last statement within this question was ‘Agreeing to create Islamic art using GIVA program in the future’ where the majority were in strong agreement. This is likely because the GIVA programme is one-of-a-kind. Others disagreed because they already use an alternate programme with which they are comfortable.

Regarding the second question ‘Based on your current knowledge and opinion of Islamic art, please indicate the likelihood of your prospective usage of the GIVA program’, three statements were presented. For the first, ‘Using the GIVA program to form Islamic art would increase my productivity’, the majority reported “strongly agree.” This is possibly due to the

programme improving their productivity because of the tools it provides (Broug 2008). However, the others who reported “strongly disagree” may have done so due to them not knowing how to use it.

The next statement for this question, ‘GIVA program is quick at finalising task of Islamic art’, had most of the respondents putting strongly agree. This is probably due to it having so many tools and efficient uses. On the other hand, those who strongly disagreed may be using an alternate programme that is fast. The final statement, ‘Applying the GIVA program features improves on Islamic art’, resulted in most of the participants strongly agreeing due to how the GIVA program makes Islamic art look professional (Necipoglu 1992, Jowers, Prats et al. 2010b). On the other hand, the participants who disagreed may consider that their Islamic art is sufficient for their standards and does not need to be improved.

4.4.7 Hypotheses of the previous use of computer programs by the participants

H1: There is a significant link between the participants' education level and their previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art.

The link between the participants' education level and their previous use of following computer programs provided a strong association. It appears that with a higher education level, the participants bring in more knowledge so they are more likely to know how to use all four programs (Abdullahi, Embi 2013). For example, when presented with the GIVA program, the participants who use Photoshop would not require much guidance.

H2: There is a significant link between the participants' occupation and their previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art.

This relationship has an impact on the knowledge of Islamic art of the participants in relation to their academic or civil servant occupations. This is as the participants may not know how to use these programs depending on their professional background. If the participant is an artist, designer or architect, they are more likely know how to use one. This also affects the quality of the artwork (Izadi et al. 2010) created with these programs.

H3: There is a significant association between the years of experience of the participants in the Islamic art field and their previous use of operationalised computer programs such as Photoshop, CAD software, MS Office and Sketchometry to create Islamic art.

The years of experience of the participants matters because if they have experience in art and design, their work will look professional (Kaplan 2005) because they are likely to know what they are doing when presented with the GIVA software. This background also supports their use of the software to its fullest potential.

4.4.8 Hypotheses of the basic principles and features in the GIVA software

H4: There is a significant like between the participants' education level and their familiarity with the basic principles and features of the GIVA software.

A strong association between the level of education and the features of the GIVA software is due to the participant needing to know what the features do before they use them effectively (Klenke 2016). With more education, they may have more experience with the features and skills associated with Islamic art-creating programs (Morse 2000), thus the better and more professional their art will appear. Furthermore, it will be easier for them to use the GIVA software with less guidance required.

H5: There is a significant link between the participants' occupation and their familiarity with the basic principles and features of the GIVA software.

This association has an impact on the use of the program if the participant's occupation is art or design. They will not necessarily struggle (Regmi 2010) with the GIVA program because they are familiar with what to do with the shapes (Ware, Warschauer 2012) and how to create them. On the other hand, for those with a civil servant or academic job, the participants may not have any familiarity with the tools provided within the GIVA software.

H6: There is a significant association between the years of experience of the participants in the Islamic art field and their familiarity with the basic principles and features of the GIVA software.

This association impacts how the participants use the program. This is because if someone has over 15 years of experience (Abas, Salman 1992), they would probably know what to do and how to do it. On the other hand, the participants with less experience might struggle, especially if their job isn't related to Islamic art/design. They would not know much about the tools and what they do in terms of improving the Islamic art designs or creating an Islamic art pattern or shape (Stiny, Gips 1971).

4.4.9 Hypotheses of the perceived usefulness of the GIVA software.

H7: There is a significant association between the participants' education level and their overall familiarity with the basic principles and features of the GIVA software.

These two aspects have an extremely strong association. This is because if the participants' level of education is higher, they are more likely to be familiar with the GIVA software (Saunders et al. 2009) principles. If the participants have more knowledge about Islamic art, when they begin working with the software, they will be familiar with the basic concepts and approaches.

H8: There is a strong association between the participants' occupation and their familiarity with the basic principles and features of the GIVA software.

This association with occupation has an impact on the knowledge of the participant concerning these programs. This is because if a participant's occupation is related to Islamic art, design or architecture (Seidman 2013), they will tend to be familiar with the basics of the GIVA program as they have likely used some form of program before to create patterns, shapes and designs (Sayed et al. 2015).

H9: There is a significant association between the years of experience of the participants in the Islamic art field and their familiarity with the basic principles and features of the GIVA software.

This association is significant when it comes to the skill of the participant. This is because they already have experience creating Islamic art digitally (Radaelli 2011). If they know how to generate Islamic art, the participants will likely know the basic approaches of the GIVA software, allowing them to know what to do (Rasouli et al. 2008b) when presented with the GIVA software.

4.4.10 Hypotheses of the participants' behavioural intentions to use the GIVA once

H10: There is a correlation between the participants' level of overall education and the perceived usefulness of the GIVA program once it is offered to them.

The correlation between these two aspects is clear as the participants need a sufficient level of knowledge and understanding that is obtained through higher education in order to use the GIVA software to its fullest potential (Abdullahi, Embi 2013). The participants also need experience in Islamic art designs.

H11: There is a correlation between the participants' occupation and the perceived usefulness of the GIVA program once it is offered to them.

The participants' occupation will have an impact on their perception of usefulness (Cohen, Manion et al. 2011) when using the GIVA software since some might not have a relevant application for the software within their professional work, such as a civil servant or an academic outside of the field of Islamic art (Gross 2001b).

H12: There is a correlation between the years of experience of the participants in the Islamic art field and the perceived usefulness of the GIVA program once it is offered to them.

This relationship has the most impact on the usefulness of the GIVA software (Lu, Steinhardt 2007) because if a participant has no experience with similar software, they will need additional guidance to perform adequately.

4.4.11 Hypotheses of the associations of computer programs computer program

H13: There is a correlation between the participants' level of education and their behavioural intention to use GIVA once it is offered to them.

This relationship matters because the participants may have an educational background in Islamic art but still not necessarily know how to create it (Ware, Warschauer 2012) using the software. Therefore in terms of using the GIVA software, it is not the most important but it will impact on the final design (Abas, Salman 1992).

H14: There is a correlation between the participants' occupation and their behavioural intention to use GIVA once it is offered to them.

This correlation impacts on how the software is used (Stavric, Marina 2011) and how the Islamic art is created. Since the occupations of the participants vary, the participants who work in fields related to art, design or architecture may have more experience (Ostromoukhov 1998) and education in Islamic art, so they will be more familiar with how to create it.

H15: There is a correlation between the years of experience of the participants in the Islamic art field and their behavioural intention to use GIVA once it is offered to them.

This relationship also has a significant impact on the creation of Islamic art because if the participants do not have experience, they will struggle with the process (Kaplan 2000) because they will not know how to begin from a pattern or shape. Although the program is easy to use for creating Islamic art, it still takes time and skill to follow a specific pattern and a clear process sequence (Flood, Necipoglu 2017, Necipoglu 1992).

H16: There is a correlation between the previous use of the following computer programs, operationalised as Photoshop, CAD software, MS office or Sketchometry, by the participants to create Islamic art and their behavioural intention to use the GIVA program once it is offered to them.

This correlation affects the skills of the participants (Necipoglu 1992) when using the GIVA program. This is because if they have previously used another program, they will be more familiar with what is required (Morse 2000). This prior knowledge will help to support the more efficient use of the GIVA software.

H17: There is a correlation between the previous use of the following computer programs, operationalised as Photoshop, CAD software, MS office or Sketchometry, by the participants to create Islamic art and the perceived usefulness of the GIVA program once it is offered to them.

The correlation between the usefulness of the software and the quality of the end product (Lu, Steinhardt 2007) is evident when the participant has used design software previously. This familiarity supports the use of the GIVA software because they already know the basic principles and features (Kaplan 2000).

4.5 SUMMARY

This chapter puts forward the statistical analysis of the non-parametric tests, including univariate descriptive analysis, to show the characteristics of the sample. In addition, this chapter discusses the bivariate and multivariate inferential statistic tests that were conducted by computing the different cross-tabulations to examine the hypotheses and the variance associations. Since this chapter builds on the initial Islamic art patterns created from the developed and modified formula used in this study, the information gained from the participants regarding their perception via the questions provided through the survey offers improvements and enhancements concerning the Islamic art patterns created during the first attempt of this study. The next chapter applies the suggestions from the survey to the formula in order to create a new variety of Islamic art patterns and designs.

Chapter V. QUALITATIVE STUDY

This chapter is the discussion of the qualitative data elicited from the nine interviews with the experts in the Islamic arts. Eight themes and 21 sub-themes have been devised from the interview transcripts which have been discussed in relation to the existing literature. This chapter also outlines the integration and synthesis of the research findings that are to be applied to improve and enhance the variety of Islamic art designs that can be created using the GIVA software.

5.1 WHY QUALITATIVE STUDY?

The qualitative study method has been selected to evaluate and assess the developed aesthetic criteria and geometric Islamic pattern rules. It will also help to evaluate and improve the quality of the produced patterns. The outcomes of this study will help to verify and validate the quality of the generated geometric Islamic patterns. Moreover, it will help to confirm the geometric Islamic pattern drawing rules in terms of defining what must be applied and what should be avoided.

The collected data for this study involved semi-structured interviews. There were several experts interviewed and they have been asked to evaluate the geometric Islamic patterns that have been produced by the proposed approach. This study helps us to engage with the experts and to have a better understating of the practices that might influence the aesthetic of the generated patterns. This kind of information allows the developed approach to avoid bad practices.

The collected data has been used to improve the developed approach and this will help to enhance the quality and aesthetic of the generated geometric Islamic patterns. Besides that, the experts provide different points of view as experts in visual Islamic art.

5.2 FINDINGS OF THE QUALITATIVE STUDY

The participants of the study included nine interviewees who took part in sessions with the researcher as the interviewer. The interviewees' age ranged from 48 to 56 years old with five males and four females as experts in the Islamic arts. All of the participants had higher qualifications ranging from a master's degree to a PhD. The participants included females working as senior lecturers or lecturers with an affiliation to King Abdul-Aziz University and others were males working as art interior designers at Nawaf's Company of General Contractors. All of the interviews took place at the locations indicated in Table 5 - 1.

Table 5 - 1 Summary characteristics of the participants

S.N.	Name of participant	Age	Gender	Participant qualification	Occupation	Location of interview
1	**MA**	46	Male	Master of Art	Consultant	Nawaf Company General Contracting
2	**SD**	50	Female	PhD in Interior Design	Senior lecturers	King Abdul-Aziz University
3	**RF**	54	Male	PhD in Islamic Architecture	Architecture	Nawaf Company General Contracting
4	**MS**	56	Female	Master of Art	Teacher	King Abdul-Aziz University
5	**FY**	44	Male	PhD in History of Art & Architecture	Architecture	Nawaf Company General Contracting
6	**WG**	56	Male	Master of Art	Interior designer	Nawaf Company General Contracting
7	**DT**	47	Male	PhD in Interior Design	Interior designer	Nawaf Company General Contracting
8	**FH**	55	Female	Master of Art	Lecturer	King Abdul-Aziz University
9	**KH**	48	Female	PhD Islamic Architecture.	Senior lecturers	King Abdul-Aziz University

5.3 EIGHT THEMES AND SUBTHEMES

The outcomes from this qualitative analysis show that there were nine interviews included within the data that has been presented below in a series of eight separate themes. Having applied the TA approach to analyse the qualitative data, the software package NVivo 12 was applied and eight themes were elicited and allocated to the subthemes illustrated in Table 5 - 2. The next section presents each theme and the respective subthemes which will be used to improve and enhance the Islamic art patterns created by the GIVA software.

Table 5 - 2 Eight themes and the subthemes elicited from the nine interviews

Theme		Subthemes
1	**User Requirements**	• **Repetition** • **Accuracy** • **Colour** • **Scalability**
2	**Spatial distance (in Design)**	• **Too wide** • **Very well made** • **Too close**
3	**Distance and Size**	• **Too big and too wide** • **Wide spaces between patterns wasted the aesthetic of the figure or quite big, but the space is just right**
4	**Colour Grading**	• **The colours all link with each other** • **The colour makes it stand out**
5	**Shape Diversity**	• **A worthy quantity of shape diversity** • **The shape of diverse requires amendment and enhancement**
6	**Uniqueness of Pattern**	• **The design is unique with a clear layout** • **The design is exceptional, but the pattern is simple**
7	**Complexity of Pattern**	• **The pattern is very complex and meaningful** • **The pattern is quite complex and has bright colour**
8	**Participant Evaluation**	• **The patterns are accurate** • **The patterns are overdone** • **The patterns are perfect**

5.3.1 User Requirements

Three subthemes belong to this theme including accuracy, colour and scalability. Each of these has been presented below.

5.3.1.1 Repetition

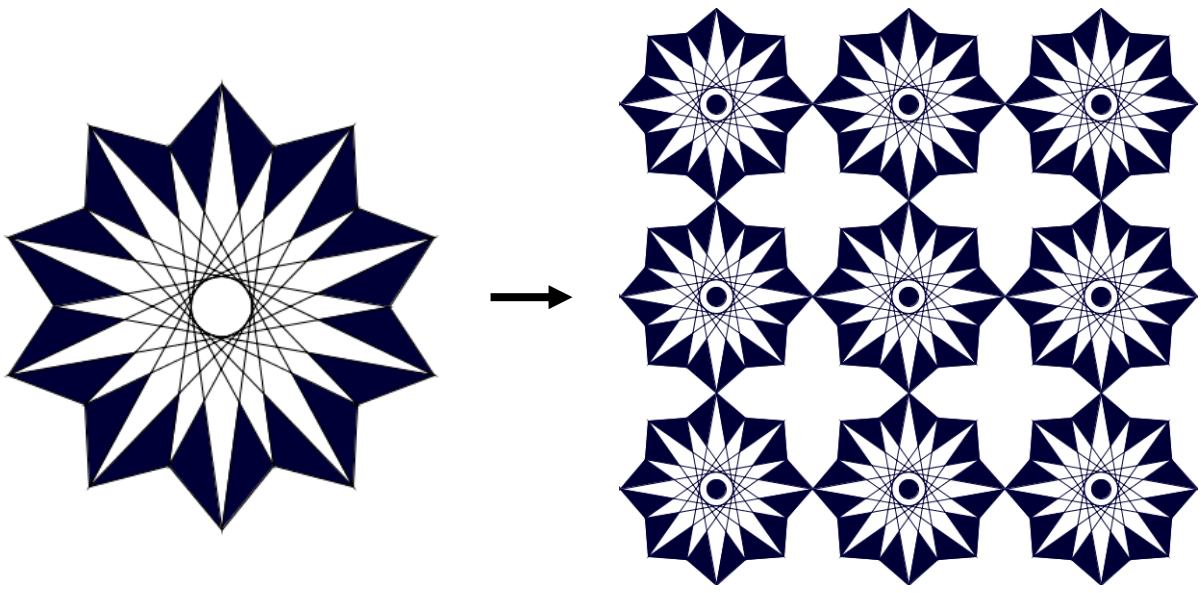
The majority of the participants expressed that repetition is important in all Islamic designs because it is a key feature of the patterns therein. Without this feature, the GIVA program would not be efficient or well-organised enough for the purpose of creating Islamic art.

'I think that repetition is what makes Islamic art stand out because most of the other art is very unrepetitive and unamusing.'

(MA, Male, 46, Master of Art)

'Repetition is the key of Islamic art shapes and patterns, and without it the art would not look the same and it would not be as eye-catching.'

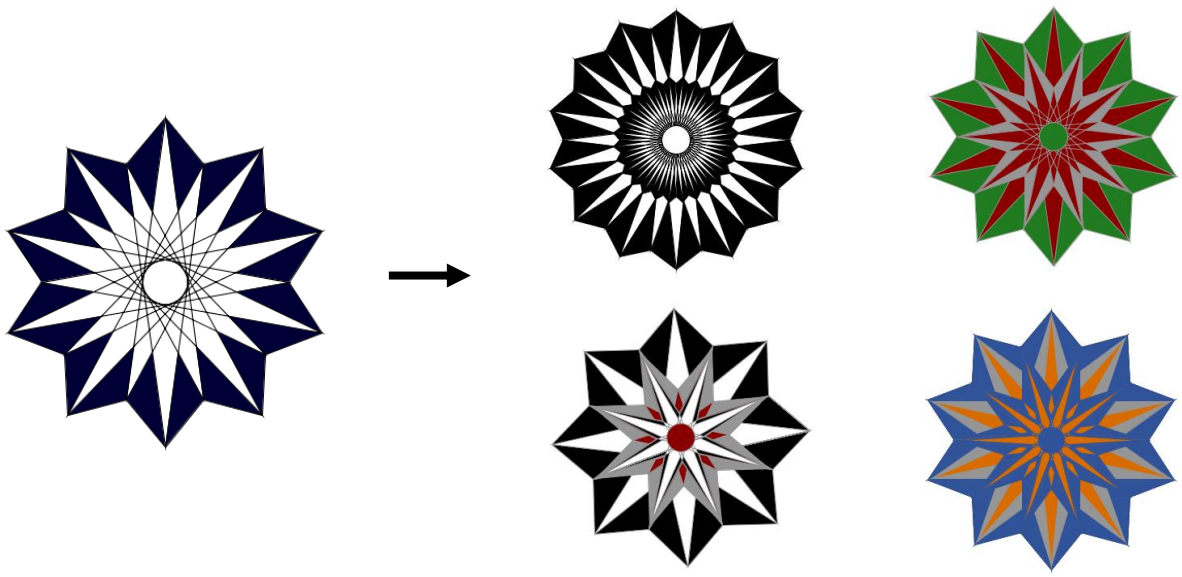
(SD, Female, 50, PhD in Interior Design)



On the other hand, two of the nine participants expressed the divergent view that Islamic art patterns do not require repetition if the other essential features are provided in the resulting patterns such as colour and shape diversity.

'I believe that Islamic art does not need repetition for it is not really too important when it comes to making Islamic art. The things that are really important are the shape interlocking and the colour because it makes the pattern or shape stand out.'

(RF, Male, 54, PhD Islamic Architecture)



5.3.1.2 Accuracy

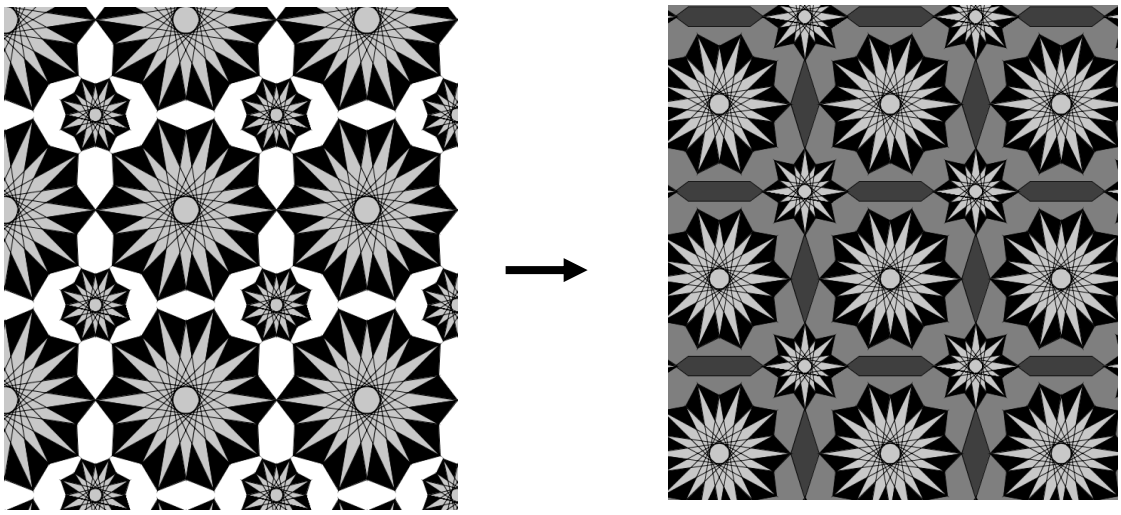
The view of most of the participants about accuracy is that it is a crucial feature of Islamic art designs. The patterns should possess accuracy as a variety of figures that are attractive to both the experts and end users is important. To adopt these patterns without prioritising accuracy would result in uneven formulated designs.

'In my opinion, accuracy is the most important feature in the GIVA software as it is what gives Islamic art its overall form and design.'

(MS, Female, 56, Masters of Art)

'I think that accuracy is a very important feature of Islamic art because it makes all the sides and the corners even and exact.'

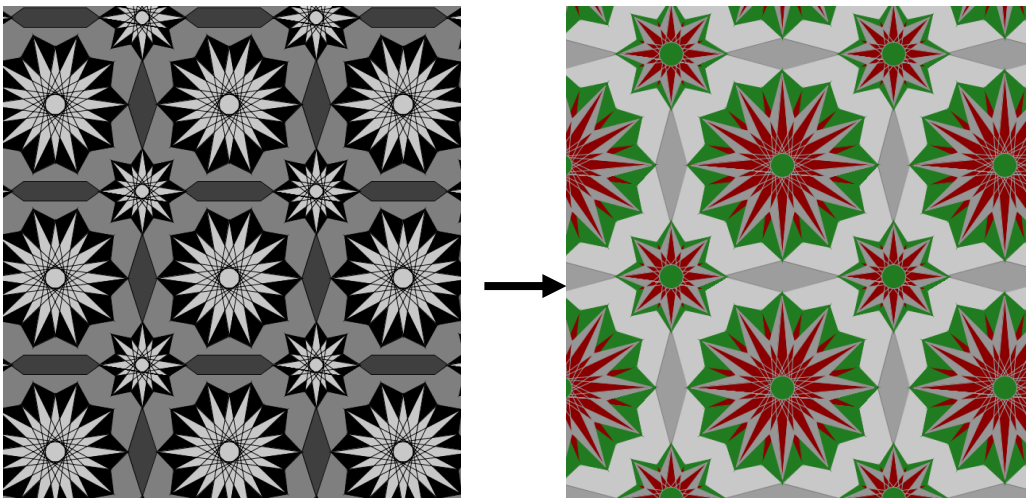
(FY, Male, 44, PhD in History of Art & Architecture)



On the other hand, one participant assumed that accuracy is disregarded when the professionals deal with large quantities of Islamic art designs or patterns while still maintaining other important features in the designs.

'I believe that accuracy is likely unimportant in Islamic art because the colour, shape diversity, and interlocking are important.'

(WG, Male, 56, Masters of Art)



5.3.1.3 Colour

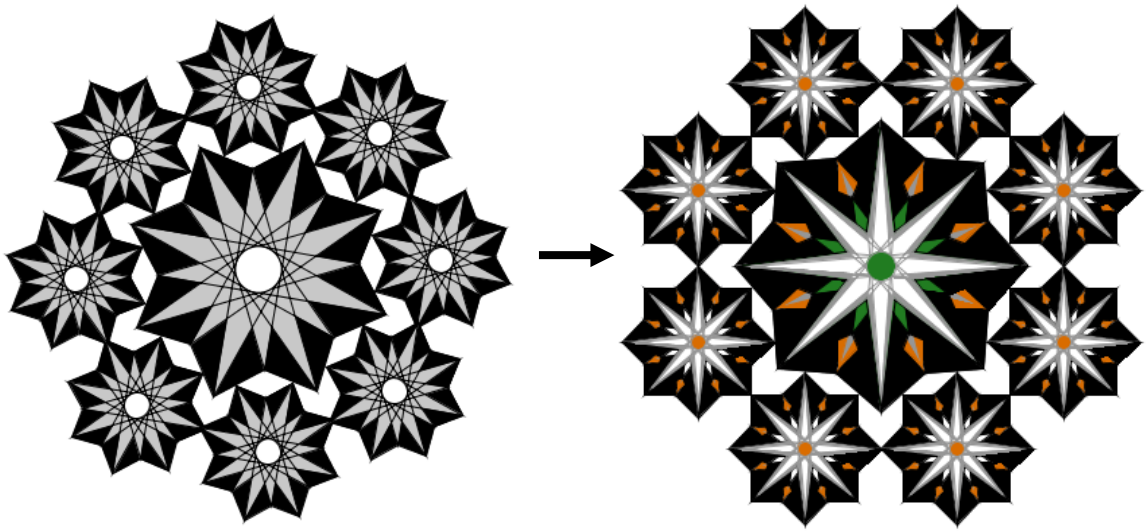
The majority of the participants stated that colour is the most important feature of Islamic art as it is what makes Islamic art stand out.

'Personally, I think the colours of Islamic art are what make it very vibrant and interesting to look at, and the colour gradients within the art are unique in many ways.'

(DT, Male, 47, PhD in Interior Design)

'I know for sure that the colour of Islamic art is what makes it stand out from other pieces of art. Not only have the colours on Islamic art evolved but the different colour schemes to make it a pleasure to look at.'

(FH, Female, 55, Master of Art)



5.3.1.4 Scalability

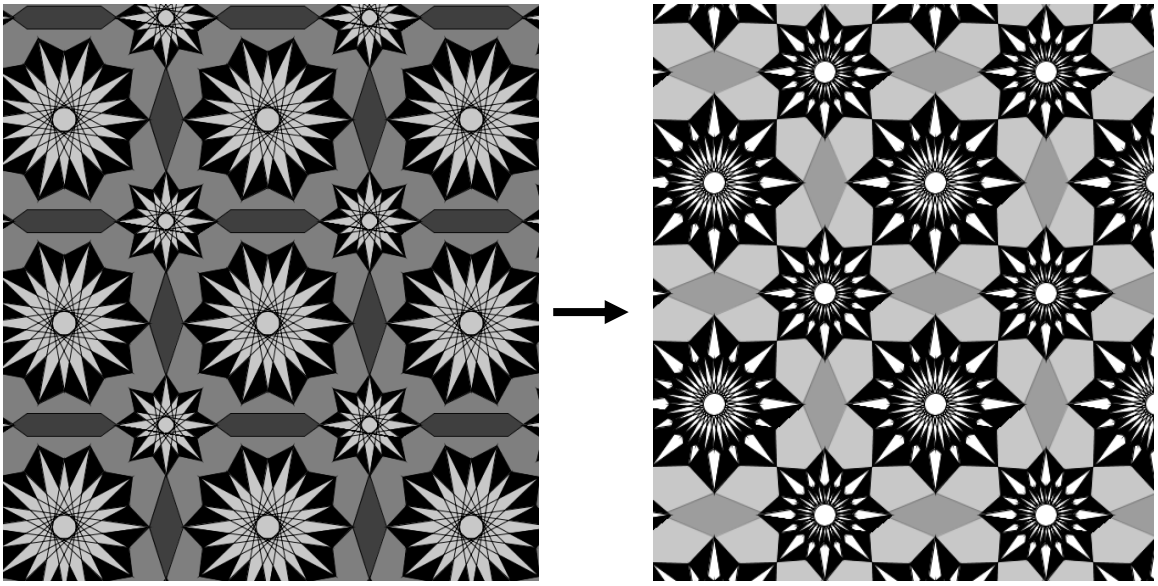
Most of the participants suggested that scalability should be provided by the GIVA program as a key feature that improves and enhances the variety of the possible Islamic art designs.

'I personally believe that scalability is an extremely important feature of Islamic art and that it should be in the GIVA software.'

(KH, Female, 48, PhD Islamic Architecture)

'I know that the scalability is very important when it comes to making Islamic art because you might want to make a shape smaller to interlock it and get that perfect corner or side.'

(RF, Male, 54, PhD Islamic Architecture)



Only one participant presumed that the scalability feature was not required because some of the pre-existing Islamic artwork disregards this feature.

'From my point of view, it seems to be that some Islamic art designs likely avoid involving the feature of scalability because if you have a pattern you need to make or a design it does not necessary need any scalability.'

(FY, Male, 44, PhD in History of Art & Architecture)

5.3.2 Spatial distance (in Design)

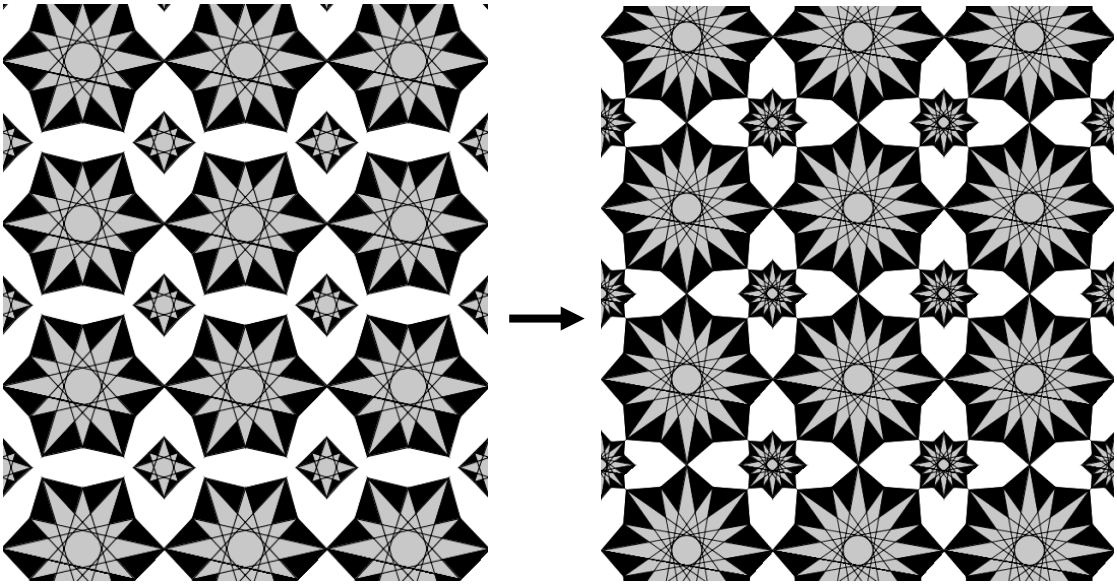
Three subthemes belong to the spaces between the stars in the pattern designs including too wide, very well made and too close. Each subtheme has been presented below.

5.3.2.1 Out of shape (too wide)

The vast majority of interviewees agreed that the spaces between the stars in the pattern designs were too wide, resulting in the work being irregular.

'I believe that if the Islamic art was very wide between patterns, from my perspective, this would make the art uneven and unattractive.'

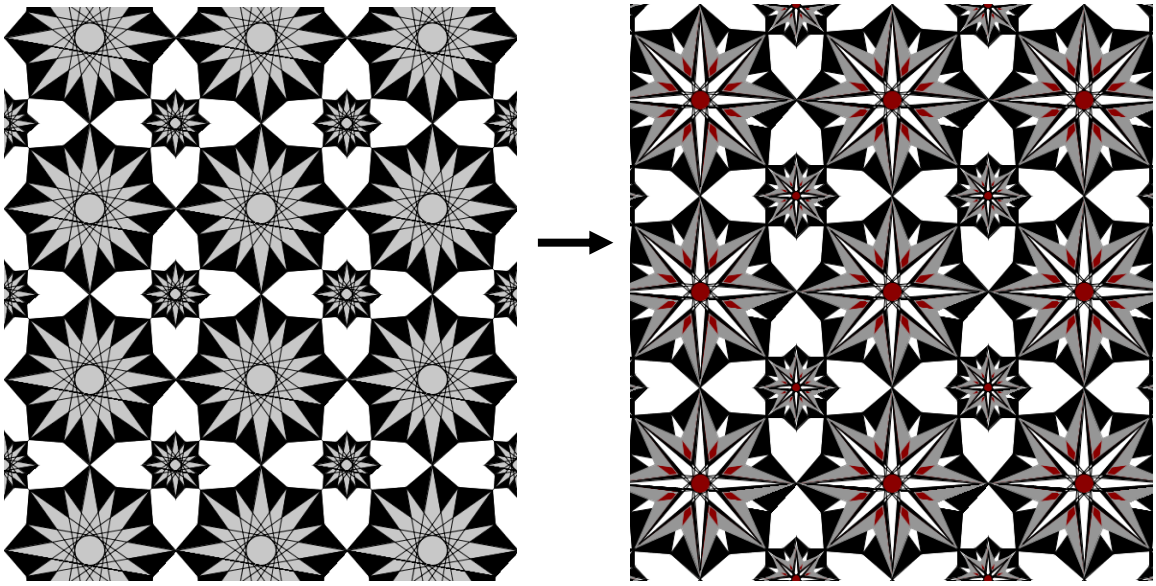
(MA, Male, 46, Masters of Art)



Two out of the nine perceived that the wide spaces between the stars in the pattern are of no concern compared to the other features and that they do not impact on the format of the designs.

'I know for a fact that this drawing is the best Islamic art can get if it has a lot of features of Islamic art, for example, shape interlocking, colour, accuracy, and many more. So, in theory, this is a perfect piece of art.'

(KH, Female, 48, PhD Islamic Architecture)

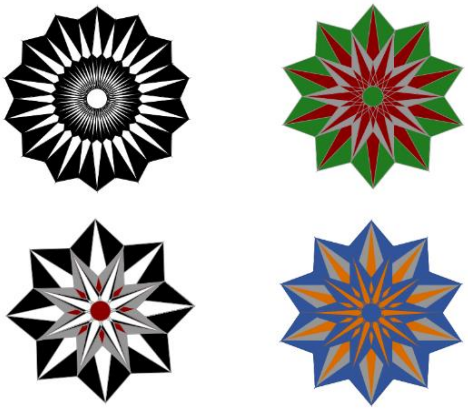


5.3.2.2 Very well made

The majority of the interviewees perceived that the spaces between the stars in the pattern design were valuable and well made so most of the participants expressed their satisfaction with the idea and the first version of the output.

'I know for a fact that this piece of art is unique. During all my years of experience, I have not seen anything as intricate and complex.'

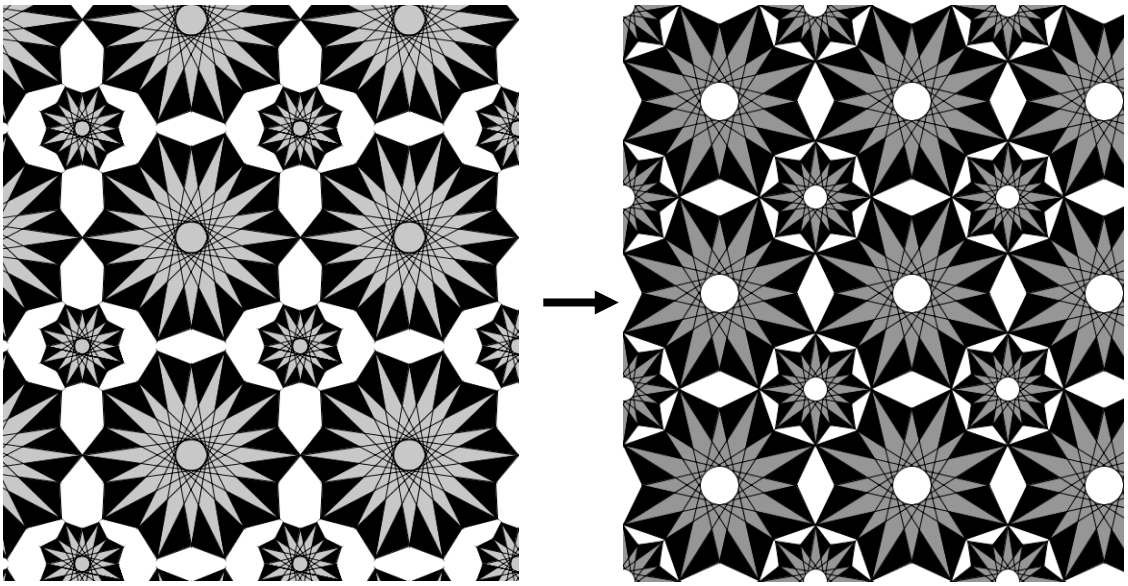
(MS, Female, 56, Master of Art, Teacher)



Only one participant suggested that the spaces between the stars in the pattern design were very small and blurred. It thus required intensive work to pique his curiosity.

'I believe that this shape is very small and close together. It would improve dramatically if it became bigger, so it would also be bigger.'

(RF, Male, 54, PhD Islamic Architecture.)

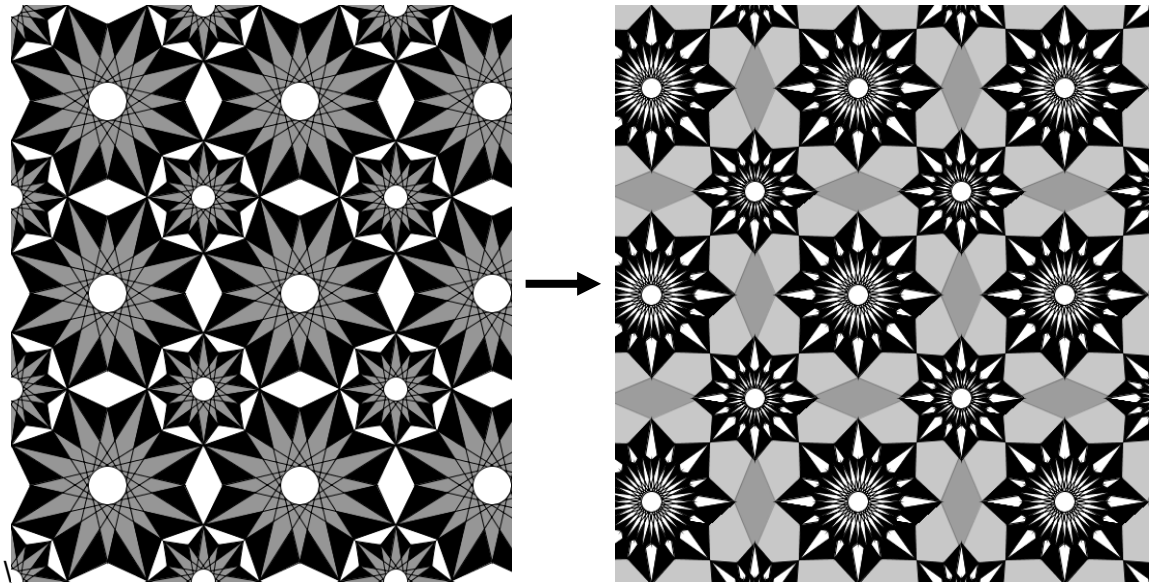


5.3.2.3 Out of shape (too narrow or close)

Most of the participants viewed that the spaces between the stars in the pattern were too close together.

'*Personally, I believe that the shapes are too compact and too close to each other. This wouldn't make the art very vast and it would also make it very small.'*

(SD, Female, 50, PhD in Interior Design)



On the other hand, two of the nine suggested that the spaces between the stars in the pattern appear too large which was unacceptable. The technique therefore might require rectifying.

'I presume that this piece of art is very narrow, and I think it needs a lot of work to improve, such as increasing the space to become wider to provide an aesthetic view of the shape of the figure of Islamic art design. I know my suggestion is probably a bit strange but this my view anyhow.'

(FH, Female, 55, Master of Art)

5.3.3 Distance and Size

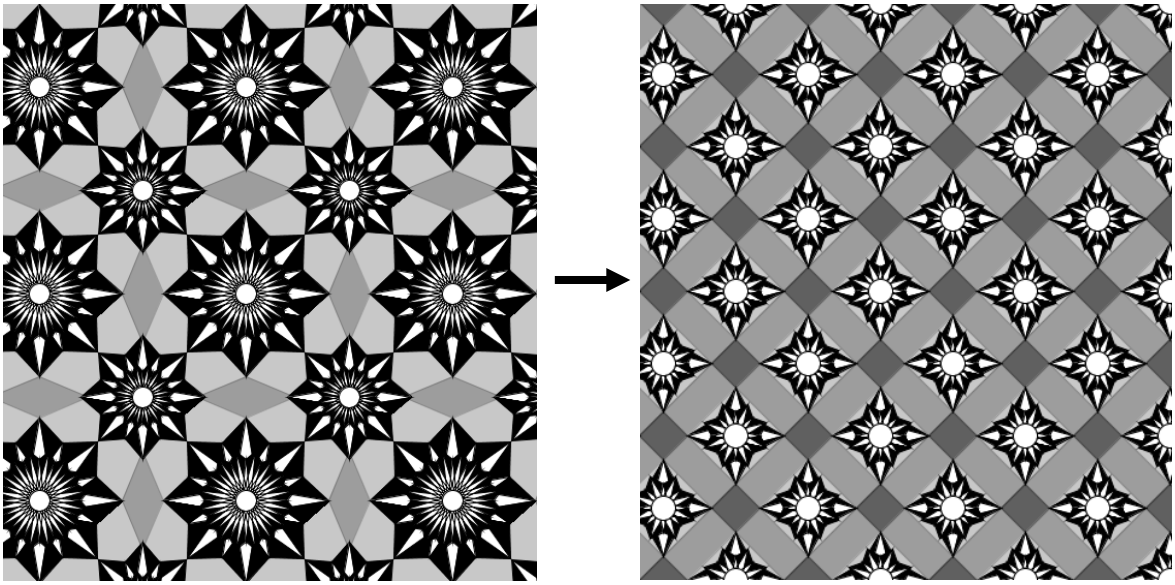
Three subthemes belong to this theme including too big and too wide, wide spaces between the patterns lessening the aesthetic and it being quite big but with the spacing just right. Each of these subthemes has been presented below.

5.3.3.1 Too big and too wide

Most of the interviewees voiced that the distance and size differences between the patterns were too wide and too big. In other words, the experts considered the pattern to not be perfect because it should be smaller.

'In my opinion, I think that the pattern is very wide and big even. Although it is balanced, it still is not even in terms of colour.'

(MS, Female, 56, Master of Art, Teacher)



One participant focused on the fact that the distance and size differences between the patterns were drawn perfectly and that it seems acceptable. One participant suggested that it was time to embark on marketing the pattern to potential clientele.

'I believe that this pattern is as good as Islamic art gets, so it is a masterpiece and I love how all the colours and shapes contract each other. I think it is time to launch this product into the marketplace, it not it?'

(MS, Female, 56, Master of Art, Teacher)

5.3.3.2 Wide spaces between patterns lost the aesthetic of figure

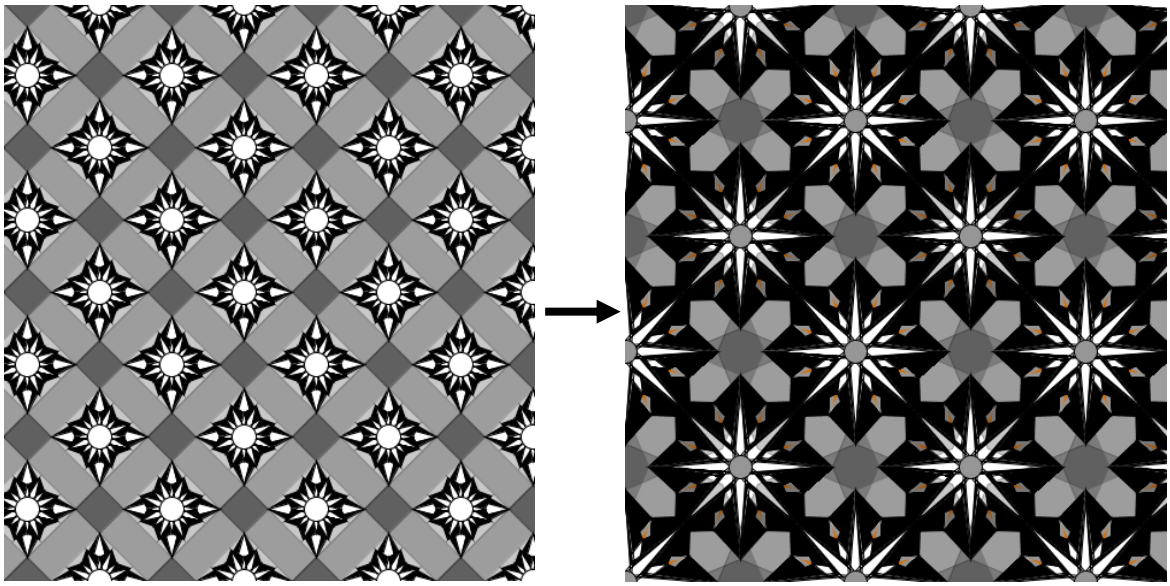
The majority of the interviewees acknowledged that the Islamic art designs in the photo have lost their aesthetic appeal due to the increase in the spaces between the figures.

'Personally, I believe that this piece of art is uneven because it is disfigured either by design or accident as the spaces between are very wide. So, I can assume the design was to disfigure the status quo. And, hence, it needs to be rectified.'

(WG, Male, 56, Master of Art)

'I strongly believe that this pattern is very unattractive and that it can be improved by rectifying and amending the shapes within the patterns through constricting the spaces.

(RF, Male, 54, PhD Islamic Architecture)



5.3.3.3 Quite big but the space is just right

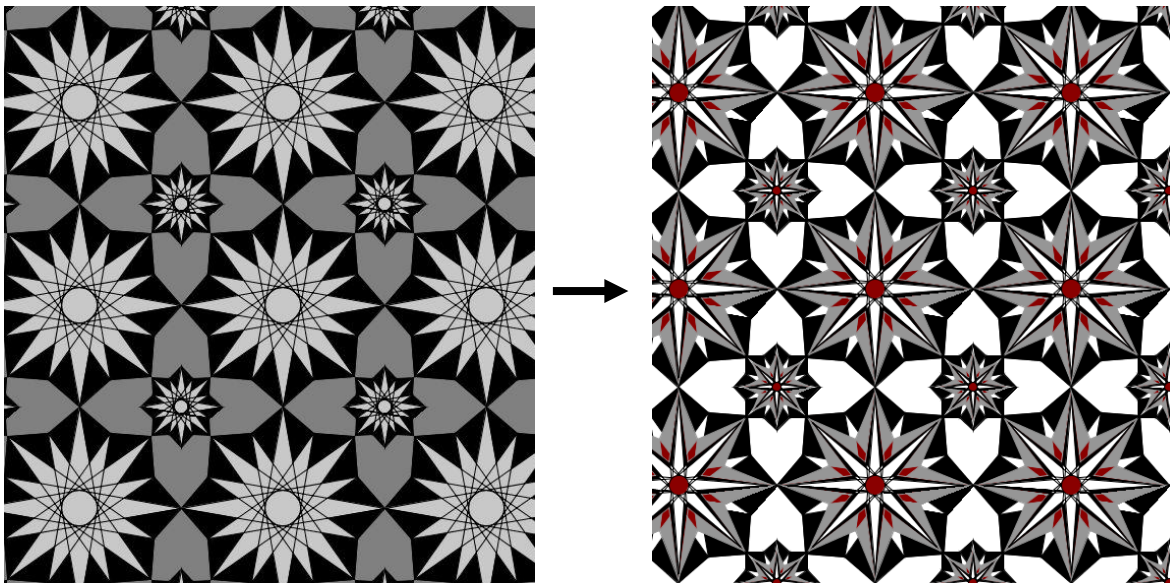
The majority of the interviewees acknowledged that this pattern is appealing. However, it is arguable that the spaces require further restriction to become attractive to customers.

'To me, this pattern is a piece of art, but it seems to be fine as long as we insert the necessary suggestion we already talked about, such as limiting the large spaces between patterns in order to become acceptable.'

(FH, Female, 55, Master of Art)

'This piece of art is one of the finest I have seen, but it really needs the essentials of amendments to converts it into one that meets the requirements of marketing and, as the view of the experts, this is my voice about this issue.'

(*RF, Male, 54, PhD Islamic Architecture)*



5.3.4 Colour Grading

Two subthemes belong to this theme including that the colours all link with each other and the colour makes it stand out. Each subtheme has been presented below.

5.3.4.1 The colours all link with each other

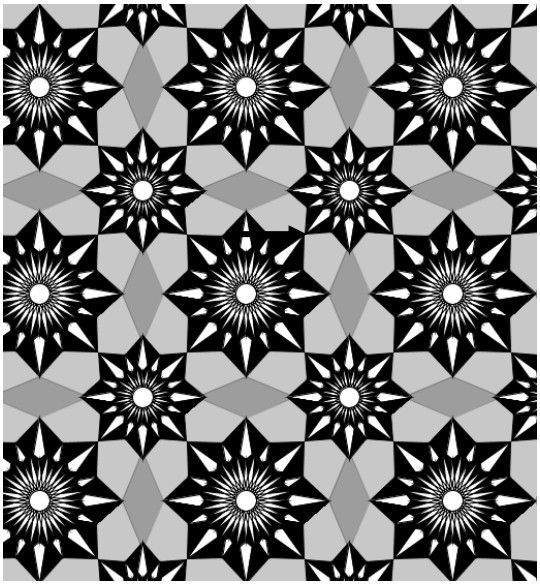
The majority of the interviewees admitted that although there was colour grading in the Islamic art patterns, the effort required by the artist must provide the connection or link between the colours in order to produce a desirable format that would be appealing to a purchaser when selling the product.

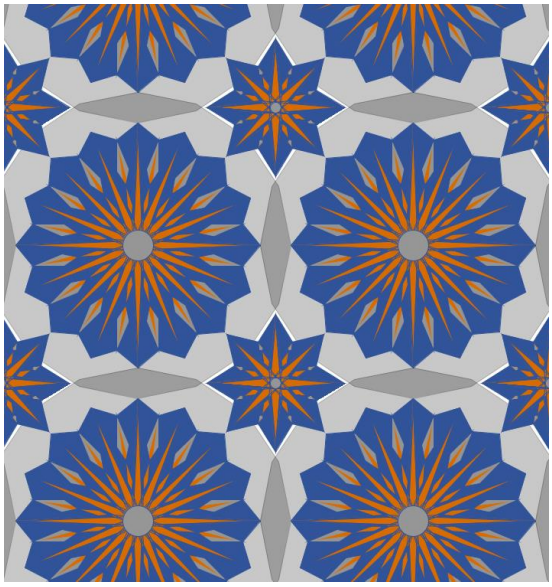
'I know for a fact that the colour on this piece of work of Islamic art is what fascinates people to look at it. It is similar to a cover on a book as no one will stare at it if the cover is unappealing or unlikable.'

(MA, Male, 46, Master of Art)

'When it comes to art, colour is an extremely important factor as it is what attracts people and makes them want to admire the work. It is like the icing on a cake no one would want to eat it if the icing looks terrible.'

(KH, Female, 48, PhD Islamic Architecture)





On the other hand, some of the participants disregarded the characteristic of colour and considered it to be a trivial issue. This is because they perceived that priority should be given to the shapes and background features.

"Personally, I can see the colour feature in Islamic art models as not a big issue on the condition that the colour was painted and places. To me, I think every artist should give their priority to the other necessary features, such as the shape of the background in the figure.'

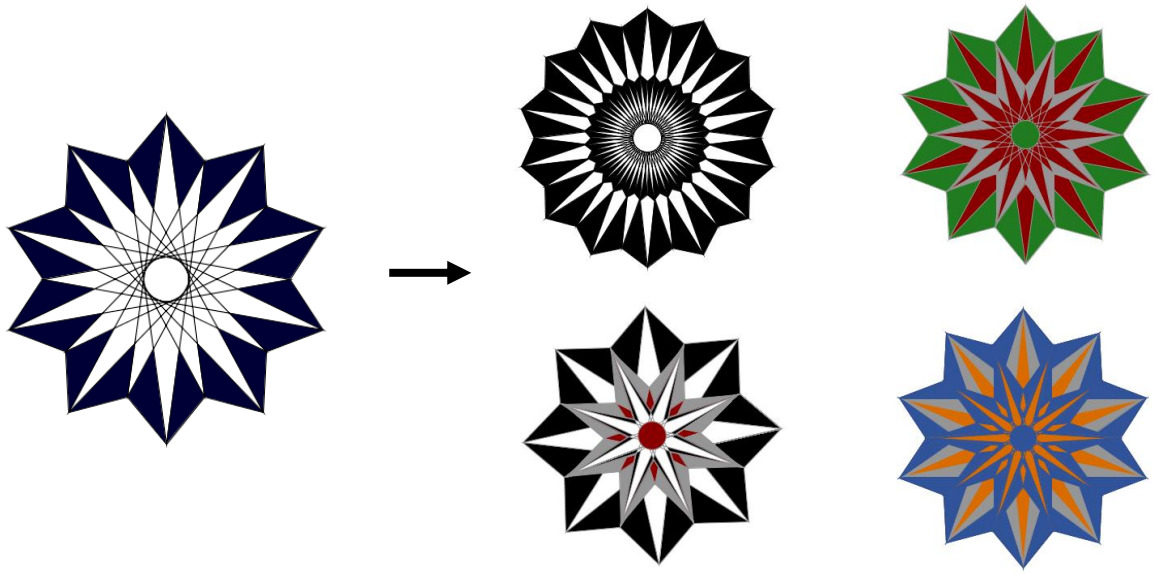
(KH, Female, 48, PhD Islamic Architecture)

5.3.4.2 The colour makes it stand out

The majority of the interviewees broadly discussed that the colour presented in Islamic art must be evident because it is a prominent characteristic. If the artist fails to apply colour appropriately, it results in the disfiguration of the pattern.

'Without colour, art wouldn't be what it is today as it is all about creativity, design, and colour. This is what is expected of most pieces of art, and it is what makes them unique.'

(FY, Male, 44, PhD in History of Art & Architecture)



Some of the participants argued that colour is not as important as the other features such as the shapes involved and the background.

'From my point of view, I assume that the colour is irrelevant to art once it is observed at the first glance in comparison with the other features of shape diversity because it is very key to catching people's attention.'

(*SD, Female, 50, PhD in Interior Design)*

5.3.5 Shape Diversity

Two subthemes belong to this theme including a worthy quantity of shape diversity and diverse shapes as a required amendment and enhancement. Each subtheme has been presented below.

5.3.5.1 A worthy quantity of shape diversity

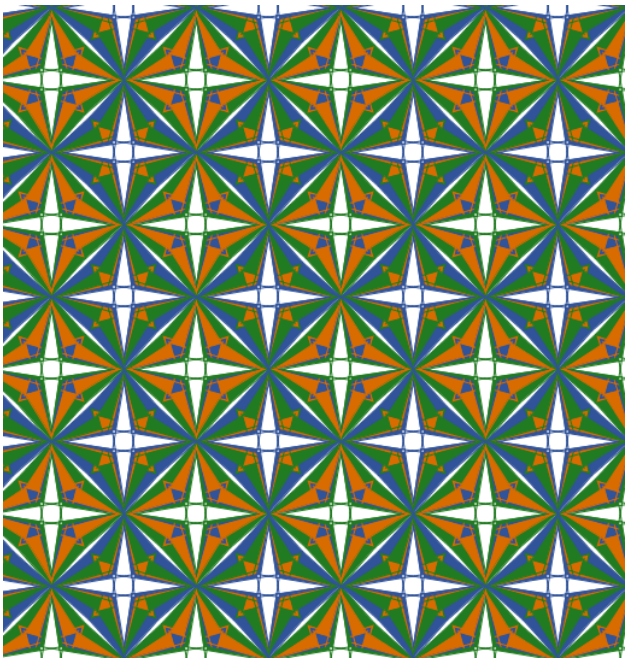
Most of the participants concurred that there exists an astonishing organisation of shape diversity within the patterns.

'This pattern has a very sufficient amount of shapes and they are very diverse, which makes them distinctive and remarkable.'

(DT, Male, 47, PhD in Interior Design)

'I should admit that this pattern has a lot of shape diversity, which makes it fabulous to look at and also makes it fascinating.'

(SD, Female, 50, PhD in Interior Design)

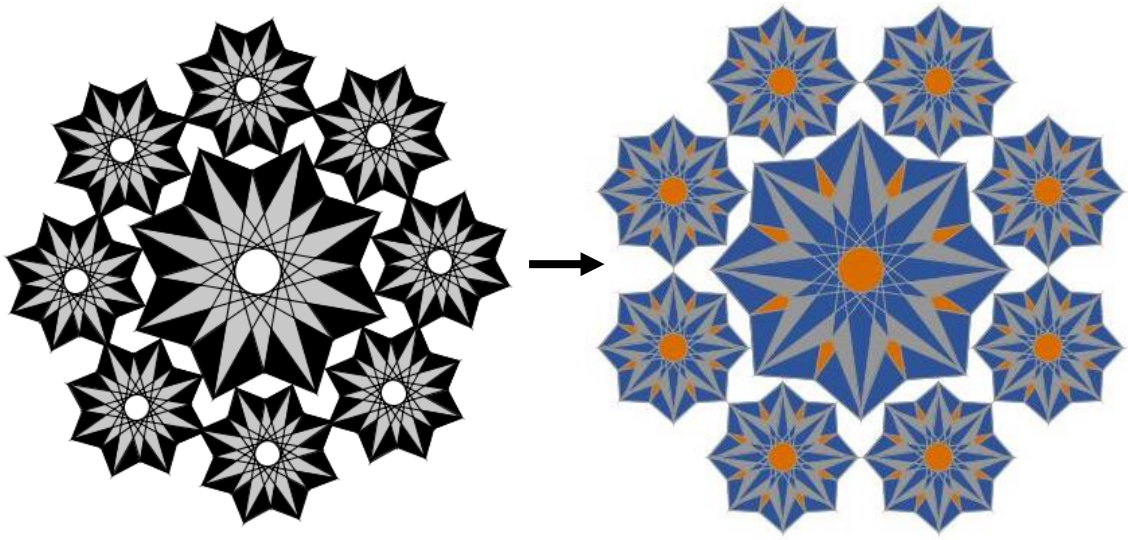


5.3.5.2 The diverse shapes require amendment and enhancement

The majority of the participants agreed that although there is a diversity of shapes within the Islamic art designs, these shapes still require amendment and enhancement in order to create the final product of Islamic art design to ensure that the customers are fascinated and purchase the design.

'I presume that this pattern is very unique because of its form and the verity of shapes, but these shapes need to be refined and reformatted into prettier shapes to be more attractive than the original.'

(MA, Male, 46, Master of Art)



The minority of participants argued that the diversity of shapes seems to be excellent and that nothing needs to be rectified compared to those formatted by manual artists.

'I personally think that the shapes are diverse, which makes this pattern exciting to look at and the experts probably accept this work and consider it as magnificent development in the Islamic art patterns.'

(KH, Female, 48, PhD Islamic Architecture)

5.3.6 Uniqueness of Pattern

Two subthemes belong to this theme including that the design is unique and has a very clear layout and that the design is quite exceptional, but the pattern looks simple. Each subtheme has been presented below.

5.3.6.1 The design is very unique and has a clear layout

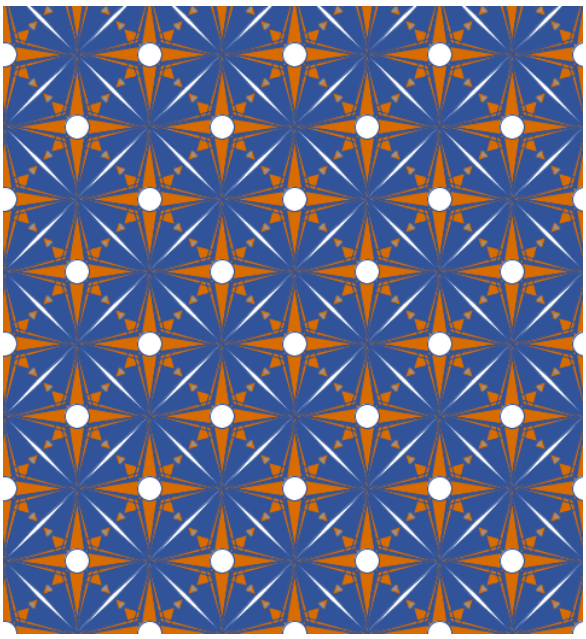
The majority of the interviewees suggested that the design of the Islamic art is very unique and it has a perfect layout as well as a pattern that fascinates the people whose occupation is relevant to the Islamic arts.

'What I like about this design is not only that it has all formal elements, but it also has a lot of complexity and is very unique.'

(KH, Female, 48, PhD Islamic Architecture)

'I like how this pattern is unique and doesn't copy elements from anywhere else as it just has its own unique style.'

(RF, Male, 54, PhD Islamic Architecture)

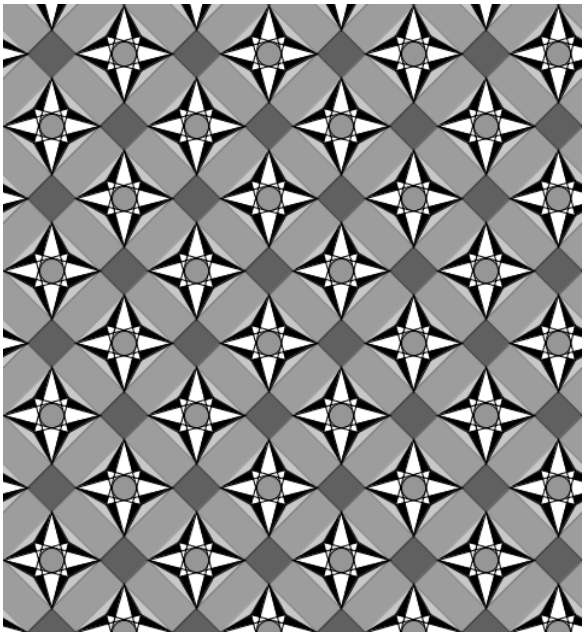


5.3.6.2 The design is quite exceptional, but the pattern looks simple

Most of the participants agreed that the design of the Islamic art was exceptional and that it looked simple, making it acceptable and reasonable only.

'I believe that this piece of art is quite exceptional in many ways, but it also looks simple. I like art that is simple, straightforward, and conventional to the point that it was designed upon.'

(WG, Male, 56, Master of Art)



5.3.7 Complexity of Pattern

Two subthemes belong to this theme, including that the pattern is very complex and meaningful and that the pattern is quite complex and has bright colours. Each subtheme has been presented below.

5.3.7.1 The pattern is very complex and meaningful

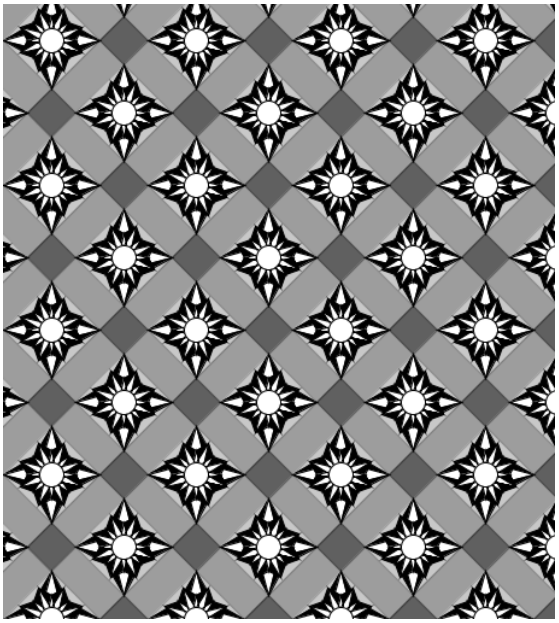
Most of the participants agreed that the pattern of the Islamic art was very complex and interconnected with a meaningful shape. These features facilitate the pattern's pretty appearance which is ideal for marketing to interested people and professionals alike.

'I like how this pattern is sort of complex and it appears meaningful, which makes it a pleasure to look at and a very professional piece of art.'

(KH, Female, 48, PhD Islamic Architecture)

'I really like how this pattern is complex yet simple as it just makes it that little bit more interesting.'

(MS, Female, 56, Master of Art)



5.3.7.2 The pattern is quite complex and has bright colour

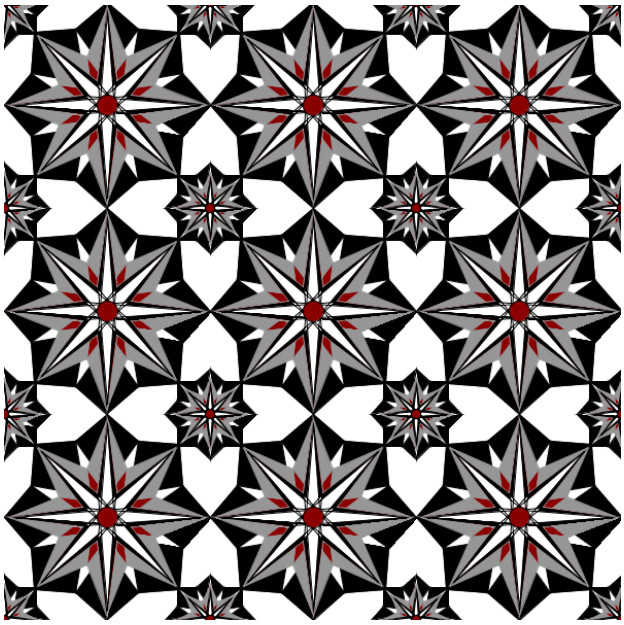
All of the participants agreed that the pattern is complex and has bright colours.

"*I really liked this pattern as it has everything in one thing and has bright and contrasting colours.'*

(KH, Female, 48, PhD Islamic Architecture)

“I like how this pattern is complex as it really gives it a professional touch and it makes it very simple and unique.’

(SD, Female, 50, PhD in Interior Design)



5.3.8 Participant Evaluation

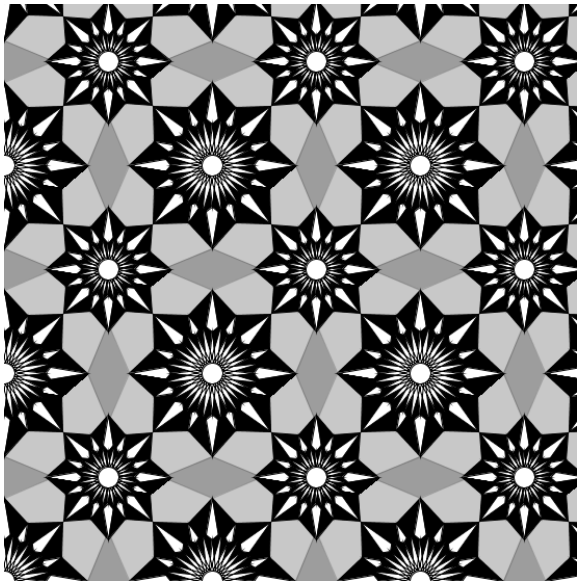
There are three subthemes belonging to this theme including that the patterns are accurate, that the patterns are a bit overdone and that the patterns are perfect. Each subtheme has been presented below.

5.3.8.1 The patterns are really accurate

The majority of the interviewees stated that the Islamic art pattern appears to be formatted by professionals with an accurate technique and they assumed that the pattern would be fascinating and interesting to people. However, some suggested that some of the patterns require more work to be considered fascinating.

'I like this pattern a lot as I like the accuracy of the corners and sides. It is also very distinctive and professional, so I reserve my opinion about the expectations of suggestions that might be needed to convert it to something more appealing.'

(MA, Male, 46, Master of Art)



One participant argued that the Islamic art pattern appears inaccurate but they felt that it might still be acceptable and attractive to some customers.

'Finally, I would like to say that, overall, this pattern is very unique and fascinating, but I wouldn't say that it is accurate because of the shape interlocking.'

(FH, Female, 55, Master of Art)

5.3.8.2 The patterns are a bit overdone

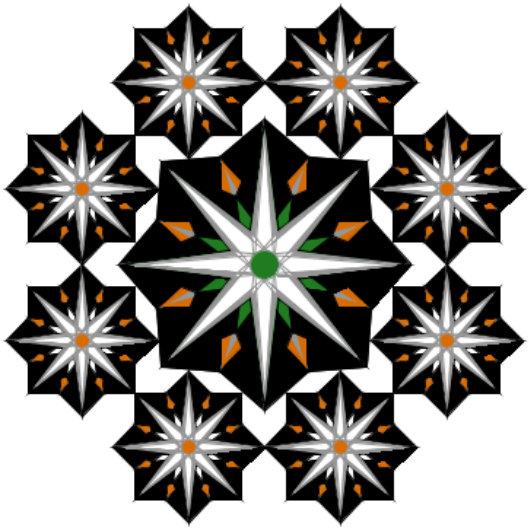
The majority of the interviewees suggested that the Islamic art patterns formatted by the researcher were created by a professional because of how intercut they were. They also stated that the patterns are slightly overdone and need some work to improve the shapes. The suggestions obtained from the study will ensure that the fundamentals are provided to enhance the pattern which in turn will make it more attractive to interested people.

'I presume that the Islamic art pattern formatted are more perfect, but this does not mean it is ready to launch in the market. I assume hard effort is still need to rectify any disfiguration of the pattern to be attractive to customers and interested people.'

(RF, Male, 54, PhD Islamic Architecture)

'I do not know if the professional can amend some defects in the shape of design, but, anyhow, it seems to be overdone and hard work is required to achieve a well-done design for the professional.'

(MA, Male, 46, Master of Art)

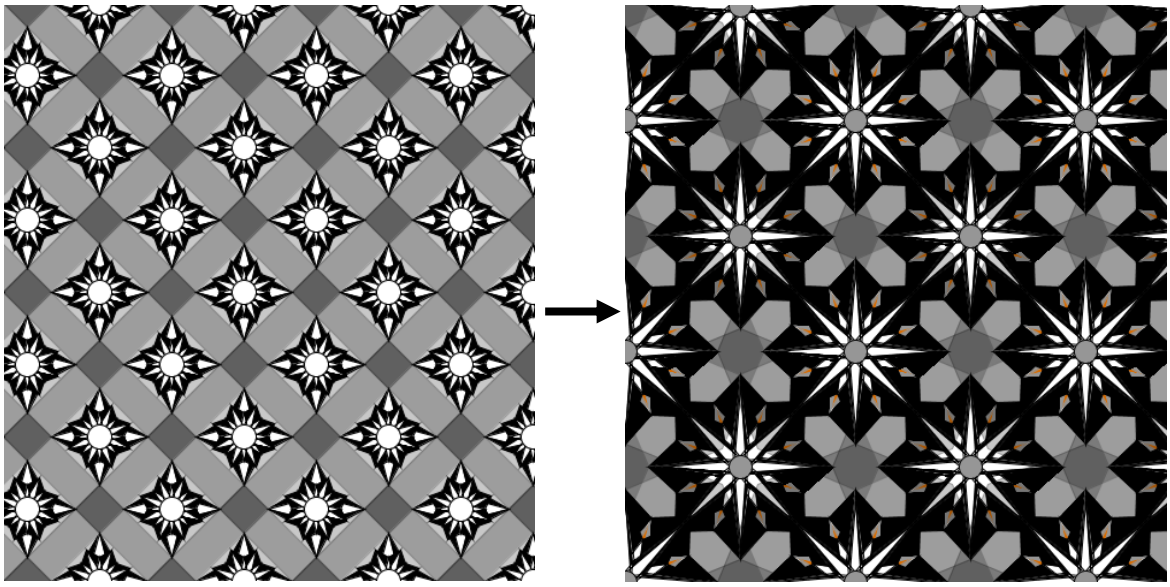


5.3.8.3 The patterns are perfect

All of the interviewees stated that the Islamic art pattern is outstanding in relation to various aspects. However, one insufficient aspect requires improvement in order to launch the product on the market and to replace the manual formatting.

'I can say that this pattern was perfect. It was one of the best I have ever seen, and it is of high standards. If I could improve a few things, I would improve the sizing of the shapes and I think that providing the enhancements, it will become more attractive to the clients.'

(DT, Male, 47, PhD in Interior Design)



5.4 VALIDITY AND TRUSTWORTHINESS OF THE RESULTS

Having sent all of the final products in a zip file via email to the nine Islamic art experts, only seven replied following repeated reminders. The seven experts were satisfied with the results and were happy with the final product as they thought it was of a high standard. Some even thought that the patterns were better than expected. One of the experts said, "*These patterns are excellent as everything about them is intricate and in-depth, and I am looking forward to seeing any future studies that are based on this one or studies that use this study as an example because it could change the way Islamic art is made forever through using computerisation.*"

5.5 DISCUSSION

This section discusses and explains the results obtained from the qualitative study. Having used the TA technique to analyse the qualitative data, the findings obtained here are represented through eight themes elicited by collating the relevant data extracts. The eight codes refer to the eight themes derived from the quotes of the nine interview transcripts regarding the development and enhancement of the Islamic art patterns created using the GIVA software.

Concerning the first theme, the interviewees all agreed that repetition, accuracy, colour and scalability are considered to be the most important features that should be provided in the formulated Islamic art patterns. These are required to derive and enhance the various parts of the designs produced in order to satisfy customers by adjusting the formula equations in the GIVA software to ensure diversity in the patterns. The significance of these features as perceived by the participants is similar to the results obtained from the previous studies in the literature (Abas, Salman 1992, Meenan, Thomas 2009). The quantitative study also found there to be an association between repetition, accuracy, colour and scalability as features that should exist in Islamic art patterns. Based on the participants' reports in the qualitative study and the findings from the quantitative phase, these findings have been applied to the Islamic art patterns in order to generate perfect patterns that will gain the attention of customers in the marketplace.

Accordingly, all of the regular patterns were updated by the researcher and all amendments were considered in the final formula. This resulted in narrower spaces so then there is more foreground showing compared to the background (Ali 2006).

The quantitative findings prove the same result regarding the importance of the spaces between the stars in the pattern design.

The third theme shows that the participants thought that the pattern was either too big or too wide or that it had wide spaces between the patterns, wasting the aesthetic of the figure. However, when the spacing is just right, improvements in the shape sizes and the spacing is required (Ascott 2000). Most of the participants reported that the pattern was not of a good scale (e.g., too wide), thus suggesting that the pattern was too large but the spacing was just right. This means that only the scaling requires improvement. From these results, the study concludes that the patterns need to have perfect scaling depending on the type of pattern. The feedback gained from this theme is the key to generating the perfect pattern because this aspect is what makes each piece of Islamic art different.

The fourth theme is interesting because it asks the participants about the grading of the colours in the patterns. The majority perceived that the colours all link to each other and that the colour makes the design stand out. The participants who did not agree with this suggested that it is the shapes and their interlocking that distinguishes the patterns (Baker, Edwards et al. 2012). This idea is reasonable as the shape interlocking allows for the edges and sides to be perfect when it comes to producing the shapes required (Bonner 2017). The quantitative study found there to be an extremely strong association between the grading of the colours and how much the patterns stand out. This association is very clear in most Islamic art patterns. The information gained from this theme was used to make what the market would consider “perfect” and meaningful art.

The fifth theme considered the shape and diversity of the patterns. The participants either stated that they had a worthy quantity of shape diversity or that it required amendment. Most of the participants stated that there was a good amount of shape interlocking (Ostromoukhov 1998), while others stated that there was not. Since the quantitative study found there to be an association between the amount of shape diversity with the experience of the participants, this theme provides important guidelines for making the “perfect” Islamic art pattern.

The sixth theme demonstrated how the participants thought the design of the patterns was unique. They either claimed that the design was very unique with a clear layout or that it was exceptional but still appeared simple. Most of the participants reported that the patterns were unique (Marranci 2004) and there were also those who did not also like the layout and colour (Kahera, Abdulmalik et al. 2009). The quantitative study established a key link between the uniqueness of the pattern and the clarity of the layout of the design. Therefore it can be concluded that the patterns require improvement by making them more unique and complex in order to appear as a professional piece of artwork.

The seventh theme shows what the participants thought about the complexity of the pattern. They reported that either it was very complex or meaningful with a complex pattern and bright colours. The quantitative study established a key association between the amount of complexity and colours. This theme therefore helped to improve the Islamic art patterns so then they appear more complex and interesting.

The eighth theme included the evaluation and assessment of the participants regarding the patterns with the feedback consisting of the patterns being really accurate, the patterns being a bit overdone and the patterns being perfect (Gross 2001). The quantitative study found there to be a key link between the degree of perfection and the quality of the Islamic art. All the feedback given was critical to improving the patterns.

5.6 SUMMARY

This chapter included all the stages undertaken to analyse the qualitative data elicited from the nine interview transcripts using the TA method. The eight themes and their respective subthemes were described as being related to the design of the innovative automatic computational method for the process of generating geometric Islamic art with its trademark aesthetic beauty. All of these themes were supported by quotes from nine experts in Islamic art in order to illustrate the findings. Finally, the feedback from the findings was applied to enhance the first version of the GIVA software to produce an improved design. The next chapter highlights the key findings and provides the implications, strengths, and limitations of this study with all possible future directions indicated.

Chapter VI. DEVELOPED APPROACH

This chapter concerns the developed approach. The organisation of this chapter can be divided into four main parts that discuss the research gap, the importance of our approach, the proposed approach and finally the developed prototype.

The fundamentals of the developed approach are discussed in the beginning which represents the defined research gap using the literature review that highlights the limitations and drawbacks of the existing approaches. After that, the importance and need for our approach has been explained. The requirements that must be supported through the proposed approach have been discussed.

After that, the developed approach is discussed and explained in terms of the concept, design, and preserved aesthetic. This part helps to understand how the patterns will be generated, how the proposed approach will guarantee the quality of the produced pattern and how the aesthetic will be preserved. Finally, the developed prototype will be explained in terms of the architecture, functions and implementations.

6.1 RESEARCH GAP

The outcomes of the literature review the quantitative and quantitative studies have been combined to define and explain the research gap. The adapted research methods discussed earlier help to fill in the defined gap and provide an accurate and reliable solution. From the previously conducted studies, the existing approaches that have been investigated show a number of limitations and drawbacks that must be solved. These limitations can be described as follows:

- Flexibility

  The existing approaches suffer from a lack of flexibility in terms of the platforms, patterns design and other aspects. Moreover, the end users expect to be allowed to configure the approach based on their needs. For example, generating a geometric Islamic pattern for fabric printing has different rules when compared to a pattern that will be engraved into wood. The variation in the requirements is associated with a variation in rules. This relies on a static approach. An approach that requires a lot of effort to adapt might not be the proper choice.

- Diversity

  The existing approaches are limited to specific types of pattern and the end user has two choices. The first choice is using the provided pattern as it is and the second choice is changing the code manually to produce the wanted pattern. All of these choices are not an appropriate solution for various reasons which will be explained later. However, the lack of diversity is an issue that has been defined based on the conducted studies. The developed approach aims to provide a wide range of choices to the end user to allow them to select the desired geometric pattern with the needed level of complexity. Practically, supporting this diversity will help to generate various geometric Islamic

patterns with the same level of aesthetic and prevent the absence of aesthetic or a decrement in the quality level of the generated patterns.

- Aesthetic preservation

  The ability to generate a geometric Islamic pattern that has a high level of aesthetic is one of the core issues that has been addressed. Relying on the end user experience as a key factor to determine the provided aesthetic is not an appropriate solution for several reasons. For example, the aesthetic level will not be constant, and it will vary based on the practice followed and the end user experience level. In addition, the absence of clear rules and criteria makes this aspect need extra attention from the developer. By providing an approach that can eliminate the human factor and guarantee the quality of the provided aesthetic based on a clear criterion that provides high quality geometric Islamic patterns, we prevent dependency on the end user experience and allow individuals to use the developed approach based on their needs.

- Level of experience

  The level of experience consists of two parts. The first part refers to the need to be an expert in geometric Islamic art in order to produce geometric Islamic patterns that have an aesthetic presentation while the second part refers to the need to be an expert in the used approach. Both parts are critical issues as a high level of expertise is not always possible for all users and it is too expensive in terms of time and training. Moreover, relying on the human factor will lead to a variation in the quality of the produced pattern caused by variations in experience and bad practices. Isolating the human factor, minimising the interaction and relying on a clear criterion will help to maintain the quality of the produced patterns and guarantee the constancy of the aesthetic of the generated pattern. In addition, eliminating the end user experience will allow for the consumption of the developed approach by individuals who are not experts in either geometric Islamic art or IT while also avoiding training needs.

- Operational cost

  Reducing the operational cost is important for individuals in relation to mass production as well. Providing an approach that is capable of reducing the operational cost while providing a high level of service will be optimally efficient. The overall operational cost comes from three aspects: hardware, training and the experience level needed. The developed approach must be easy to use and easy to learn by individuals. Preventing dependency on the experience of the end user will reduce the operational cost in a direct way as there is no need for experts to configure and use the approach. In an indirect way, this will avoid issues that might occur as a consequence of bad practices. By avoiding the need for training, the time taken up will be saved. Besides that, the operational costs will be reduced as relying on an automated approach will help to save on the provided resources and capabilities while increasing productivity.

- Portability

  The absence of portability and the program being limited to a specific machine for several reasons such as the high level of installation or the high level of requirement is an issue that will increase the operational cost. This also reduces the effectiveness of the consumed approach. Developing an approach that prevents dependency on the used platform will help to enhance the flexibility of the used platform. This portability allows the end user to use the approach based on the application rather than the platform. For instance, for wallpaper printing or as part of a wood decoration. Moreover, it allows individuals to use the developed approach with no need to use a specific machine that might be too expensive for them.

- Automation

  Automated support is needed as the end user must be capable of producing the wanted geometric Islamic patterns in a simple and easy way. The end-user only needs to enter the specifications of the wanted pattern in terms of the number of heads, dimensions and colour. By supporting automation, lack of experience is not an issue anymore and productivity will be increased due to the reduced operational costs. Relying on an automated approach helps to guarantee the aesthetic of the produced pattern while avoiding issues that might happen as a result of end user bad practices.

Obviously, the defined limitations and issues are linked together. These issues have implications which shows that these aspects must be considered during the development phase in terms of their connection in order to prevent any conflicts that might occur. As we declared earlier, this study aims to develop an innovative and automatic approach for generating geometric Islamic patterns based on pre-defined rules that guarantee the quality of the produced pattern while considering aesthetic metrics in a manner that is easily implemented by individuals. The developed approach aims to lessen the cost in terms of time and resources while avoiding the need for experience to produce geometric patterns that are aesthetic and of good quality. Moreover, enhancing the flexibility level is one of the core targets as the novel approach can be implemented across several platforms and delivered as an executable file to the end user.

6.2 APPROACH IMPORTANCE

After explaining the identified research gap, this part will explain the importance of the developed approach and why it is needed. In addition, an explanation of how the proposed approach is distinguished from the existing approaches will be provided.

First of all, the proposed approach can be used by both individuals and organisations that aim to produce geometric Islamic patterns that have an aesthetic. The use of the proposed approach varies between the users based on the application. This variation will not influence the quality of the produced patterns. It allows users who are not experts in geometric Islamic art to use it with confidence concerning the quality of the produced patterns. The applications of the proposed approach vary including fabric printing, glass painting, wood engraving and other applications based on the user's needs. The expected users include artists, interior designers, fashion designers, students and anyone who is interested in geometric Islamic patterns.

In terms of the strong points of our approach, the developed approach will not force the user to commit to a specific platform as it supports flexibility in terms of the required hardware and software. This helps to save in terms of the operational cost in relation to the required resources. Moreover, it also saves time as it will be delivered to the user as an executable file format. There is no need for complicated process such as configuration which might lead to reducing the quality of the produced patterns. In addition, avoiding the need for training is one of the other strong points as it will conduct all the calculations and complicated processes internally in an automated way without the need for user interaction. By utilising our approach, the user will be asked to choose the pattern complexity level in terms of size and the number of heads. Providing the patterns' colouring features will save time and help the user to evaluate the colour selection of the final product.

This approach is different than the existing approaches in reference to various aspects. For example, this approach supports portability that allows it to move between different machines based on the application used. By supporting portability, the developed approach does not need to be configured each time as it will be delivered as an executable file that produces the wanted geometric pattern in an automated way. The automation of the generation process distinguishes the proposed approach from the others, as all of the implementation calculations, positioning procedures and drawing will be completed in an automated and internal way. Moreover, the developed approach provides diversity in terms of the shapes, pattern design complexity and colouring. This helps to enhance the level of delivered flexibility that leads to extending the range of supported applications. Finally, isolating the human factor and relying on a clear set of criteria for preserving the aesthetic will ensure the quality of the produced patterns and guarantee the consistency of the aesthetic and elegance level.

Finally, the need for the proposed approach comes from the need to overcome the shortage of experts while saving on the time that needs to be consumed to gain such knowledge in order to produce Islamic geometric patterns that preserve the aesthetic. In addition, minimising the human factor will help to avoid variations in quality and any issues that might occur due to bad practice and a lack of experience. There is a need to develop an approach that accelerates geometric pattern generation in order to meet the mass production application requirements that require a high level of flexibility and quality in terms of aesthetic and accuracy. There is also the need to lessen the reliance on hand-made products. The need for our approach is not limited to mass production applications. The approach is expected to be utilised by various applications with the same level of effectiveness. This means that it is important to develop an approach that is easy to consume, is capable of preserving the aesthetic, supports portability, avoids complexity and provides a high level of flexibility in terms of the shape diversity and working environment.

6.3 PROPOSED APPROACH REQUIREMENTS

The need for such an approach has been defined via the literature review, end user survey and expert interviews. The outcomes of the previous studies have helped to define the requirements and key aspects that must be supported and maintained through the proposed approach. The requirements can be categorised into 3 groups: the environment, performance and the end user requirements.

The environmental requirements represent the key factors that are related to the approach environment, which refers to the implementation platform. One of the key features that must be supported by the developed approach is portability. This allows the user to move the approach from one machine to anther based on the needed application. In addition, supporting diversity in terms of the platform will help to reduce the cost of the needed resources. Moreover, avoiding complexity and delivering an executable file format will help to lessen the operational costs in terms of time and experience. This also prevents the user from being restricted to a specific hardware. By providing this level of flexibility in terms of the environment, the proposed approach can be used on the platform that best meets the end user's needs.

The performance requirements for the proposed approach concern the approach behaviour. The proposed approach must be capable of generating the requested patterns automatically. All of the conducted calculations must be done internally with no interactions from the user side. This is as the end user only needs to decide on the size and complexity of the requested pattern. Practically, relying on an automated mechanism will prevent any of the issues that might happen as a result of bad practice. This will help to guarantee the quality of the produced pattern. Besides that, the proposed approach must save the provided resources and avoid the sort of complexity that might lead to an increased need for the human factor during the pattern producing process. The approach must enhance the flexibility and diversity of the shapes and colouring.

Finally, the end user requirements illustrate what the end user expects from the developed approach. The most important aspect is maintaining the aesthetic of the produced pattern which is at the core of this approach. In addition, improving the delivered flexibility in terms of diversity in relation to the used platform and the diversity of the produced patterns themselves have both been identified as two of the core limitations of the existing approach. Moreover, the end user wants to use an approach without the need for advanced training or requiring the user to be an expert in either art or IT.

As we discussed earlier, these defined requirements have been stated based on the conducted literature review, distributed questionnaire and semi-instructed interviews. These requirements have helped to shape the proposed approach in terms of capability, behaviour and performance. These requirements also help to overcome the obstacles, to guarantee quality and to solve the existing approach issues. Figure 6 - 1 illustrates the requirement groups.

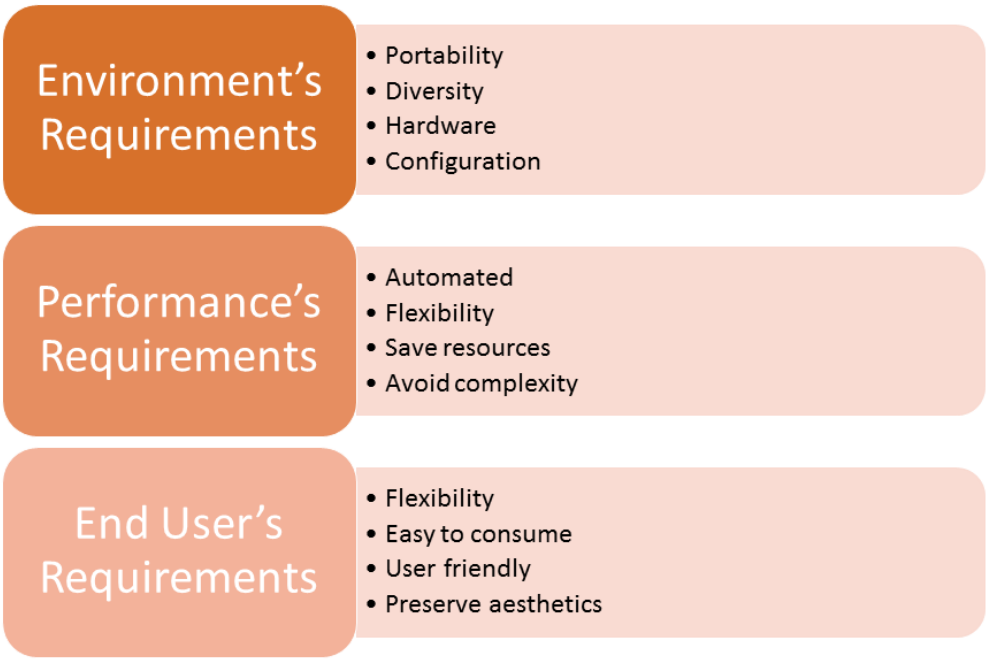


Figure 6 - 1 Proposed approach requirements

6.4 PROPOSED APPROACH CONCEPT

As we discussed earlier, the developed approach must be capable of overcoming the defined limitations. For that, the developed approach is not limited to a single pattern as the end user can determine the type, size, colours and dimensions of the generated pattern with a high degree of accuracy since the pattern dimensions do not affect the pattern resolution. Moreover, the end user can test the aesthetic of the produced pattern via the existing theories.

In this stage, the primary need for the design stage is to develop the algorithm that satisfies the requirements of the end user. The solution uses the core features of Islamic geometric patterns such as the congruence and symmetry of the pattern portions. Through the literature investigation and direct Islamic geometric pattern observations, the researcher noticed that the core pattern was able to be divided into identical portions that can then reproduce the core pattern through repetition. In addition, the researcher combined this concept with circle and triangle geometry laws in order to develop an approach for generating various types of Islamic geometric pattern. Figure 6 - 2 illustrates how the Islamic geometric pattern can be divided into identical portions.

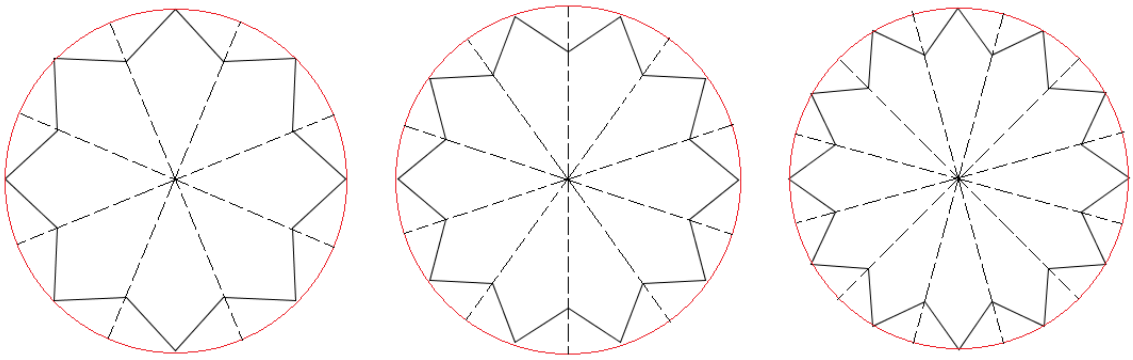


Figure 6 - 2 Geometric patterns portions

The approach generates the requested pattern by first drawing the portion and then repeating that portion as shown in Figure 6 - 3.

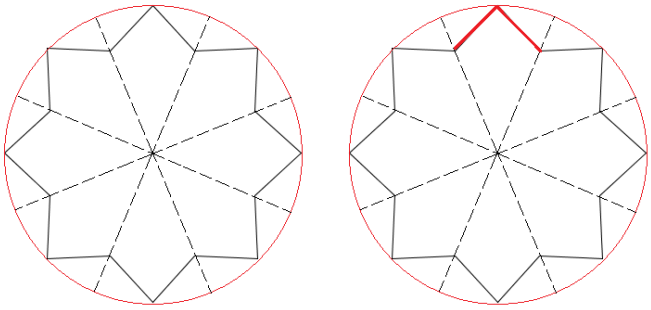


Figure 6 - 3 Example of a repeated portion

To draw the portion, a prototype is used to facilitate the generation of an IGP consisting of 2 core patterns. This is achieved by dividing the targeted pattern into sub-portions based on the number of requested pattern heads to be aesthetically repetitive. The generating function relies on the following steps:

1. The end user enters the number of *pattern heads* defined as "*a list of numbers that follow a certain sequence or pattern*" (e.g. 4, 6, 8, 10…).
2. The width of the head base and the distance between the head and the pattern core is calculated according to the number of pattern heads.
3. The generation of the complex geometric pattern using the positions (*x*, *y*) of the pattern and the sketch, head width, head height and head number according to the parameters.

The complex geometric pattern is based on the internal and outer patterns. The pattern head number for the internal pattern is double that of the outer pattern because there is an internal head for each outer convergence point. The end user can also generate more than one Islamic pattern in the same sketch as they determine what is aesthetically pleasing.

In the first step, the width and height of the patterns is calculated according to the number of pattern heads. The generating function relies on the core parameter that is entered by the end user. This is an even number of pattern heads (e.g. 4, 6, 8 or 10) and this has been shown in Figure 6 -4.

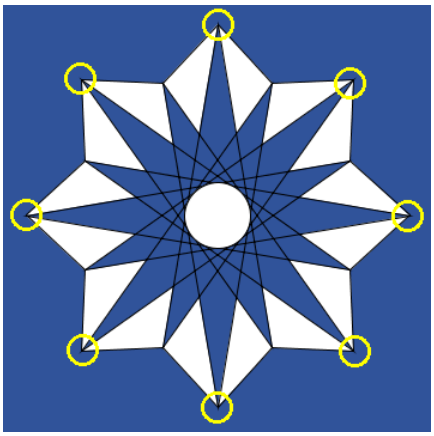


Figure 6 - 4 The number of geometric pattern heads

After passing this parameter into the developed function, it calculates the width of the head base, as shown in Figure 6 - 5, and the distance between the head and the pattern core, as shown in Figure 6 - 6.

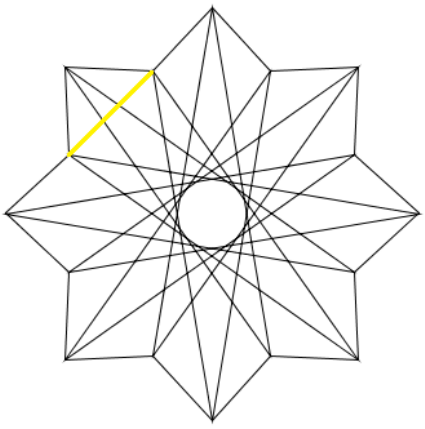


Figure 6 - 5 Head width measurement

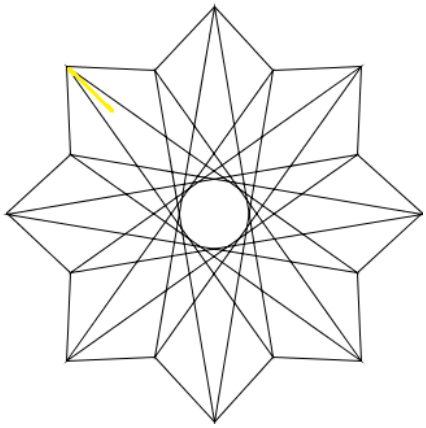


Figure 6 - 6 Head height measurement

The width of the head base from Figure 6 - 5 is determined by

$$w = n * 10 \quad \text{Eq. 4.1}$$

where *w* is the width of the head base and *n* is the number of portions.

The distance between the head and the pattern core shown in Figure 6 - 6 is determined by

$$h = w + 20 \quad \text{Eq. 4.2}$$

where *h* is the head height.

The positions (*x*, *y*) of the pattern in the sketch, the head width, the head height, and the patterns heads' number are the parameters used to generate the intricate geometric pattern.

To draw the obvious pattern, the identical portions are first drawn and then repeated. Furthermore, the following equations calculate the values of (*sx*, *sy*), which determine the positions of the start and end of each line drawn via the vertex.

$$\text{float } sx = x + \cos(a) * h \quad \text{Eq. 4.3}$$

$$\text{float } sy = y + \sin(a) * h \quad \text{Eq. 4.4}$$

where *a* represents the portion's share of 2π, while the half angle represents the other half of that share. The values of (*sx*, *sy*) are multiplied by *h* and *w*. Next, (*sx*, *sy*) are recalculated and multiplied with *w* to meet the identified width following

$$sx = x + \cos(a + \text{half-angle}) * w \quad \text{Eq. 4.5}$$

sy = y + sin(a + half-angle) * w Eq. 4.6

These equations represent the external core pattern as in Figure 6 - 7. A key feature of an IGP is the avoidance of blank area (e.g., gaps). Therefore, to meet this requirement, the researcher generate two internal patterns that match the core pattern with the heads' number but are different in the dimensions.

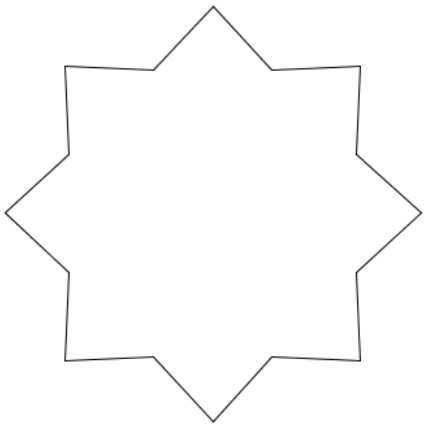


Figure 6 - 7 Example of an external pattern

The internal patterns have the same heads' number and width as shown in Figure 6 - 8. For the internal patterns' height values, a pattern exists with a height similar to the external core pattern with the heads matched while the heads of the other pattern are the cross point of two portions, as shown in Figure 6 - 9.

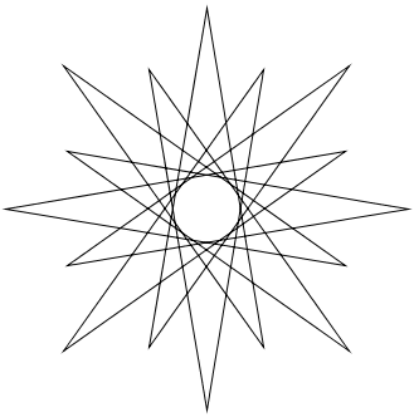


Figure 6 - 8 Example of an internal pattern

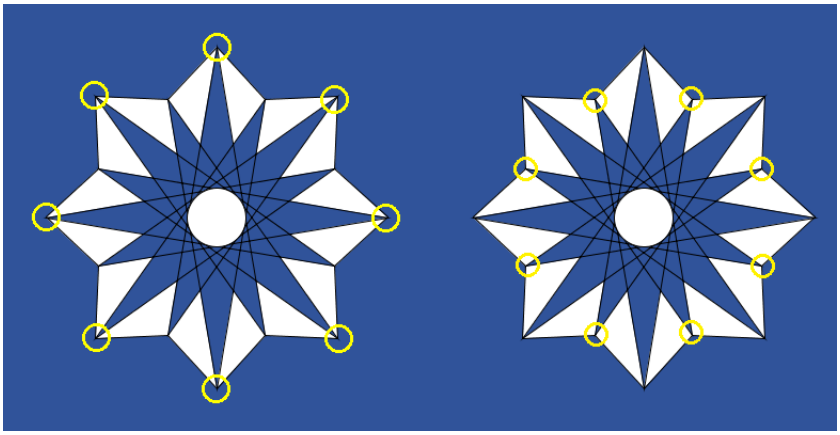


Figure 6 - 9 Example of internal heads

For generating the internal patterns, the following equations calculate the values of (*sx*, *sy*) which determines the position of the start and end of each line for each internal pattern. Here, the researcher decreases *x* and *y* by cos(*a*) * *h* and sin(*a*) * *h* respectively to reduce the width of the internal heads and to prevent unwanted matching with the external pattern.

sx = x - cos(a) * h	Eq. 4.7
sy = y - sin(a) * h	Eq. 4.8
sx = x + cos(a + halfAngle) * w	Eq. 4.9
sy = y + sin(a + halfAngle) * w	Eq. 4.10

This approach provides the end user with flexibility regarding the size and shape type. This is achieved by parsing these elements as parameters. Figure 6 – 10 provides the workflow artefact. The developed approach will maintain the aesthetic of the generated pattern. Said aesthetic and the related mechanism will be discussed later. The quality of the produced pattern is one of the core issues that must be solved by the developed approach.

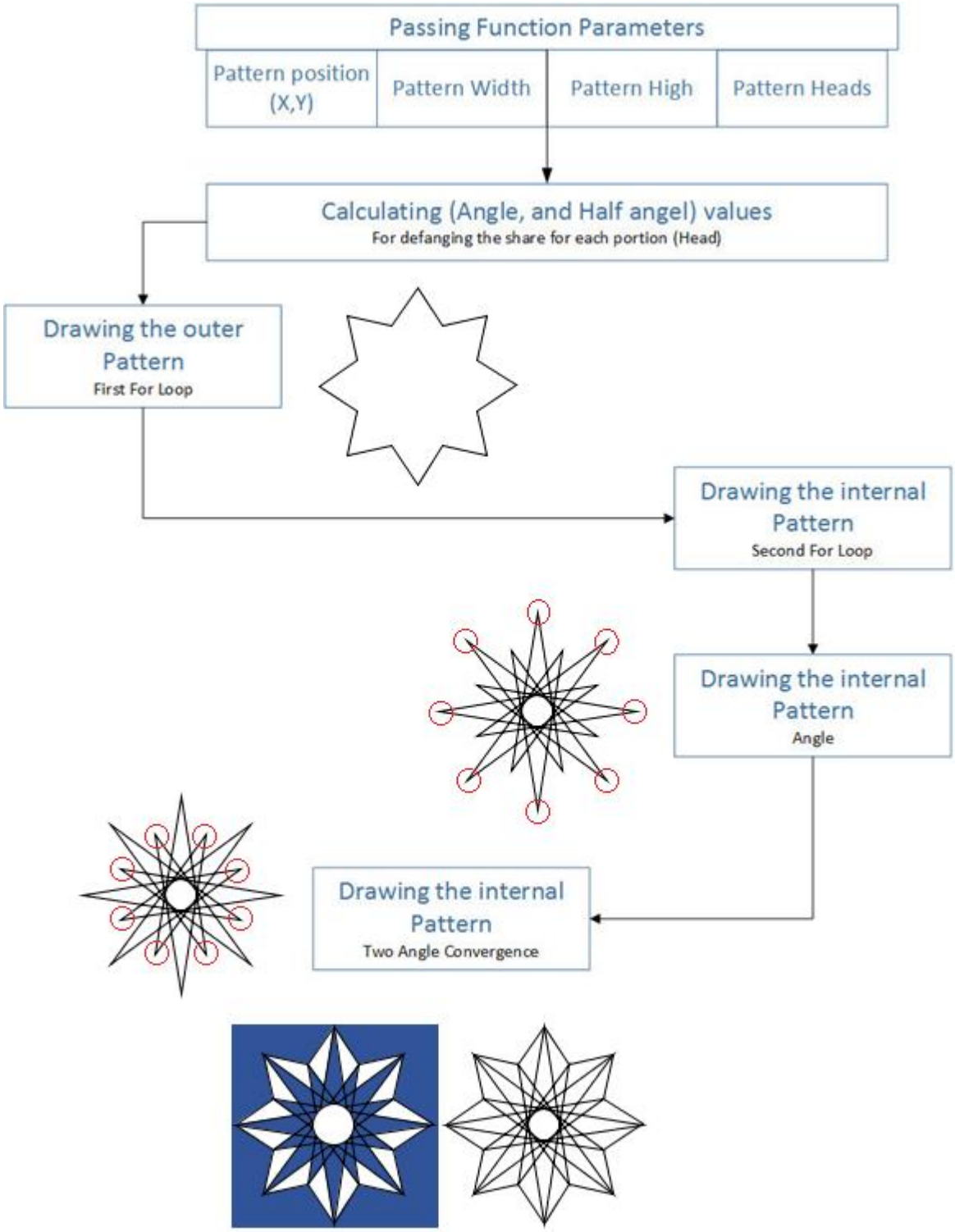


Figure 6 - 10 Core pattern workflow

6.5 PROPOSED APPROACH DESIGN

The proposed approach architecture consists of 5 core modules. These modules interact with each other to produce a geometric Islamic pattern with the intended aesthetic. Figure 6 - 11 shows the approach design. Practically, each module will be responsible for specific tasks that will not interfere with the other modules. The aesthetic preservation module will interact with all of the other modules in order to maintain the pattern aesthetic. Next, the approach modules will be explained to clarify the responsibilities of each one and to define the outcome of each module. The technical aspects and module implementation will be discussed later on in the application tasks.

- Aesthetic preservation

  This module is concerned with maintaining the aesthetic and generated geometric Islamic pattern. This module is related to all the other modules and it is capable of altering and modifying the other modules in order to preserve the aesthetic.

- Positioning

  This module is responsible for calculating the dimensions of the pattern produced and determining the position of the core pattern. The calculation process depends on the core pattern and final product size. This module was introduced to maintain the aesthetic of the generated pattern.

- Head numbers

  The responsibility of this module is receiving the end user requirements, calculating the essential pattern and providing the parameters of the secondary pattern that will be developed in order to preserve the aesthetic.

- Core pattern

This module focuses on the core pattern generation. Here we focus on the pattern itself in terms of the dimensions, length, angles, and all the other aspects that are related to the core pattern.

- Colouring

  The colouring module is responsible for painting the generated pattern based on the end-user selection. However, this module also allows for the selected colours to be changed to maintain the aesthetic of the generated pattern.

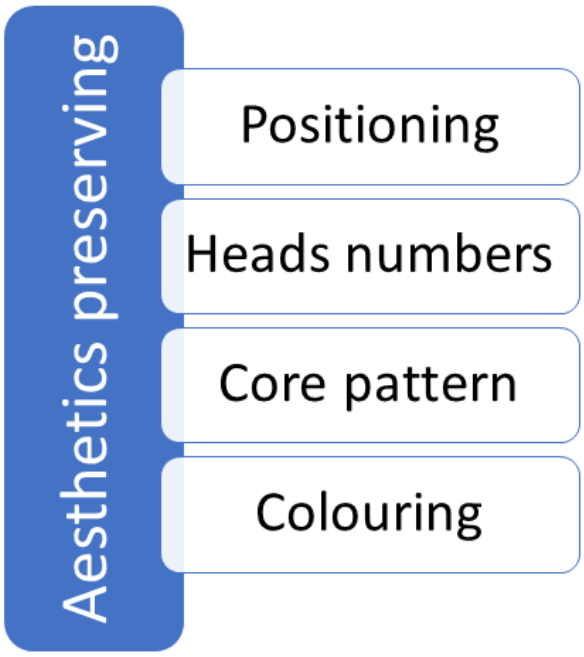


Figure 6 - 11 Approach modules

6.6 DEVELOPED PROTOTYPE

6.6.1 Algorithm diagram

UML (Unified Modelling Language) is an ordinary language used for visualising, constructing and documenting the various types of artefact that are found in software systems. However, UML is a tool that uses different UML diagram types including structure and behaviour in order to model the various software solutions. Furthermore, UML has a direct relationship to various object-oriented types of analysis and design. The main goal of UML can be defined as a rather simple modelling appliance related to all he practical systems in a modern-day complex environment. The class diagram is one of the UML diagrams types. It is also widely used in the overall modelling of various object-oriented systems because they mainly are considered to directly represent UML diagrams. They can be put in place almost immediately compared to other object-oriented programming languages. Furthermore, the class diagram illustrates a view of the system which represents various aspects of the developed application.

The class diagram developed for our algorithm has been presented in Figure 6 - 12. Here, the geometry class is the superclass designed for the purpose of drawing the single Islamic geometry pattern using functions *pattern1* and *pattern2*. *G_Patterns1*, *G_Patterns2*, and *G_Patterns3* are sub-classes of the superclass Geometry and they inherit all of the member variables (n Points, Height, and Width) and methods (getPoints, getWidth) from its superclass. They further define another public method and its constructors as shown in Figure 6 - 12.

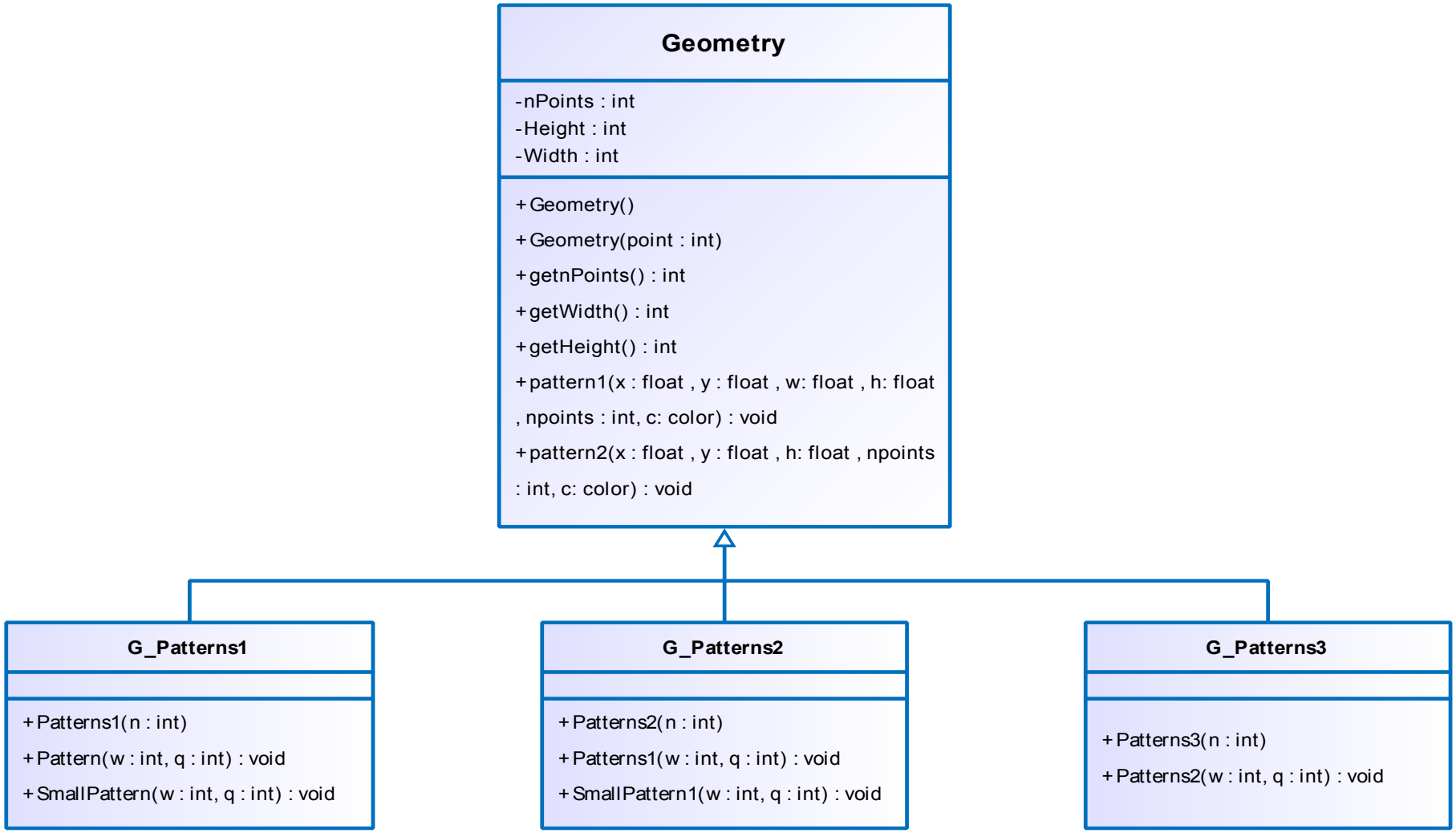


Figure 6 - 12 The UML class diagram of the proposed algorithm

Each function in the UML class diagram has a different functional usability. The *pattern1* and *pattern2* functions of the Geometry class generate different patterns and have been illustrated in Figures 6.2 and 6.3. *G_Patterns1, G_Patterns2,* and *G_Patterns3* are the classes used to implement the function in the Geometry class that is in turn used to generate the aesthetic by combining the patterns in a geometrical manner by calculating the exact distances between the subsequent patterns as further described below.

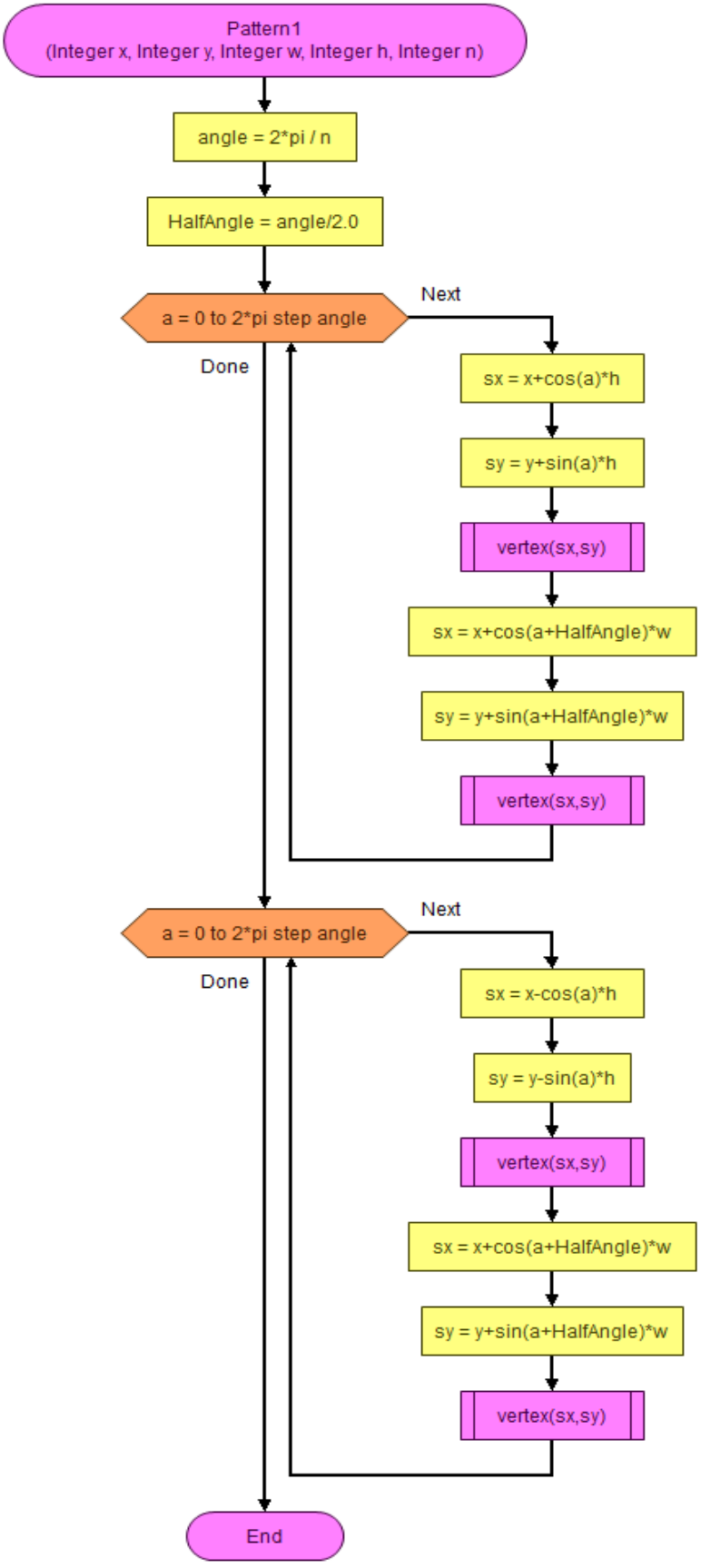


Figure 6 - 13 Flowchart of the *pattern1* method

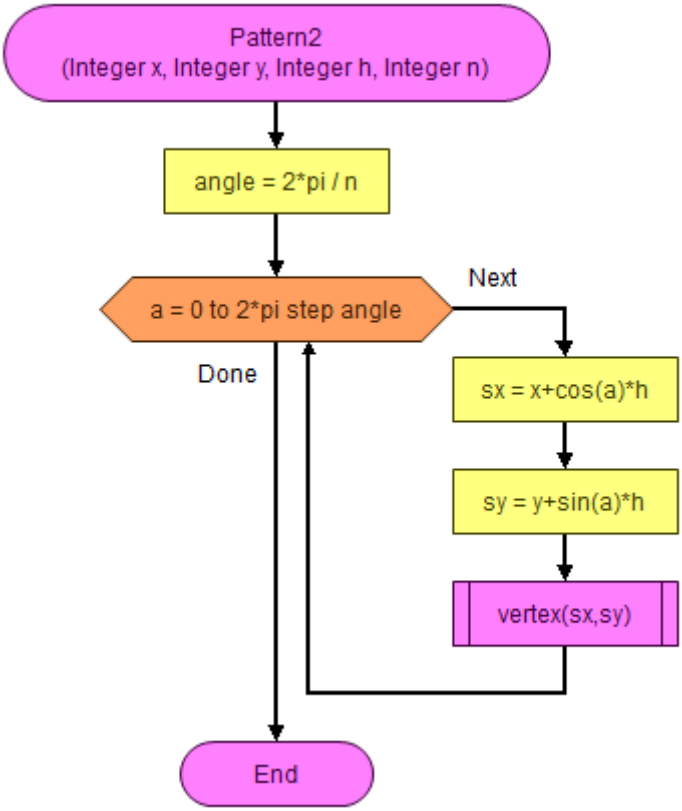


Figure 6 - 14 Flowchart of the *pattern2* method

A general diagram illustrating the process to generate the sketch of the patterns is shown in Figure 6 - 15.

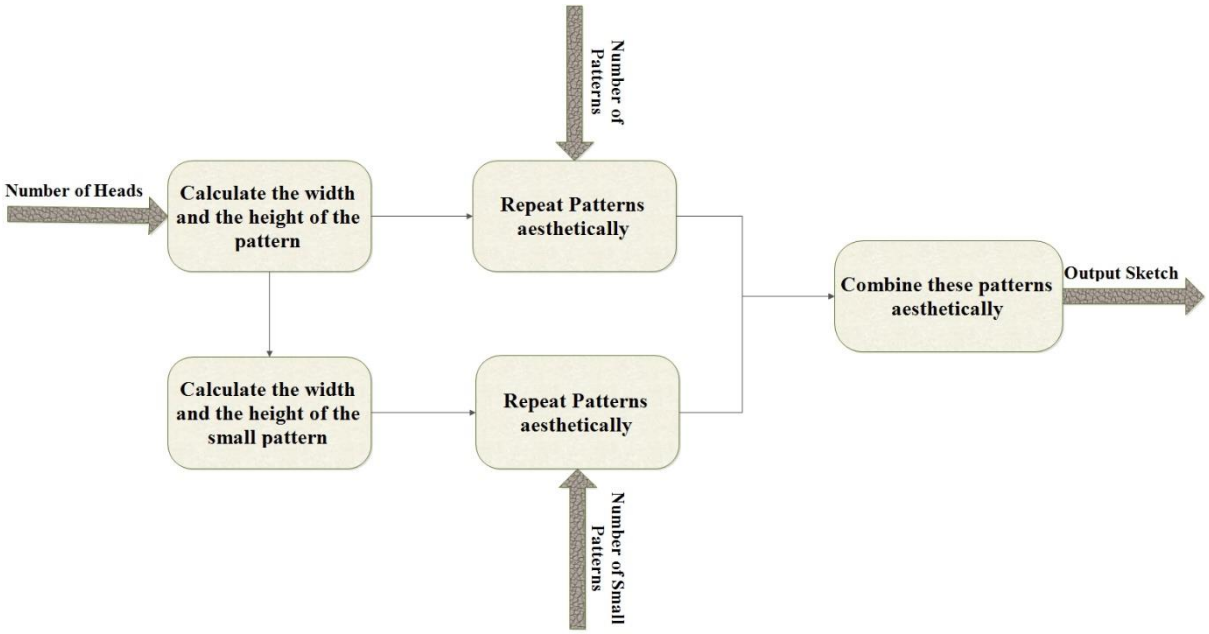


Figure 6 - 15 Process diagram of the proposed approach

The end user must enter the number of heads and the number of patterns to be generated. Using the number of heads, first the width and height of the primary patterns are calculated. Second, using the number of patterns, the patterns are drawn aesthetically. Third, using the previous width and height, the width and height of the small patterns are calculated to draw the small patterns. Finally, the process generates the final desired sketch.

6.7.3 Implementation

The Processing Development Environment (PDE) was selected for use in the implementation phase. Processing is a software package, sketchbook and a language used for teaching people how to code within the context of the graphical arts. Since 2001, art processing has encouraged many different software languages within the different arts for use in modern technological devices. For the past couple of years, Processing has endorsed software literacy, mainly within the visual literacy and arts communities.

Furthermore, the overall processing process has evolved into an electronic tool for development that is mainly used by professionals. Likewise, the Processing Development Environment (PDE) puts in place a rather simple text editor for writing code, managing the coded files and even supporting an individual in starting to code. The software was written using Processing via the named sketches with outlines written in the text editor. Processing was mainly designed to make it simple to draw the different graphic elements, for instance, lines and curves.

The enhanced algorithm was implemented using the Processing language. In this section, the results of the implementation are shown. The Geometric Islamic Visual Art (GIVA) program is the software used in the approach and in Figure 6 - 16, a basic pattern is shown which was used for generating the different patterns by repeating it aesthetically.

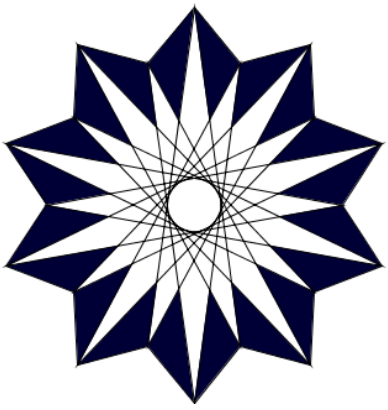


Figure 6 - 16 A basic pattern of ten heads

In the beginning, the pattern in Figure 6 - 16 is repeated in a simple way using a loop to generate a pattern for the number of heads. Figures 6 - 17 and 6 - 18 show this generation for 8 and 16 heads respectively.

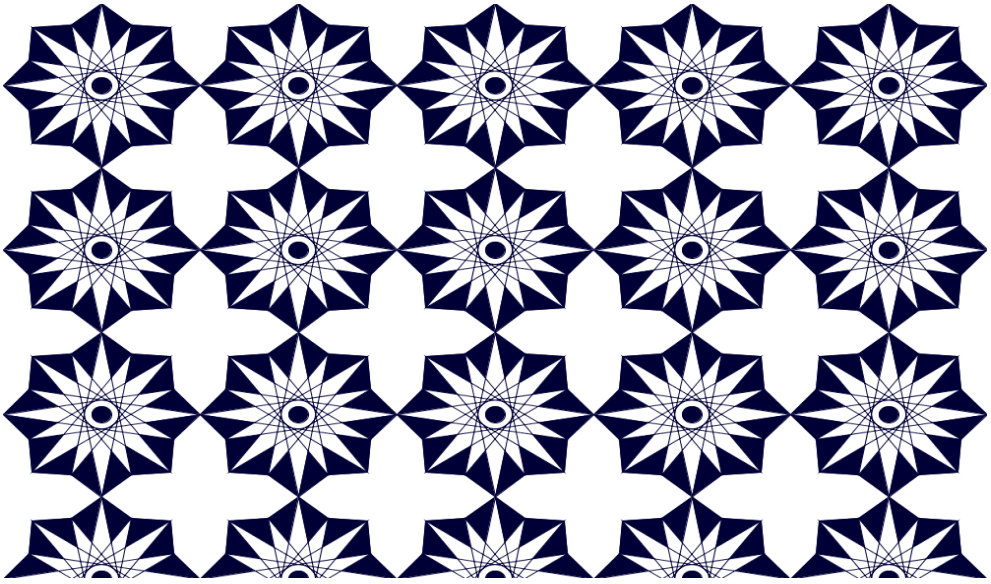


Figure 6 - 17 Shape of repeating patterns for eight heads

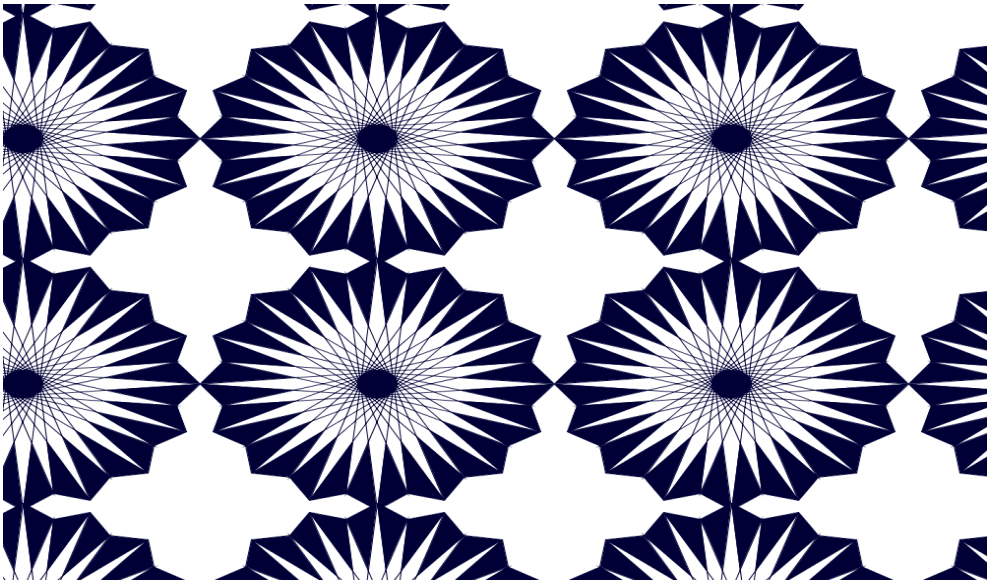


Figure 6 - 18 Shape of repeating patterns for 16 heads

Based on the interviews conducted with the experts, some of the feedback recommended making improvements to the quality of the patterns. They suggested that there should not be much space between the patterns. Small patterns were therefore generated in the empty spaces as shown in Figures 6 - 19 and 6 - 20 for 8 and 10 heads respectively.

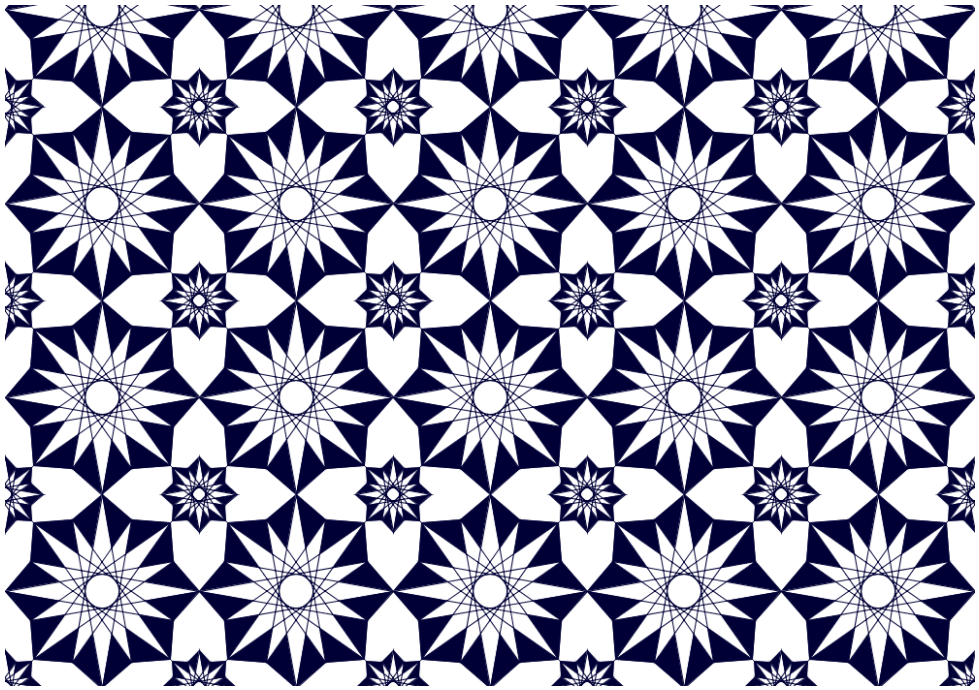


Figure 6 - 19 Shape of repeating patterns with small interior patterns for eight heads

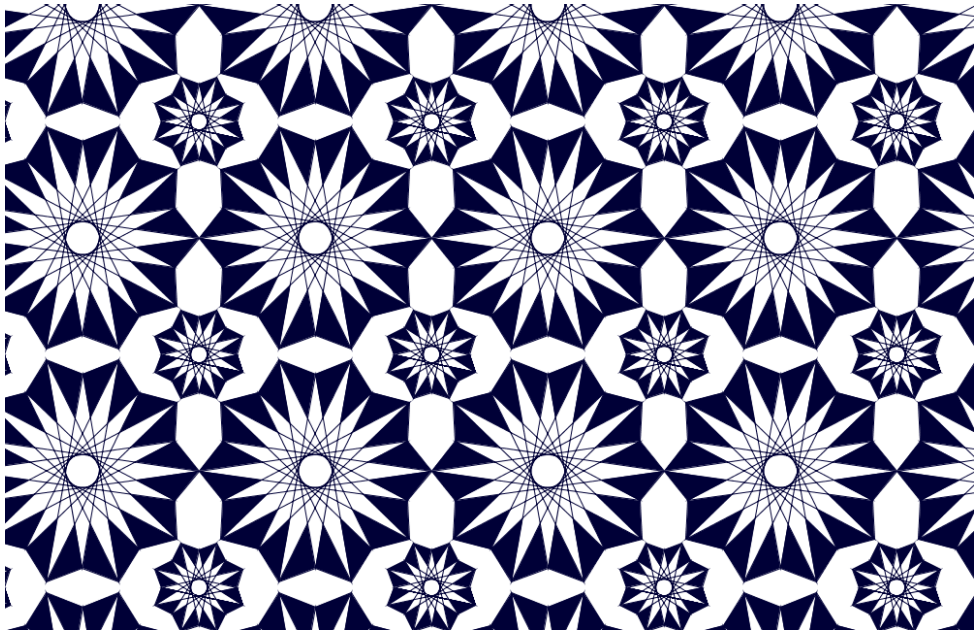


Figure 6 - 20 Shape of repeating patterns with small interior patterns for ten heads

Based on the second round of interviews conducted, the feedback recommended that the connection between the patterns must be more closed and have more of an aesthetic shape. Thus, the GIVA program was further developed to generate the shapes shown in Figures 6 - 21, 6 - 22 and 6 - 23.

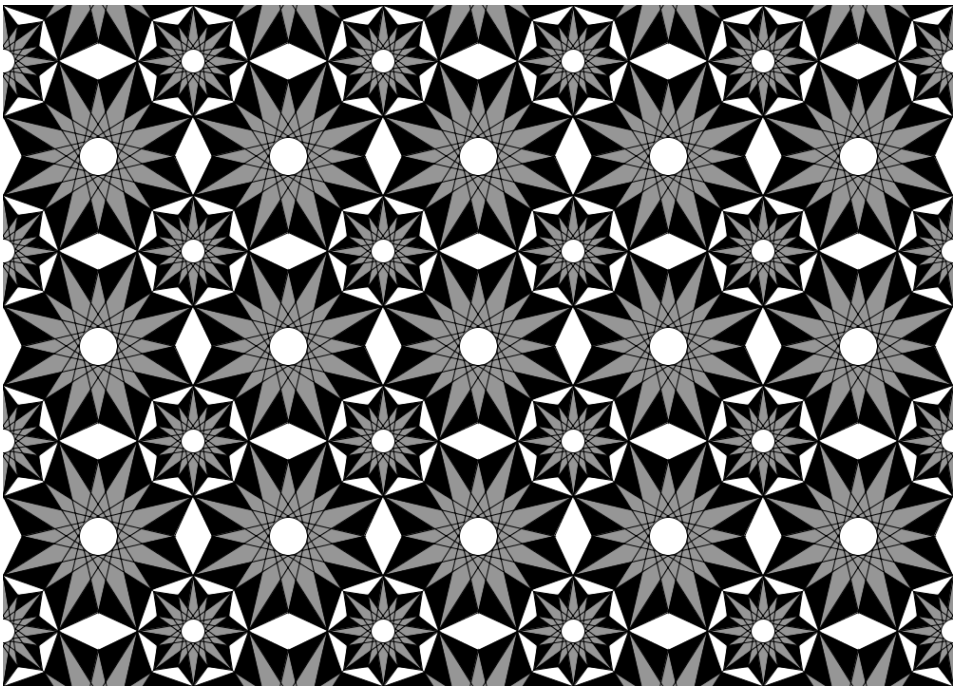


Figure 6 - 21 Shape of the GIVA patterns2 class for eight heads

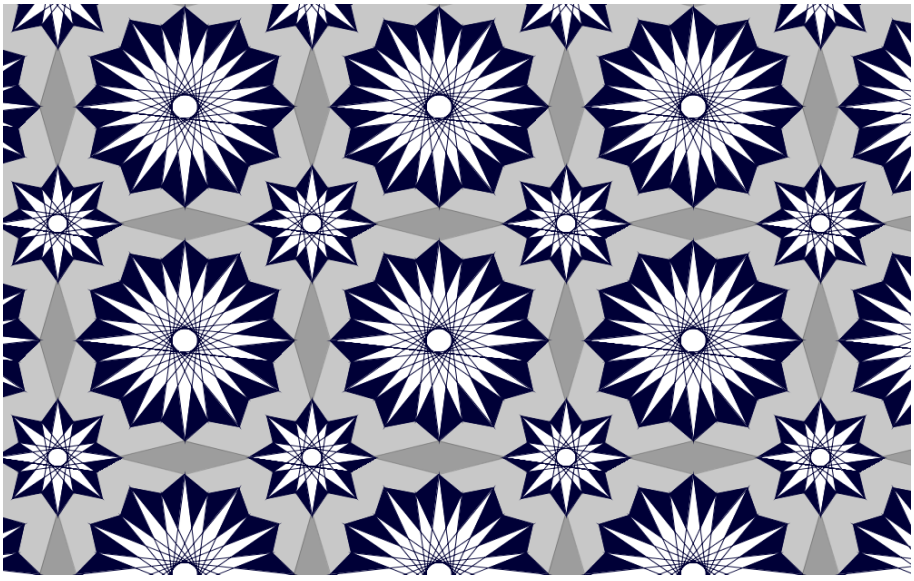


Figure 6 - 22 Shape of the GIVA patterns1 class for 12 heads

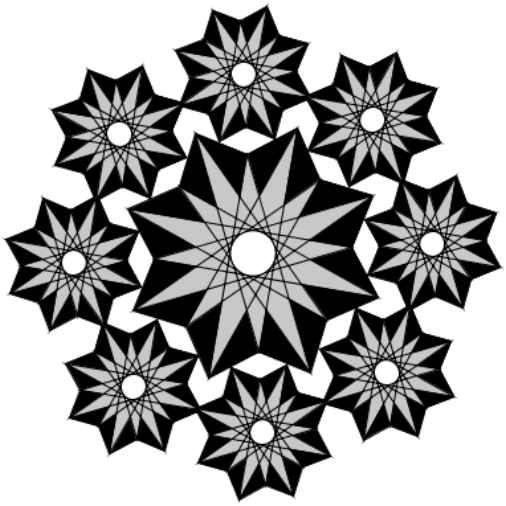


Figure 6 - 23 Shape of the GIVA patterns3 class for eight heads

The first GIVA program generated shapes for use in a single pattern with various heads as shown above. This basic pattern was then further developed to generate more aesthetically pleasing patterns. In Figure 6 - 24, 4 patterns have been generated from the changes to the basic pattern to generate more suitable versions. These patterns are different in terms of the number of repeating patterns, the width and height of each and the number of colours used in each portion of the pattern.

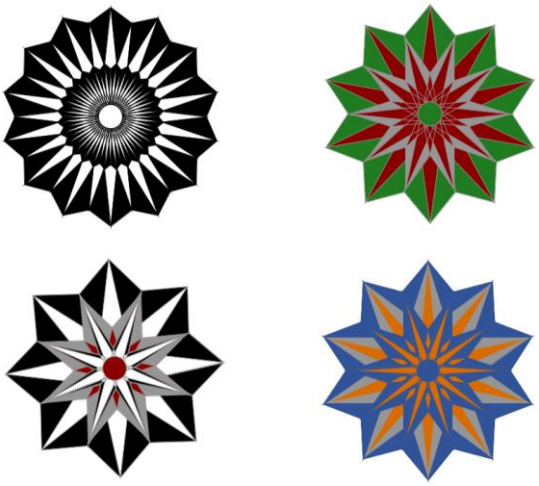


Figure 6 - 24 Different patterns based on a range of the number of heads

From these patterns, the GIVA program generates various aesthetically pleasing shapes that are grouped according to the generated shapes. In the first group, the primary patterns are drawn followed by the small interior patterns used to connect them.

6.7.2 Application's Tasks

The GIVA application is a simplified end user application that is part of our proposed method. This application is implemented using two tools. The first tool is the Processing development Environment (PDE) software used for generating the Islamic geometric patterns. The second tool is the Eclipse IDE software that is used for designing the GUI so then the end user can use it easily. To integrate these tools, the Processing library is imported to the Eclipse Java application program where the Windows Builder library is used to create the GUI forms. The end user only needs to install Java to run the GIVA application on their own PC. The main page of the GIVA application that will appear when the end user opens the application has been shown in Fig. 6 - 25.

The user must select the number of heads for the Islamic geometric pattern and then select the number of colours used to generate all possible sketches. In this application, the user can select from 4, 8, 10 and 12 heads as shown in Fig. 6 - 25.

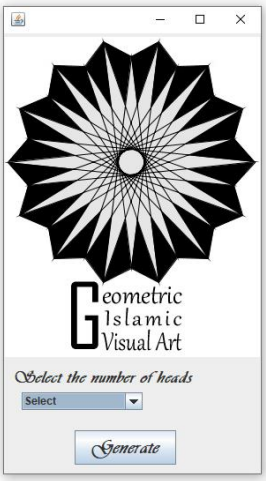
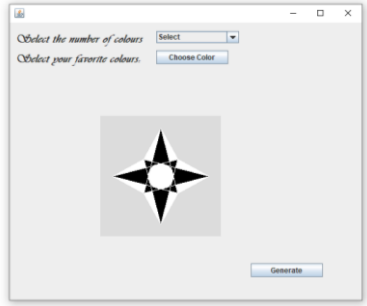


Fig. 6 - 25 Main Page of GIVA Program

From the main page, if the user selects 4 for the number of heads and presses the generate button, the window in Fig 6 - 26 (a) will appear and the user must select the number of colours to be used and then select the desired colour from the choose colour button. The window shown in Fig 6 - 26 (d) will appear and contain all the possible colours that the user needs.

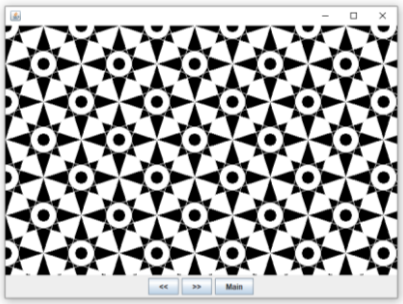
Fig 6 - 26 (b – c) presents an example for 4 heads and 2 colours, Fig 6 - 26 (e – f) presents an example for 4 heads of different colours and Fig 6 - 26 (g – j) presents an example for 8 heads of different colours.



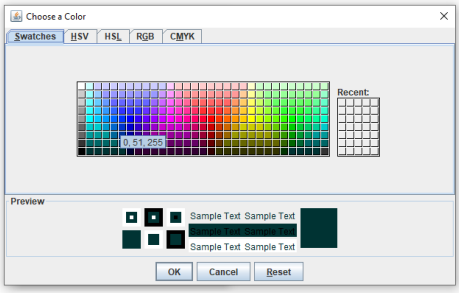
a)



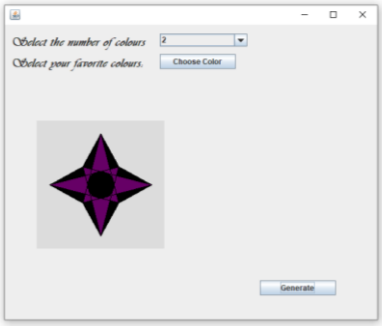
b)



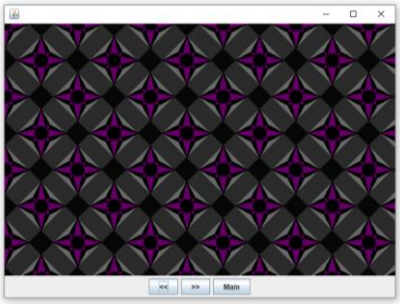
c)



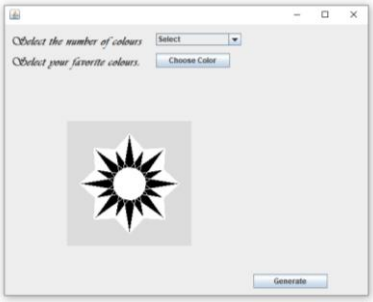
d)



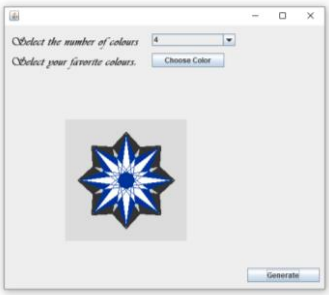
e)



f)



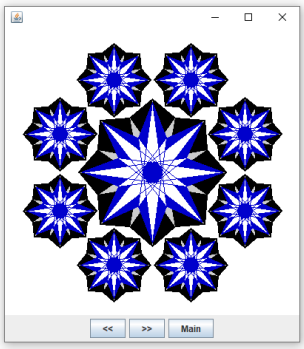
g)



h)



i)



j)

Fig. 6 - 26 Example of a geometric pattern using the GIVA program

To generate the Islamic geometric patterns shown in our thesis, the main functions that are used in the program were written using the following pseudocodes. These functions are Pattern 1 that was used to draw the single Islamic geometric pattern and Pattern 2 that was used for generating the shape used to make a shadow with a 50% transparency around the Islamic geometric pattern. Pattern and Small Pattern are used to repeat the Islamic geometric patterns as shown in Fig 6 - 26 (b – f) while Pattern 1 and Small Pattern 1 were used to generate the Islamic geometric patterns as shown in Fig 6 - 26 (c - i). Pattern 2 was used in Fig 6 - 26 (j). The pseudocode of the functions is as follows:

- **Pattern1 Function:**

```
ENTER x, y, w, h, n
   angle = (2 * pi) / n
   HalfAngle = angle / 2
   FOR a = 0 TO 2*pi STEP angle DO
      sx = x + cos(a) * h
      sy = y + sin(a) * h
      vertex( sx, sy)
      sx = x + cos(a + HalfAngle) * w
      sy = y + sin(a + HalfAngle) * w
      vertex( sx, sy)
   END FOR
   FOR a = 0 TO 2*pi STEP angle DO
      sx = x - cos(a) * h
      sy = y - sin(a) * h
      vertex( sx, sy)
      sx = x + cos(a + HalfAngle) * w
      sy = y + sin(a + HalfAngle) * w
      vertex( sx, sy)
   END FOR
RETURN
```

- **Pattern2 Function:**

```
ENTER x, y, h, n
   angle = (2 * pi) / n
   FOR a = 0 TO 2*pi STEP angle DO
      sx = x + cos(a) * h
      sy = y + sin(a) * h
      vertex(sx, sy)
   END FOR
RETURN
```

- **Pattern Function:**

```
ENTER w , q
   x = -h * 2
   y = -h * 2
   h1=h+20;
   FOR j = 1 TO q STEP 1 DO
      FOR i = 1 TO w STEP 1 DO
         CALL Pattern2 (x, y, h1, n)
         CALL Pattern1(x, y, w-20, w, n)
         y = y + h * 2
      END FOR
      y = – h * 2
      x = x + h * 2
   END FOR
RETURN
```

- **SmallPattern Function:**

```
ENTER w , q
   x = -h
   y = -h
   h1 = h / 2 + n / 8
   FOR j = 1 TO q STEP 1 DO
      FOR i = 1 TO w STEP 1 DO
         CALL Pattern1 (x, y, h1, w1, 8)
         y = y + h * 2
      ENDFOR
      y = - h
      x = x + h * 2
   END FOR
RETURN
```

- **Patterns1 Function:**

```
ENTER w , q
   x = -h
   y = -h
   FOR j = 1 TO q STEP 1 DO
      FOR i = 1 TO w STEP 1 DO
         CALL Pattern1(x, y, w, h, n)
         y = y + h * 2
      ENDFOR
      y = – h
      x = x + h * 2
   END FOR
RETURN
```

- **SmallPatterns1 Function:**

```
ENTER w, q
   x = -h * 2
   y = -h * 2
   w1 = w / 2 – n / 8
   h1 = w1 - 10
   FOR j = 1 TO q STEP 1 DO
      FOR i = 1 TO w STEP 1 DO
            IF ((n % 8 == 0 or (n + 2) % 8 == 0) and (n / 2) % 2 == 0)
                  CALL Pattern2(x, y, h1, w1, n);
            ELSE IF((n % 8 == 0 or (n + 2) % 8 == 0) and (n / 2) % 2 != 0)
                  CALL Pattern2(x, y, h1, w1, n-2);
            ELSE IF ((n / 2) % 2==0)
                  CALL Pattern2(x, y, w1, h1, n);
            ELSE
                  CALL Pattern2(x, y, w1, h1, n - 2);
            END IF
        y= y + h * 2;
      END FOR
      y = – h* 2
      x = x + h * 2
   END FOR
RETURN
```

- **Patterns2 Function:**

```
ENTER w, q
   x = 125
   y = 52
   w1 = w/2
   h1 = w1 + 10
   FOR j = 1 TO 2 STEP 1 DO
      FOR i = 1 TO 2 STEP 1 DO
         CALL Pattern2(x, y, w1, h1, n)
            CALL Pattern2(y, x, w1, h1, n)
         x = -x
      END FOR
      y = – y
   END FOR
RETURN
```

6.7 SUMMARY

This chapter has provided a clear explanation of the research gap. The research gap shows the issues and limitations that must be solved by the developed approach. The importance of developing such approach has been discussed to provide a better understanding of the need for our approach and it also shows how the developed approach will be different from the existing approaches. Next, the new approach requirements are defined based on the conducted studies which help to form the developed approach behaviour to achieve the study aim.

After that, the core concept of the developed approach and design are discussed. The preserved aesthetics are discussed in terms of their meaning, importance, and how the approach will maintain said meaning. Finally, the developed prototype is discussed in detail. The prototype part covers the prototyping environment, algorithm design, prototype tasks and prototype implementation.

Chapter VII. RESULTS AND DISCUSSIONS

This section focuses on the experiments conducted to prove that the developed prototype worked as expected and met the end user needs. This chapter starts with an overview of the importance of testing and the testing environments. The implemented tests are then discussed in terms of their purpose, design, implementation, and the collected data. Next, the collected data and observed behaviour is discussed and explained. Finally, the issues and challenges faced during the study are indicated.

7.1 TESTING

As argued by Boehm (1981) the aim of conducting software testing is to provide a clear answer to the questions ‘Are we building the right product?’ and ‘Are we building the product, right?’

Conducting software testing aims to prove that the performance of the developed software meets the end user expectations and requirements and that it behaves as expected (Sommerville, 2011). In addition, Gomaa (2011) argues that software testing helps to discover any faults and/or unwanted behaviour that might occur as result of bad programming and implementation practices. Technically, the testing definition differs due to the test purpose (Luo, 2001). However, the Institute of Electrical and Electronics Engineers (Radatz, Geraci & Katki, 1990) provides the following definition for software testing: *‘an activity in which a system or component is executed under specified conditions, the results observed or recorded, and an evaluation made of some aspect of the system or component’*.

The environment of the conducted experiments was a real machine as there is no need for a virtual one. Practically, the developed prototype implements a set of calculations that does not exhaust the used machine and does not expose the platform to any threats. As we discussed earlier, processing was selected to develop the prototype alongside Eclipse. In addition, there were a set of device monitoring and management tools used to monitor, log and audit the machine behaviour and the resources therein.

Next, the experiments are discussed in detail and the collected data will be presented and explained in order to provide solid evidence that the tested prototype performed as expected. This is in addition to the addressed approach requirements having been fulfilled.

7.2 EXPERIMENTS

The experiments were concerned with the tests conducted in order to validate and verify the developed approach and prototype. There were two main experiments; one concerned with performance and one concerned with the user experience. Each experiment will be explained in terms of the aims, environment, implementations, participants and collected data.

7.2.1 Performance

The aim of this experiment was to examine the performance of the developed prototype and to provide a measurement of the consumed time, CPU and RAM. The experiment proves that the developed prototype works as expected. The experiments were conducted using 3 different machines with 4 different dimensions for each pattern. Table 7-1 shows the testing machine specifications and the generated image dimensions, respectively.

During this experiment, 4 geometric patterns were tested over 3 different machines (physical) with 4 different dimensions for each pattern. Image 1 was 200*200 px, Image 2 was 520*254 px, Image 3 was 1024*512 px and Image 4 was 1500 * 1000 px. This means that every pattern was tested across 12 configurations. The diversity in terms of the physical machines and image dimensions will provide the reliability and accuracy of the conducted test. All of the implemented tests were completed successfully and there were no failures or unexpected behaviour. The experiment was based on the testing environment (machine). For Machine 1 which has the larger RAM and the fastest CPU, increasing the complexity of the generated pattern led to an increase in the consumed time, and occupied more RAM and CPU. In addition, increasing the size of the generated pattern had an impact on the consumed resources but the impact was not significant. Generally, Machine 1 has a better level of performance as it generates the pattern faster than the other two machines. This saves the provided resources better than the others. Appendix C shows the performance experiment outcomes in detail.

	Operating system	System type	CPU	RAM	dedicated graphics cards
PC 1	Windows 7 Ultimate	64-bit	i7-3770	16 GB	No
PC 2	Windows 7 Ultimate	64-bit	i5-2400	8GB	No
PC 3	Windows 7 Ultimate	64-bit	i3-2120	4GB	No

Table 7 - 1 Testing machines, and Images specifications

7.2.2 User Experience

Implementing the user experience test was done in order to investigate whether the tested prototype has met the participant's needs and performed as expected. This test measured the 5 aspects that represent the experience of the consumed prototype. These aspects are helpfulness, efficiency, learnability, flexibility and usability (Bevan, 1995).

Practically, the prototype was inspected by 50 participants who were asked to provide feedback on the prototype via a questionnaire that provided a 1 to 5 scale to evaluate the aspects. Valid feedback was gathered from 46 participants which represents 92% of the sample. More than 60% of the participants were female and about 40% were aged between 40 and 49 years old. There were only 4 participants with a Diploma Certificate while more than 40% of the participants have a Bachelor's degree. In terms of the years of experience, there were no participants with less than a year of experience while about 50% of the participants had between 10 – 15 years of experience, Table 7-3 below shows the socio-demographic data of the participants.

when analysing the collected responses, there were only 4 participants who thought that the tested prototype was inefficient while about 95% of the participants were satisfied with the provided efficiency. On the other hand, there were only 2 participants who were not satisfied with the usability and flexibility of the tested prototype. However, 95% of the participants were satisfied with the provided level of flexibility and found the prototype easy to use. They were able to generate the desired geometric patterns easily. In terms of learnability, there was only

one participant who believed that the tested prototype was difficult to learn while 50% of the participants said it was very easy to learn. Table 7-4 below shows the participant feedback in detail.

Socio-demographic data	Number	Percentage
Age		
20 – 29	**6**	13%
30 – 39	**14**	30%
40 – 49	**18**	39%
Above 50 years	**8**	17%
Gender		
Male	**18**	39%
Female	**28**	61%
Level of education		
Doctorate Degree	8	17%
Master's Degree	14	30%
Bachelor's Degree	20	43%
Diploma Certificate	4	9%
Occupation		
Artist	13	28%
Interior designer	12	26%
Architecture designer	12	26%
Academic	5	11%
IT	4	9%
Years of experience		
Less than a year	0	0%
1-5	5	11%
6-10	13	28%
11-15	22	48%
> 15 years	6	13%

Table 7 - 2 Socio-demographic data

	Efficiency	Helpfulness	Learnability	Flexibility	Usability
Strongly disagree	**1**	**2**	**1**	**0**	**0**
Disagree	**3**	**3**	**4**	**2**	**2**
Neutral	**2**	**4**	**2**	**3**	**5**
Agree	**18**	**17**	**16**	**10**	**10**
Strongly agree	**22**	**20**	**23**	**31**	**29**

Table 7 - 3 User Experience results

7.3 DISCUSSION

7.3.1 Performance

For the performance experiments, the aim was to investigate the performance of the prototype in various environments. For Machine 1, we observed that the occupied CPU regarding the pattern generation process was increasing gradually and that increments were associated with the increasing complexity of the pattern and size as well. Practically, the incremental increases were not significant. For instance, the prototype occupied 11% of the CPU when generating Image 1 with 4 heads and 12% of the CPU when generating Image 4. This increase is not significant, and it is expected and logical. Moreover, the same behaviour was found in the other machines (2 and 3). For instance, Machine 2's CPU was occupied by 14% during the production of Image 1 and this percentage reached 16% for Image 4. As we mentioned earlier, increasing the complexity and size of the generated pattern will lead to an increase in the consumed CPU. Reducing the capability of the machine will lead to an increase in the occupied CPU percentage. Figures 7-1, 7-3 and 7-5 show the CPU that was occupied during this experiment.

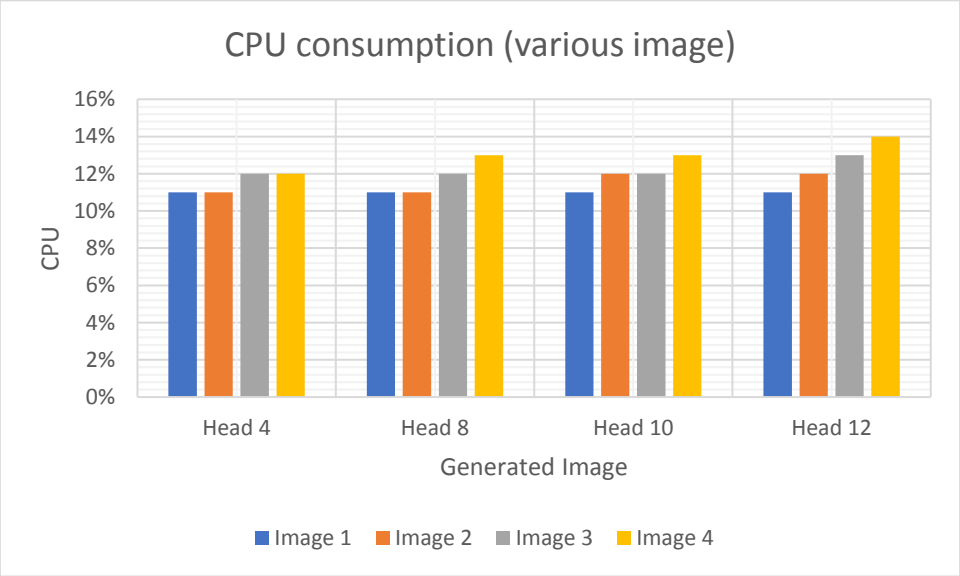


Figure 7 - 1 Machine 1 CPU consumption

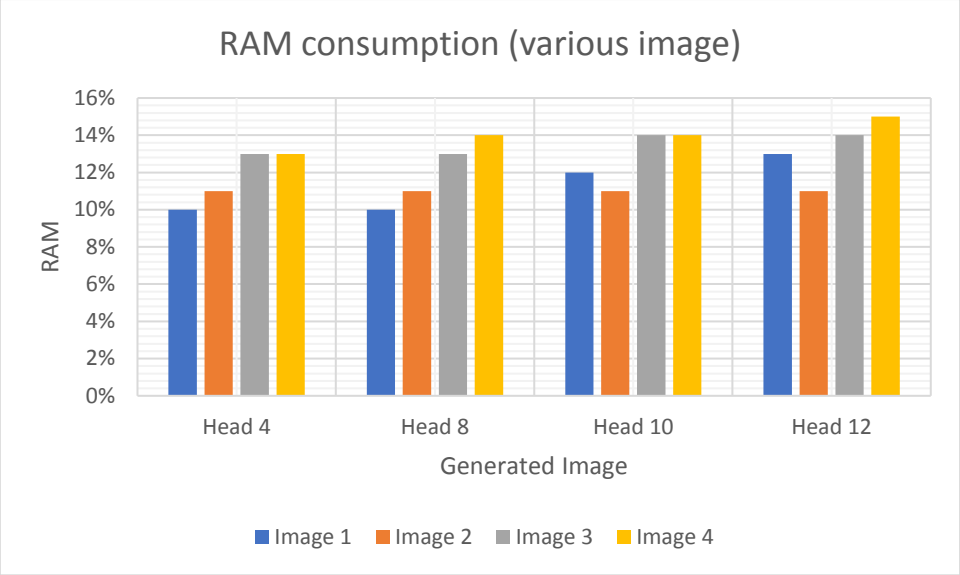


Figure 7 - 2 Machine 1 RAM consumption

It is obvious that Machine 1 consumes less RAM than the other machines. The incremental increases in terms of the complexity in relation to the number of heads and pattern size will lead to an increase in the RAM taken up. In Machine 1, the occupied RAM for the 4 head pattern varied between 10 % and 13%. This percentage is logical as the size increments are followed by an incremental increase in the resource consumption. In addition, the same machine occupied 15% of the provided RAM when it produced a pattern with 12 heads.

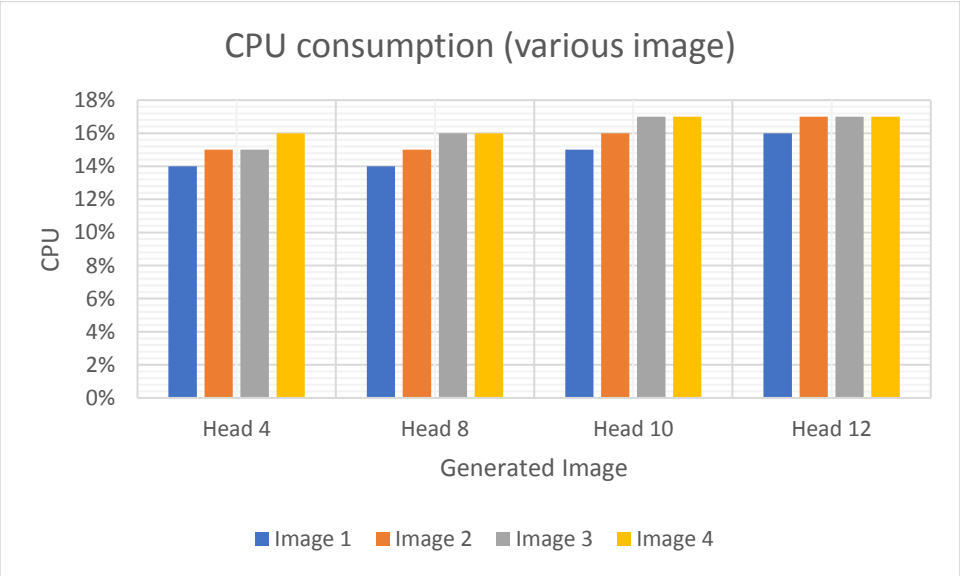


Figure 7 - 3 Machine 2 CPU consumption

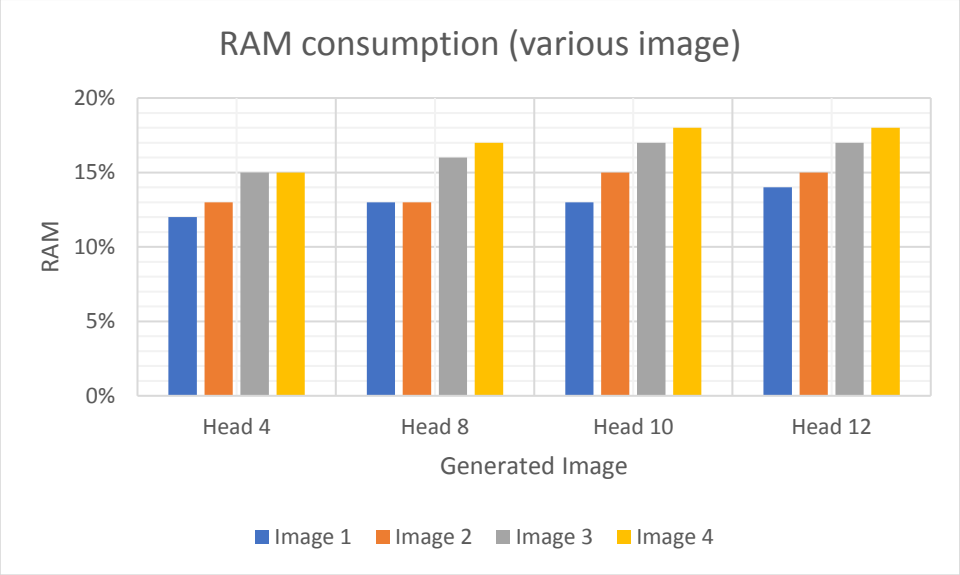


Figure 7 - 4 Machine 2 RAM consumption

By comparing the three machine readings for the same pattern, we found that Machine 3 consumes more than the other machines. This is caused by the hardware. For instance, producing a 12 head pattern for Image 4 occupied 15% of Machine 1 but 18% of the provided RAM for Machine 3. In some cases, changing the size of the produced pattern had no significant impact on the consumed resources in terms of RAM. The impact can instead be observed clearly in terms of the time taken and the CPU. Figures 7- 2, 7- 4 and 7- 6 show the RAM consumption for the various images over the 3 testing machines and it is clear that Image 4, which is the largest image, consumed the most RAM compared to the other images. Image 1, the smallest image, consumed less RAM than the other images. Generally, increasing the complexity of the geometric pattern will increase the RAM consumption.

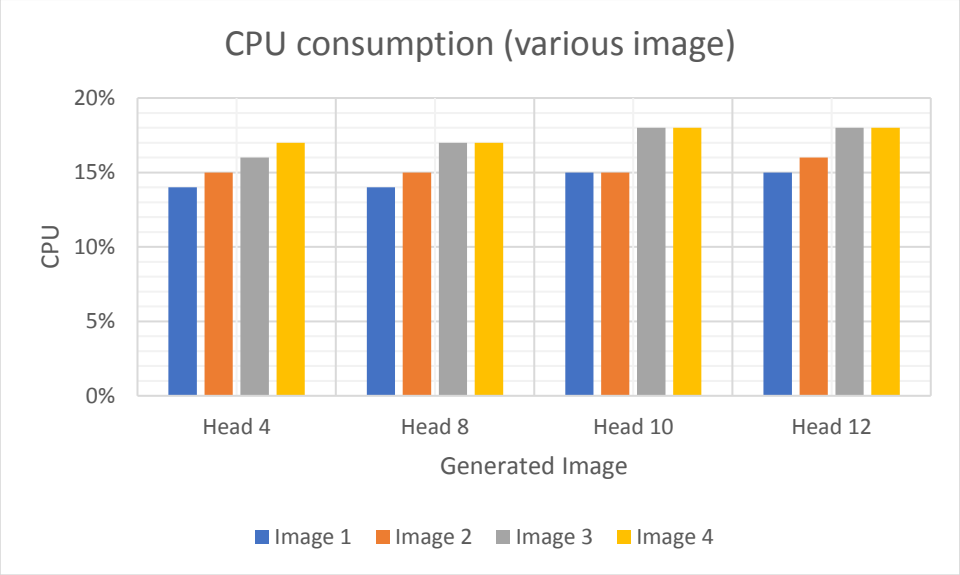


Figure 7 - 5 Machine 3 CPU consumption

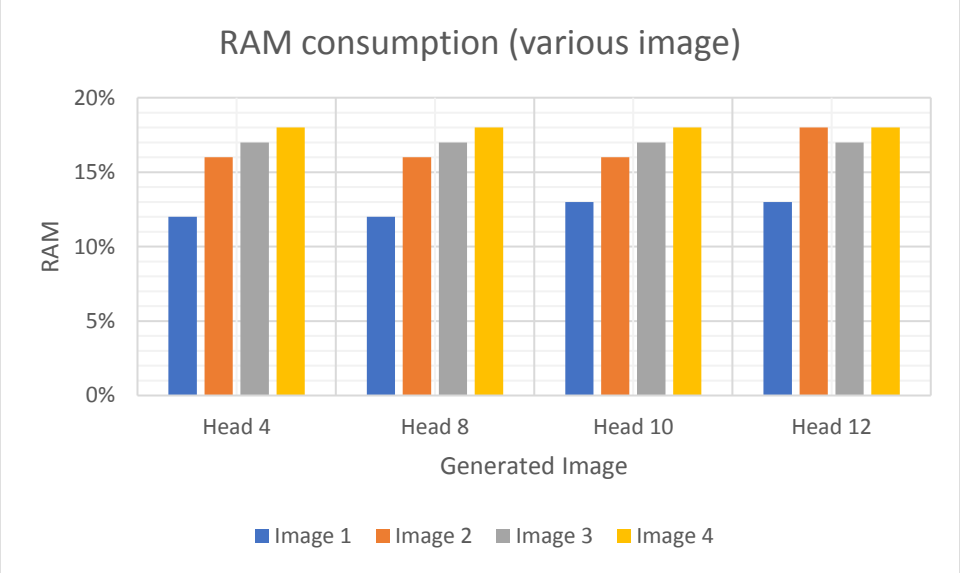


Figure 7 - 6 Machine 3 RAM consumption

The third measured aspect examined through the performance experiment was the consumption of time. Machine 1 was the fastest machine capable of generating the requested pattern for all 3 images. However, this time saving comes from the use of high-end hardware which is much more expensive than the other machines. For the first image, Machine 1 took about 3 seconds to produce a 12 head pattern while Machine 3 took about 5 seconds to complete the same task. Practically, the 2 second delay could be acceptable in some applications but the delay might not be accepted in the context of mass production. By comparing the time taken for the same pattern over the same machine, it is obvious that the size of the produced pattern has an impact on the time taken. For instance, Machine 3 took about 3.2 seconds to produce Image 1 with a 10 head pattern and about 7 seconds to generate the same pattern with larger dimensions. To summarise, the end user must know his / her needs and determine what is acceptable and what is not acceptable based on that. For example, a mass production application might be concerned about the speed (time consumption) more than saving the other resources. On the other hand, a fabric printing application for a small company will not be concerned about the time taken compared with reducing the cost of the resources used. Figures 7 – 7 and 7 – 8 show Image 1 and 2's consumed time for all 3 machines respectively. Figures 7 – 9 and 7 – 10 illustrate the time taken for Images 3 and 4.

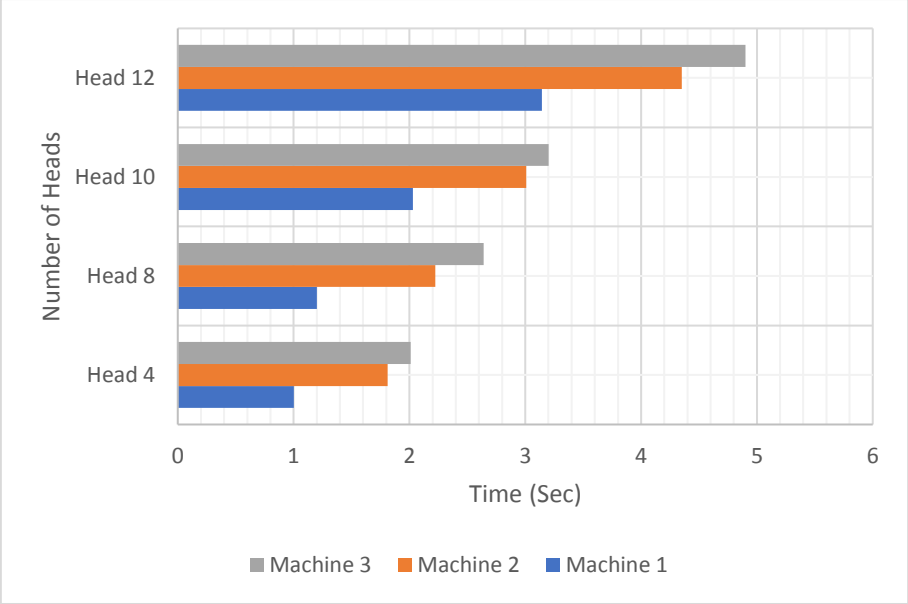


Figure 7 - 7 Image 1 consumed Time (All Machines)

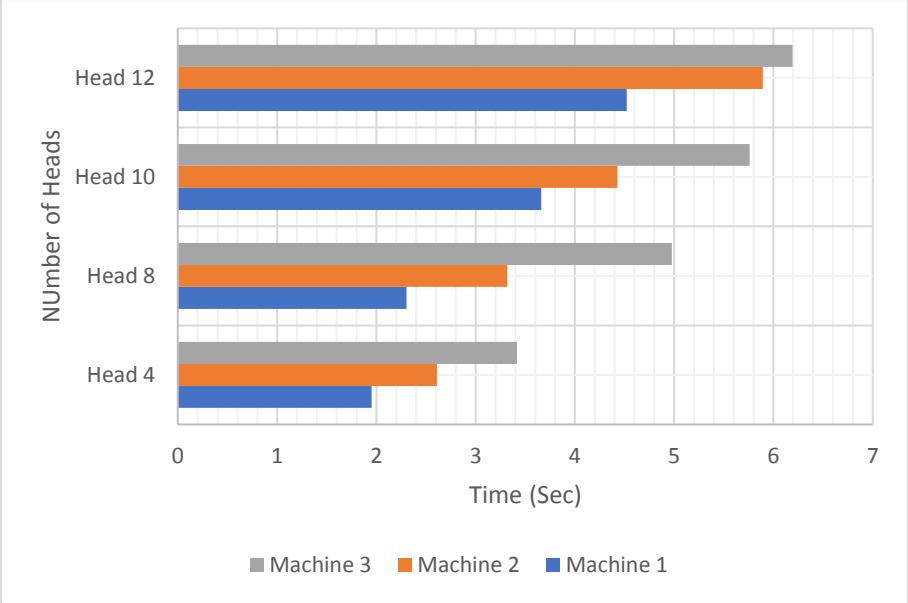


Figure 7 - 8 Image 2 consumed Time (All Machines)

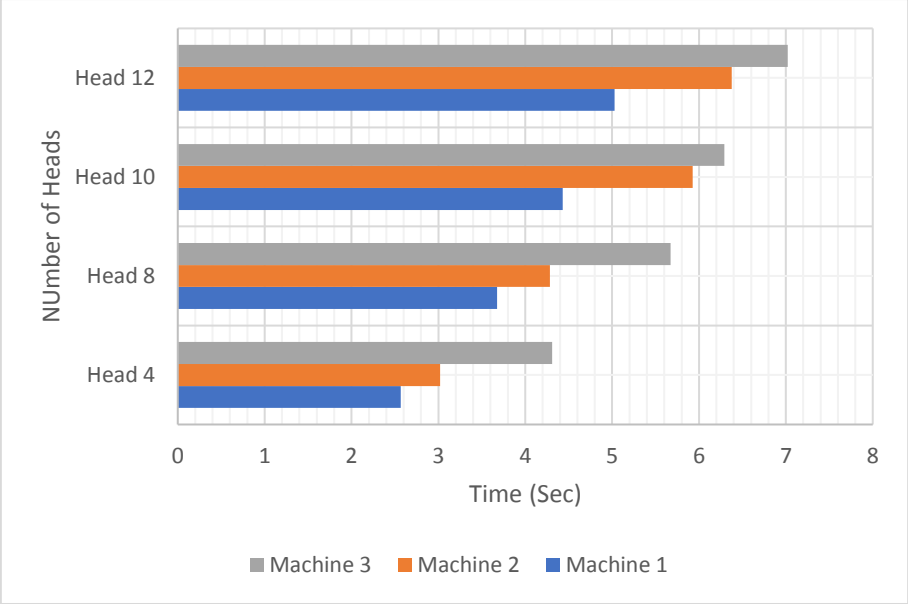


Figure 7 - 9 Image 3 consumed Time (All Machines)

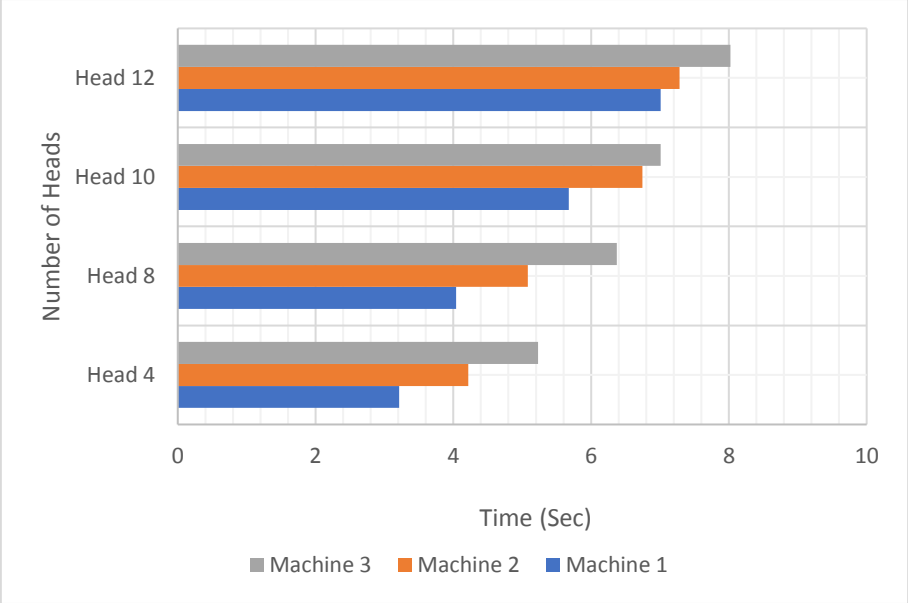


Figure 7 - 10 Image 4 consumed Time (All Machines)

7.3.2 User Experience

The positive feedback was obvious for all of the measured aspects. There were 5 participants who were not satisfied with the learnability and helpfulness and this was the largest amount of negative feedback we received. Figure 7-11 shows the collected feedback. Most of the participants said that the prototype was easy to learn, totalling 90%. They believe that the tested software is easy to learn and that there is no need to be an expert or receive training to use it. This means that the developed approach can be consumed by individuals who are not experts in either IT or art and that they can produce Islamic geometric patterns that meet the required standards of aesthetic regardless. In terms of helpfulness, only 2 of the participants believed that the prototype was unhelpful and did not facilitate the production of Islamic geometric patterns.

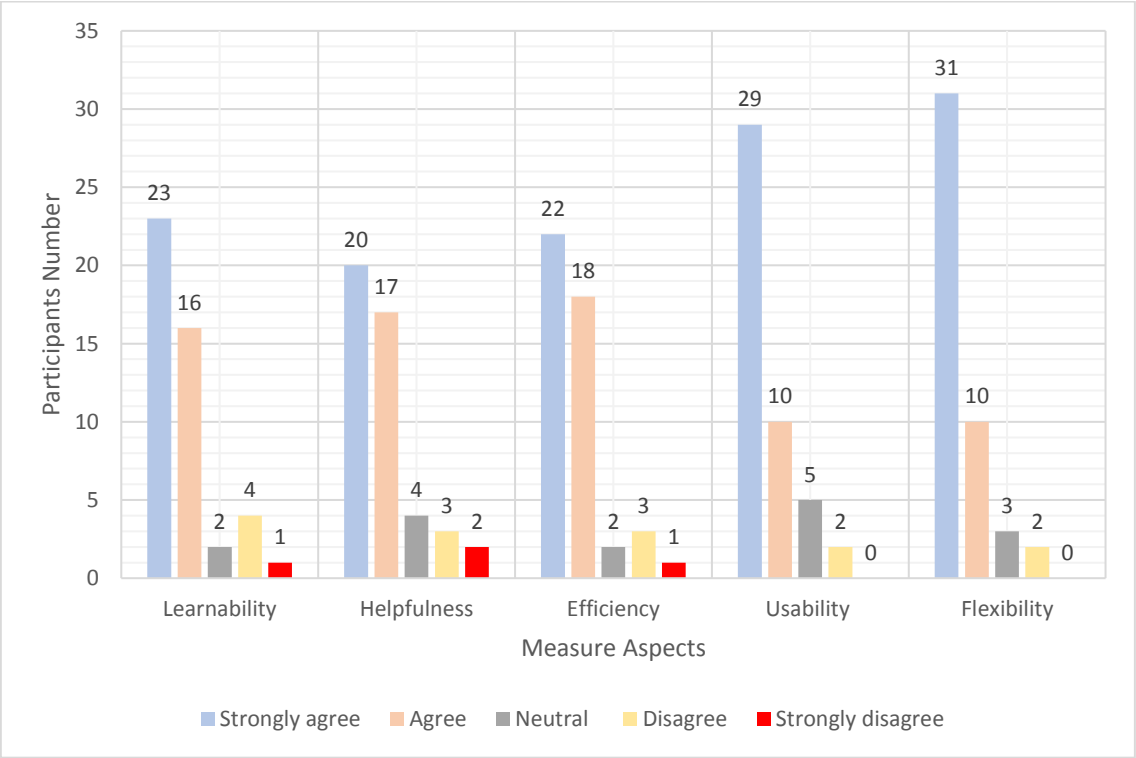


Figure 7 - 11 User Experience Results

On the other hand, about 80% of the participants said that the approach helped them to generate the desired geometric patterns smoothly. In addition, 95% of the participants said that the tested prototype was flexible and allowed the user to select the geometric pattern in terms of the number of pattern heads, colouring and the size (dimensions). Only one participant was not satisfied with the delivered efficiency level. Most of the participants believe that the developed approach is an efficient solution to address the defined issues. It also has the capability to maintain the aesthetic of the generated geometric patterns and to provide a high level of flexibility in relation to the user producing a pattern that meets his/her needs.

Only two of the participants said that the prototype has a lack of usability while the rest of participants, who represent about 95%, believe it to be very useful. This means that the developed prototype was easy to use, that the developed interface was not complicated and that the end user can navigate the tasks easily. To summarise, the feedback proves that the majority of the participants were content with the developed approach, believe that it works as expected and find it capable of generating geometric Islamic patterns successfully.

According to the data collected from the implemented experiments and interviews, we can say that this study has achieved the defined aims. The developed approach and tested prototype prove that the approach performs as expected, successfully filling in the defined gaps and solving the previous approach issues and challenges. However, there are several of challenges and issues that have been faced throughout our study. These issues and challenges will be discussed later. Practically, the developed approach helps to overcome a few of the key limitations and drawbacks of the previous approaches that have become the strong points of our approach. These are as follows:

- Portability

  The developed approach is not limited to being used on a specific platform. This point means that there is no need to do the configuration each time there is a need to change platforms. Moreover, supporting portability helps to reduce the operational cost in terms of the hardware and level of experience needed. This is as the approach can be installed and used by individuals.

- Flexibility

  The developed approach is not limited to a fixed or specific geometric pattern. Our approach allows the end user to select the desired Islamic geometric pattern in terms of the pattern head number, the generated pattern size and the colouring of the produced patterns. This flexibility level makes the developed approach suitable to be used in connection to a wide spectrum of applications.

- Cost

  The developed approach helps to reduce the expenses compared with both the previous approaches and the traditional method as well. Practically, the developed approach can be installed and used to generate geometric Islamic patterns that preserve the aesthetic with no need for any kind of training or previous experience. The developed approach can be used by individuals who are neither technicians nor artists to produce accurate and high quality geometric Islamic patterns. In addition, it helps to prevent dependency on a single machine as it does not require any kind of configuration or complex installation process that needs a high level of knowledge. It can be used on a machine that meets the end user needs.

- Diversity

  As we discussed earlier, the previous approaches support a specific pattern and the user must reconfigure and alter the algorithm in order to change or modify the wanted pattern. The developed approach supports diversity as the user can select the size, colour and complexity of the generated pattern.

- Quality assurance

  The quality of the produced pattern is preserved by the defined aesthetic criteria approved by the experts. By relying on the defined criteria and metrics, having the same level of aesthetic is guaranteed. This has been proven in the test and through the collected feedback.

7.4 ISSUES AND CHALLENGES

As we discussed earlier, the developed approach fills in the gaps and overcomes the defined obstacles of the previous approach. The tested prototype generates the selected pattern in a smooth and successful way. Practically there are several challenges and obstacles that have been faced during this study that must be addressed to be investigated in the future. In addition, the collected data from the conducted interviews, experiments and questionnaires provide very useful outcomes that help to enhance the developed approach in terms of performance and usability. The addressed obstacles, issues and challenges are as follows:

- The colouring features need more investigation and development as there is a critical need to set a clear and accurate criterion that prevents issues like colour matching between the adjoining pattern sectors. The absence of an appropriate colouring influences the aesthetic of the generated pattern.
- To enhance the diversity and flexibility possible by expanding the supported shapes. Visual Islamic art is not limited to geometric patterns as discussed in Chapter III. There are a lot of other patterns possible such as florals, lines and ovals.
- The absence of clear colouring rules leads to the production of a pattern that does not meet the aesthetic of a geometric pattern. Moreover, some experts argue that colouring the pattern affects several aspects. For instance, the coloured surface type (glass, gypsum etc) and the type of colour itself.
- The size and the dimensions of the generated patterns must stick to the core rules as cutting the generated pattern at the edge might led to distorting the whole drawing.
- The shade, brightness and lighting are the factors that must be considered during the generation process. These factors need to be investigated in terms of balance and harmonisation. Either ignoring these factors or considering each factor as an individual

and isolated factor will lead to the interference and distortion of the produced pattern in a partial or complete way.

- To expand the developed approach to take into consideration the aim of the pattern generation. For instance, the factors that must be considered when the pattern will be printed on fabric are different from when the pattern will be engraved into wood or on a lampshade.

- Allowing for a combination of three or more different patterns is an aspect that needs more investigation. Combining different patterns relies on several aspects. For instance, defining the core pattern, positioning the patterns, determining where the patterns join each other and determining how the aesthetic will be preserved.

- In order to improve the developed approach and to enhance the delivered experience, the approach must be moved forward and the researchers must combine it with artificial intelligence technology in order to expand the gained knowledge. The developed AI application is capable of generating, assessing and evaluating geometric Islamic patterns.

7.5 SUMMARY

This chapter has evaluated the implemented experiments in terms of their aim, implementation and results. Throughout this chapter, the measured and observed elements and the experimental environment have been analysed to provide clear and accurate results. The collected results have been explained to prove that the developed prototype works as expected. In addition, these results have been used to prove that the conducted study achieved the defined aims and filled in the defined gaps discussed earlier. Finally, the issues and difficulties of the conducted study are discussed. The next chapter illustrates the conclusion of this study and shows the limitations and potential for future work.

Chapter VIII. CONCLUSION AND FUTURE WORK

8.1 OVERVIEW

Islamic art is commonly considered to be vibrant and distinctive. It is different from western religious art in that it is not constrained by religious themes. Islamic art has been suggested as having a continuing aesthetic appeal that transcends time and space along with variances in the language and different cultures. The patterns of Islamic art are distinctive in appearance as they have multiple geometric shapes such as lines, points, surfaces, and polygons. However, Islamic art is not a random combination of shapes. It follows specific rules that are applied to create the patterns (Broug 2013). Practically, there is a demand for perfect modern Islamic art pattern for sacred places as well as museums, houses, schools, and public places. There is a shortage of studies solely dedicated to the topic as explained in Chapter I. As defined in Chapter I, this study aimed to develop an innovative and automatic approach for the purpose of generating geometric Islamic patterns based on the pre-defined rules that guarantee the quality of the produced pattern.

As discussed in Chapter II, the conducted study has utilised the mixed method approach to provide a deep understanding of the Islamic art patterns created by the GIVA software through integrating the findings into the mathematical formula applied by the computer to generate Islamic art. This is in addition to the findings of the quantitative and qualitative approaches. In addition, the triangulation methods effectively validated the findings which can then be utilised by Islamic art experts and people interested in Islamic art. However, the limitation of this mixed method was that the research design was very problematic and time-consuming as well as difficult to implement, integrate and synthesise as part of establishing the final findings of the study.

As presented in Chapter III, the majority of investigated approaches have a number of drawbacks and limitations. The defined limitations have been explained in detail earlier, but

the core limitations are the absence of flexibility, diversity and portability. Practically, the investigated approaches are static and do not allow the end user to configure the generated pattern based on his/her needs. Moreover, the absence of clear and accurate rules and standards that guarantee the quality of the produced pattern is one of the limitations.

In addition, the investigation of the literature shows that there are specific features that geometric Islamic art has. These features must be maintained in order reach the minimum geometric Islamic art standard. These rules, metrics and features have been defined and gathered from various resources such as the literature and experts in order to define and develop a set of criteria that guarantees the quality of the produced geometric patterns and to ensure that the pattern has the needed aesthetics.

In Chapter IV, a survey addressing the end users was developed and deployed. The conducted survey aimed to highlight the requirements and use of such an approach. The outcomes of this survey were combined with the critical literature review outcomes in Chapter III and the outcomes of the expert interviews and feedback from Chapter V. This combination led to producing a list of features and capabilities that must be included in the developed approach alongside the set of criteria that helped to preserve the aesthetic of the geometric Islamic patterns.

Practically, there was a need to develop an approach in order to fill in the defined gaps to solve the addressed issues and to meet the end user requirements. Chapter VI represents the developed approach that aims to generate geometric Islamic patterns based on pre-defined rules that guarantee the quality of the produced pattern while considering aesthetic metrics and the individual ability to implement it. The developed approach saves money in terms of the consumed time and resources while avoiding the need for experience to produce geometric patterns that have the required aesthetic and quality. In addition, this chapter illustrates the prototype that has been developed in order to examine the approach in terms of performance and user experience.

The conduced experiments that examined the developed prototype have been discussed in Chapter VII. There were two experiments conducted for this purpose. These experiments examine the prototype across several machines with various levels of complexity in terms of the produced pattern. In addition, the end user experience for this prototype was tested in terms of flexibility, usability, learnability, efficiency, and helpfulness. The approach works successfully and has implemented all the involved tasks in a smooth way. At the end of this chapter, the issues and challenges faced have been listed to inspire future work.

Practically, the developed approach helps to overcome a number of key limitations and drawbacks found in the previous approaches which becomes a strength of our approach. These are as follows:

- Portability

  The developed approach is not limited to a specific platform. This means that there is no need to repeat the configuration each time we need to change platform. Moreover, supporting this portability helps to reduce the operational cost in terms of the needed hardware and level of experience as the approach can be installed and used by individuals.

- Flexibility

  The developed approach is not limited to fixed or specific geometric patterns. Our approach allows the end user to select the desired Islamic geometric pattern in terms of the pattern's head number, the generated pattern size, and the colouring of the produced patterns. This flexibility level makes the developed approach suitable to be used on a wide spectrum of applications.

- Cost

  The developed approach helps to reduce the expenses compared with the previous approaches and traditional methods. Practically, the developed approach can be installed and used to generate geometric Islamic patterns that preserve the aesthetic

with no need for any kind of training or previous experience. The developed approach can be used by individuals who are neither technicians nor artists to produce accurate and high quality geometric Islamic patterns. In addition, it helps to prevent dependency on a single machine as it does not require any kind of configuration or complex installation process that needs a high level of knowledge.

- Diversity

  As we discussed earlier, the previous approaches support a specific pattern, and the user must reconfigure and alter the algorithm to change or modify the pattern. The developed approach supports the diversity of the geometric Islamic patterns produced as the user can select the size, colour, and complexity of the generated pattern.

- Quality assurance

  The quality of the produced pattern is preserved, and the defined aesthetic criteria have been approved by the experts. By relying on the defined criteria and metrics, having the same level of aesthetic is guaranteed and this has been proven during the tests and through the collected feedback.

8.2 ADDRESSING STUDY OBJECTIVES

The defined aims of this study were to study the existing approaches in order to define the capabilities, limitations and gaps and to develop an innovative and automatic approach for generating geometric Islamic patterns based on pre-defined rules that guarantee the quality of the produced pattern. This is while considering the aesthetic metrics and whether the program can be implemented by individuals who are not experts in either the arts or IT. In addition, the developed approach aims to save money in terms of the consumed time and resources. This is to avoid the need for experience to produce geometric patterns that have both the required aesthetic and quality. Moreover, this enhances the flexibility level which is one of the core targets. The approach can be implemented in several platforms and delivered as an executable file to the end user. As we discussed in Chapter I, the defined research

objectives were divided into three main stages. The stages start with defining the research gaps and the end user requirements. Next, there is the approach development stage and finally the approach validation stage.

The addressed objectives in the first stage aim to define the research gaps and the end user requirements. The first stage helps to highlight the issues that need to be solved and the obstacles that must be overcome. In addition, it also provides clear expectations regarding the end user requirements and needs. The addressed objectives for this stage were:

- To investigate and evaluate the literature on the existing approaches for the purpose of generating geometric patterns and defining the capabilities and limitations of each approach.

    - The critical literature review has investigated and evaluated the existing approaches for the purpose of generating geometric patterns. This study has provided a detailed evaluation of the investigated approach in terms of capabilities, algorithms, scope and limitations (Chapter III).

- To conduct a study that aims to define the end user needs and the expectations from such an approach.

    - We have developed and deployed a questionnaire that aims to define the end user needs and expectations of such an approach. In addition, it highlighted the users' current status in terms of their level of experience, used applications and the purpose of the approach (Chapter VI).

- To conduct a literature review and meet experts to define the metrics, features and rules that help to guarantee the quality and aesthetic of the geometric Islamic patterns.

    - We have investigated the literature in order to define the rules for Islamic geometric patterns, helped to define the rules of the Islamic geometric patterns

and come to understand what we should and should not do to improve the quality and aesthetic of the produced patterns. In addition, there were a number of experts interviewed in order to evaluate the produced patterns and to give their thoughts on the applied rules and criteria (Chapter III and Chapter VI).

The second stage aimed to develop an approach that is capable of overcoming the defined limitations of the previous approaches and to generate the wanted geometric Islamic patterns based on the pre-defined rules that guarantee the quality of the produced pattern. This is in addition to considering the aesthetic metrics and how this process can be implemented by individuals who are not experts in either the arts or IT. Two objectives were addressed in this stage:

- Develop the criteria to ensure the aesthetic of the geometric Islamic patterns produced.
    - The rules of Islamic geometric patterns and the aesthetic aspects must be preserved to enhance their quality. This has been discussed and explained. In addition, bad practices that influence the pattern quality and aesthetics have been defined to help to avoid mistakes.
- Propose an approach that generates geometric Islamic patterns based on pre-defined rules that guarantees the quality of the produced pattern and considers the aesthetic metrics. It should be able to be easily implemented by individuals.
    - We have developed an approach for the purpose of generating geometric Islamic patterns in automatic way. In addition, the developed approach is capable of providing a list of features that have been defined as limitations and obstacles as explained in Chapter VI.

The third stage aimed to validate the developed approach and to provide reliable and accurate evidence that the developed approach is valid and capable of performing as expected. This stage has three objectives:

- Develop an application (prototype) for the purpose of generating geometric Islamic patterns based on the proposed approach.

    - An application was developed based on the developed approach. The developed application applied the developed criteria and took into account all of the metrics that might influence the quality of the produced pattern (Chapter VI).

- Test the developed prototype in order to provide evidence in terms of performance and to assess the prospective usefulness, behavioural intentions and ease of use of the developed prototype.

    - The developed prototype was tested to investigate the performance and the end user experience. The conducted experiments were discussed in terms of the aims, design, and their implementation. All the collected data had to be explained and discussed in detail to prove that the developed prototype is valid and performs as expected (Chapter VII).

- Produce theoretical and practical implications to further advance the existing knowledge in computer science.

    - The key findings and practical implications of the conducted study have been addressed and discussed. The conducted discussion combined with the research limitations, recommendations and future work directions have helped to provide a roadmap for researchers (Chapter VIII).

At the end of this study, we can declare that this study has successfully achieved the defined study aims. All the defined research objectives were reached. There are a set of contributions to the body of knowledge that have been added:

- Developing a critical study that investigates the existing approaches that have been developed to produce geometric Islamic patterns. This study highlights the methods, features, weaknesses, and limitations of the studied approaches. In addition, this study illustrates how these approaches can be improved.
- Developing a criterion that can be used to categorise and evaluate the geometric Islamic patterns in terms of aesthetics. This helps to guarantee the quality of the generated patterns.
- Highlighting the need for a proposed approach that is capable of overcoming the previous approach limitations while meeting the end user needs.
- Developing a new approach that generates the desired geometric Islamic patterns automatically while guaranteeing the aesthetic and quality of the produced patterns.
- Developing an application that applies the developed approach which helps to validate and verify the application in the real-world. This is in addition to providing more knowledge in terms of performance, effectiveness, and efficiency.
- Defining the study limitations and providing a guide for future work which will contribute to the body of knowledge.

8.3 RESEARCH OUTCOMES

The results of this study can help with the key implication of providing comprehensive knowledge about how the GIVA software and its features operate in order to create Islamic art designs. In addition, this study can facilitate and accelerate the design of more aesthetically beautiful Islamic art patterns targeting the interests of a broad population in the marketplace.

Using a mixed method style to address Islamic art in Saudi Arabia has not been conducted before within computing and Islamic art studies in relation to the wider art and computer science sector. This study paves the way for researchers from the diverse Islamic art, computer science and design technology sectors in addition to architectural institutions seeking to adopt similar approaches to address other types of Islamic art including digital Islamic art or the performance of further research on Islamic art in Saudi Arabia.

The recruitment and visiting process of the participants within their place of work, followed by distributing the questionnaire under personal supervision, is to our knowledge a unique approach because it is time-consuming. Many researchers will avoid this data collection technique for other projects. Furthermore, both survey questionnaires and semi-structured interviews were utilised in this research and that because they are considered to be successful within a Saudi culture context. Additionally, these are mainly linked to the pragmatic worldview stance of the researcher. Likewise, the main factor needed in this study is the minimisation of the risks for future researchers who may have various concerns related to using these specific data collection approaches. This could also apply to other researchers doing a similar thing in the Saudi context. The study's outcomes also influence the Saudi knowledge of Islamic art and how it is created and designed efficiently. Through informing interested people, this study can establish a keystone for policy makers to allow them to develop effective programs for enhancing the formulas for the purpose of generating diverse Islamic art designs and patterns. This allows them to be utilised as ornaments in relation to the aspects of art, design, and computing within Saudi Arabia.

8.4 STUDY LIMITATIONS

The following section reviews the limitations that possibly impact on the overall outcome of this study. These have been divided into the limitations associated with methodology and the limitations related to the developed approach, respectively.

The first aspect for the quantitative research is the implementation of the cross-sectional design. This excludes the determination of simple inferences. Likewise, since this design is only a snapshot, there may be different outcomes if another timeframe is selected (Carlson, Morrison 2009). While the qualitative research of the study has implemented semi-structured interviews, a criticism is directed toward the qualitative approach in terms of the researcher failing to identify the appropriate approach used in this study. Aligned with a pragmatic stance and following the previous studies, this study selected semi-structured interviews for the qualitative phase (Rowley 2012).

Relying on the mixed method approach was very problematic and time-consuming as well as difficult to implement, integrate and synthesise. A further issue was that the survey questionnaire used in this study was predominantly pre-existing, having been previously well-tested and validated for reliability. On the other hand, a significant number of limitations are related to the pre-existing questionnaire. The literature shows that one study that used the same questionnaire suggested that there is a lack of questionnaires combining Islamic art design with computer science. This may influence the results that are relevant to this study when it comes to the lack of subscales such as shape and pattern comparisons.

The last limitation of this study was that the formula used to create and draw the Islamic art on the computer relied on the assumption made by other studies by focusing on the star shape. This study was restricted to using this assumption in other formulas for the polygons, pentagons, hexagons and other Islamic art shapes.

8.5 RECOMMENDATIONS FOR FUTURE RESEARCH

This study also recommends that future work can report on this topic using different mathematical formulas to generate a variety of Islamic art shapes (e.g. polygons, hexagons and pentagons) through a more efficient programming interface to maximise the complexity of the Islamic art shapes and designs. Another prospective research suggested by this study includes recruiting more professionals who work in a wider variety of jobs related to Islamic art since this work does not clarify additional jobs beyond the five included here. Future researchers could also include more participants to increase the statistical significance of the results.

Future researchers should consider artificial intelligence and machine learning solutions necessary to improve the developed approach and to enhance the delivered experience. The approach must be moved forward, and the researchers must combine the existing work with that of Artificial Intelligence technology to expand the gained knowledge. The developed AI application should be capable of generating, assessing, and evaluating geometric Islamic patterns. In addition, machine learning technology will help to develop solutions that are capable of enhancing the quality of the generated patterns.

There could be an expansion of the developed approach to take into account the purpose of patterned material production. For instance, the factors that must be considered when the pattern is to be printed on fabric are different from when the pattern will be engraved in wood or placed on a lampshade. In addition, combining that with other factors such as shade, brightness and lighting will help to improve the quality of the produced pattern. Ignoring these factors and considering each factor as individual and isolated will lead to the interference and distortion of the produced pattern in a partial or complete way.

The final state of this study means that it is recommend that future researchers carry out the same study with a larger sample in a variety of cities to obtain a broader generalisation in the results. This study suggests that researchers should conduct surveys in neighbouring Arab countries. Following these suggestions will increase the attention on the topic of Islamic art and computerisation across a wider area of Islamic countries to contribute new knowledge and information to the literature.

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APPENDICES

APPENDIX A SURVEY QUESTIONNAIRE

SURVEY QUESTIONNAIRE

Dear Participant,

The current survey is requested as a part of my PhD thesis titled "*The Design of an Innovative Automatic Computational Method for Generating a Geometric Islamic Visual Art with Aesthetic Beauty"*

The survey questionnaire is carefully designed to assess the views of Islamic art practitioners towards the design of an innovative automatic computational method for generating a Geometric Islamic Visual Art (GIVA). To achieve this aim this survey examines the practitioners' perceived usefulness, and behavioural intentions of the prospective GIVA program.

- ***Your participation is voluntary.***
- ***Your response to the questionnaire are completely anonymous***

Researcher hereby undertakes that no information provided by the respondent will be used for any purpose other than academic research. No information collected through this survey will be disclosed to any third party. If you wish to withdraw your responses at any time prior to the write up of the research report you can do so by informing the researcher. Moreover, if you wish to inquire about the survey, please don't hesitate to contact the researcher through the details below:

Researcher Name: ***Marwah M Ibrahim***

Email-address:
Marwah.Ibrahim@study.beds.ac.uk

Your cooperation is very important to the success of this survey program and is greatly appreciated.

إستبيان

عزيزي المشارك...

هذا الإستبيان مطلوب كجزء من رسالة الدكتوراة التي أعدها بعنوان

"The Design of an Innovative Automatic Computational Method for Generating a Geometric Islamic Visual Art with Aesthetic Beauty"

تم تصميم الإستبيان بدقة من أجل تقييم وجهات نظر ممارسي الفن الإسلامي نحو تصميم طريقة حسابية مبتكرة لتوليد الفن البصري الإسلامي الهندسي. ولتحقيق هذا الهدف، يفحص هذا الاستقصاء الاستفادة المحتملة من جانب المستخدمين وقابلية الاستخدام للبرنامج المرتقب.

- ***مشاركتك إختيارية.***

إجاباتك على هذا الإستبيان ستكون غاية في السرية

يتعهد الباحث أن المعلومات التي يقدمها المشاركون في هذا الإستبيان لن تستخدم لأي غرض آخر سوى البحث الأكاديمي ، كما لن يتم تقديم أي معلومات جمعت من خلال هذا الإستبيان إلى أي طرف ثالث. يمكنك إذا رغبت في أي وقت سحب مشاركتك قبل كتابة تقرير البحث وذلك بإعلام الباحث.

إذا كنت ترغب في مزيد من الإستفسار حول هذا الإستبيان فلا تتردد في الإتصال بالباحث على العنوان أدناه:

أسم الباحث : مروه محمد إبراهيم

بريد إلكتروني: Marwah.Ibrahim@study.beds.ac.uk

تعاونك جداً مهم في إنجاح برنامج الاستبيان و يحظى بفائق التقدير.

العمر:

Age:

118 - 25 years	☐	18- 25 سنة
25 - 35 years	☐	35-25 سنة
36 - 45 years	☐	45-36 سنة
46 - 55 years	☐	55-46 سنة
Above 56 years	☐	أكثر من 56 سنة

Academic qualification: **المؤهلات العلمية :**

Doctorate Degree	☐	دكتوراه
Master Degree	☐	ماجستير
Bachelor Degree	☐	بكالوريس
Diploma Certificate (Ordinary and Higher)	☐	شهادة دبلوم (عادي وعالي)
High School Certificate	☐	الشهادة الثانوية

Years of working in Islamic art field: **عدد سنوات العمل في مجال الفن الإسلامي:**

Less than 1 year	☐	أقل من سنة واحدة
1 - 5 years	☐	1- 5 سنة
6 - 10 years	☐	6- 10 سنة
11 - 15 years	☐	11- 15 سنة

16 - 20 years	☐	16- 20 سنة
21 - 25 years	☐	21- 25 سنة
More than 25 years	☐	أكثر من 25 سنة

Profession / position: **الوظيفة :**

Artist	☐	رسام
Interior designer	☐	مهندس ديكور / مهندس داخلي
Architecture designer	☐	مهندس معماري
Academic	☐	اكاديمي
Other _____		اخرى _____

Are you currently using a computer software to create Islamic Art shapes?

هل تستخدم حاليا برنامج كمبيوتر لإنشاء أشكال الفن الإسلامي ؟

Yes ☐ نعم

No ☐ لا

If you are using a computer program to create Islamic Art shapes, are you satisfied with the results?

إذا كنت تستخدم برنامج كمبيوتر لإنشاء أشكال الفن الإسلامي، هل أنت راض عن النتائج؟

Yes ☐ نعم

No ☐ لا

I do not use لا استخدم اي برنامج

If you are using a computer program to create Islamic Art, could you select the utilised software, please?

إذا كنت تستخدم برنامج كمبيوتر لإنشاء أشكال الفن الإسلامي، ما هي البرمجيات المستخدمة؟

Photoshop ☐ Photoshop

CAD-software ☐ CAD-software

MS office ☐ MS office

Sketchometry ☐ Sketchometry

I do not use ☐ لااستخدم اي برنامج

Others: ☐ أخرى

....

Based on your experience, what are the features and the capabilities that need to be supported through GIVA software?

من خلال خبرتك ، ما هي الوظائف و الإمكانيات التي يجب توفرها في برمجيات رسم الفن الإسلامي؟

Accuracy	☐	الدقة
Repetition	☐	التكرار
Scalability	☐	سهوله الاستخدام
Colour	☐	التلوين
Size control	☐	التحكم في الحجم
Others:	☐	أخرى
.....		.....

Based on your experience,

what are the principles that need to be considered through GIVA software, in order to guarantee the quality of the produced draw?

من خلال خبرتك ، ما هي معايير الرسم التي يجب توفرها في برمجيات رسم الفن الإسلامي لضمان جودة الرسم المنتج؟

Repetition	☐	التكرار
Contrast		التباين
Symmetry	☐	التماثل
Balance	☐	التوازن

Shape diversity	☐	التنوع في الاشكال
Interlocking shapes	☐	ترابط الاشكال وتشابكها
Proportionality		التناسب
Others:	☐	أخرى
.....		.....

Based on your current knowledge and opinions of Islamic Art, please indicate the likelihood of your prospective usage of the GIVA program:

بحسب معرفتك وارائك عن الفن الاسلامي الرجاء الاشارة الى مدى قابلية استخدامك المتوقعة لهذا البرنامج

Using a scale of 5 to 1, with 5 being strongly agree and 1 being strongly disagree; please circle the appropriate number for each of the following statement.

بإستخدم المقياس من5- 1 حيث تكون 5 أوافق جداً ، 4 أوافق ،3 محايد ،2 لا أوافق و 1 لا أوافق مطلقاً ، الرجاء ضع دائرة حول الرقم الذي تراه صحيحاً أمام العبارات الآتية.

5	4	3	2	1
Strongly Agree	Somewhat Agree	Neutral	Somewhat Disagree	Strongly Disagree

1	2	3	4	5
لا أوافق مطلقاً	لا أوافق	محايد	أوافق	أوافق جداً

Statements						البيان
Using the GIVA program would make it easier to do my job.	1	2	3	4	5	استخدامي لهذا البرنامج سيسهل عملي
I would find the GIVA program useful in my job.	1	2	3	4	5	استخدامي لهذا البرنامج سيفيد عملي.
Using the GIVA program in my job would increase my productivity.	1	2	3	4	5	استخدامي لهذا البرنامج سيزيد من انتاجي.

If we developed a GIVA software, please indicate the likelihood of your prospective usage of it:

في حال تطوير برنامج للرسم الإسلامي و فق احتياجاتك، ما مدى قابلية استخدامك المتوقعة لهذا البرنامج

Using a scale of 5 to 1, with 5 being strongly agree and 1 being strongly disagree; please circle the appropriate number for each of the following statement.

بإستخدم المقياس من **5 - 1** حيث تكون **5** أوافق جداً ، **4** أوافق، **3** محايد ، **2** لا أوافق و **1** لا أوافق مطلقاً ، الرجاء ضع دائرة حول الرقم الذي تراه صحيحاً أمام العبارات الآتية.

5	4	3	2	1
Strongly Agree	Somewhat Agree	Neutral	Somewhat Disagree	Strongly Disagree

1	2	3	4	5
لا أوافق مطلقاً	لا أوافق	محايد	أوافق	أوافق جداً

Statements						البيان
I intend to use the GIVA program in the future.	1	2	3	4	5	انا انوي استخدام هدا البرنامج في المستقبل
I will always try to use the GIVA program in my work.	1	2	3	4	5	ساحاول دائما استخدام هذا البرنامج في عملي
I plan to use the GIVA program frequently.	1	2	3	4	5	اخطط في استخدام البرنامج في كثير من الاحيان

Thank you for taking the time to complete the questionnaire.

Your contributions to this effort are greatly appreciated.

THANK YOU

شكراً حيث منحتنا الوقت اللازم لإستكمال هذا الإستبيان

مشاركتك تجد مني كل تقدير

APPENDIX B: INTERVIEW QUESTIONNAIRE FOR SEMI-STRUCTURED INTERVIEW

University of Bedfordshire

Interview questionnaire for semi-structured interview

Participant Initials:

Interview length: ----- minutes

About the interviewee

Age: **Gender:**

Profession:

Length of the employment:

Education level:

Date:

Time:

……..

Section 1: Introduction

Thank you for being willing to take part in an interview in this project. Can I first of all assure you that remain completely anonymous and no records of the interview will be kept with your name on them.

In addition to, I would like to ask you for permission to audio record this interview. The main reason behind this recording is to have the set of accurate data – your responses and opinions. In addition to , it will facilitate the analysis of the date we have to conduct during the course of the project.

If you do not have any further question, I would like briefly to introduce you to the subject of this interview.

All questions will be connection with the topic entitled "**The design of an innovative automatic computational method for generating a geometric Islamic visual art with aesthetic beauty**". More precisely, this research is not concerned with right or wrong answers, rather it is concerned with your perceptions and understanding of the representations themselves.

Section 2: Qualitative interview questions:

9. What do you require on the GIVA software? what features would you like to be in the GIVA software?

- Probes:

    ii) What are the features you would like in the GIVA software?

10. What do you think of the spaces between the patterns and shapes?

- Probes:

    ii) Are the spaces too wide, too thin or Just right?

11. What are the distance and size differences between the shapes on this pattern?

- Probes:

    ii) Are the spaces and size differences? What is different about them?

12. What do you think of the colour grading of the patterns? Do they link in any way?

- Probes:

    ii) Do you like the colours on the patterns? Do they match?

13. Is there shape diversity within the pattern?

- Probes:

    iii) Is there a lot of diversity in this pattern?

    iv) are there a lot of different shapes in the pattern?

14. Is the design of this pattern unique?

- Probes:

    iii) Have you seen this pattern before?

    iv) Does it have features that are on other art?

15. Is this pattern complex? If so why?

- Probes:

    iii) Does this pattern look complicated?

    iv) Does it look like it is hard to make?

16. What are your overall perceptions of this pattern?

- Probes:

    ii) What do you think of this pattern? Is it good?

Section 3: Closure

- We seem to have covered a great deal of ground and you have been very patient. But do you think these' anything we have missed out?
- Do you have any other comments about what we have discussed, or about the research as a whole?
- Do you want to see a transcript of the interview?
- We will send you a summary of the research findings some time toward the end of 2018, probably December and you are welcome to have a full copy of the final report too.

Thank you very much for taking the time to talk to me.

APPENDIX C : PERFORMANCE EXPERIMENT OUTCOMES

	Pattern Heads	PC 1			PC 2			PC 3		
		time	CPU	RAM	time	CPU	RAM	time	CPU	RAM
image 1 200*200 px	4 Heads	1.003	11%	10%	1.812	14%	12%	2.011	14%	12%
	8 Heads	1.201	11%	10%	2.223	14%	13%	2.641	14%	12%
	10 Heads	2.031	11%	12%	3.007	15%	13%	3.203	15%	13%
	12 Heads	3.144	11%	13%	4.351	16%	14%	4.902	15%	13%
	Pattern Heads	PC 1			PC 2			PC 3		
		time	CPU	RAM	time	CPU	RAM	time	CPU	RAM
image 2 520*254 px	4 Heads	1.951	11%	11%	2.611	15%	13%	3.416	15%	16%
	8 Heads	2.303	11%	11%	3.32	15%	13%	4.977	15%	16%
	10 Heads	3.661	12%	11%	4.427	16%	15%	5.761	15%	16%
	12 Heads	4.522	12%	11%	5.891	17%	15%	6.192	16%	18%
	Pattern Heads	PC 1			PC 2			PC 3		
		time	CPU	RAM	time	CPU	RAM	time	CPU	RAM
image 3 1024*512 px	4 Heads	2.567	12%	13%	3.019	15%	15%	4.311	16%	17%
	8 Heads	3.674	12%	13%	4.285	16%	16%	5.674	17%	17%
	10 Heads	4.431	12%	14%	5.927	17%	17%	6.291	18%	17%
	12 Heads	5.029	13%	14%	6.377	17%	17%	7.021	18%	17%
	Pattern Heads	PC 1			PC 2			PC 3		
		time	CPU	RAM	time	CPU	RAM	time	CPU	RAM
Image 4 1500 * 1000 px	4 Heads	3.213	12%	13%	4.217	16%	15%	5.229	17%	18%
	8 Heads	4.039	13%	14%	5.083	16%	17%	6.371	17%	18%
	10 Heads	5.676	13%	14%	6.744	17%	18%	7.01	18%	18%
	12 Heads	7.01	14%	15%	7.284	17%	18%	8.021	18%	18%

APPENDIX D : ETHICAL APPROVAL

UNIVERSITY OF BEDFORDSHIRE

Research Ethics Scrutiny (Postgraduate Research Students)

When completing this form please ensure that you read and comply with the following:

Researchers must demonstrate clear understanding of an engagement with the following:

1. *Integrity* - The research has been carried out in a rigorous and professional manner and due credit has been attributed to all parties involved.
2. *Plagiarism* - Proper acknowledgement has been given to the authorship of data and ideas.
3. *Conflicts of Interest* - All financial and professional conflicts of interest have been properly identified and declared.
4. *Data Handling* - The research draws upon effective record keeping, proper storage of date in line with confidentiality, statute and University policy.
5. *Ethical Procedures* - Proper consideration has been given to all ethical issues and appropriate approval sought and received from all relevant stakeholders. In addition the research should conform to professional codes of conduct where appropriate.
6. *Supervision* - Effective management and supervision of staff and student for whom the researcher(s) is/are responsible
7. *Health and Safety*- Proper training on health and safety issues has been received and completed by all involved parties. Health and safety issues have been identified and appropriate assessment and action have been undertaken.

The **Research Institutes** are responsible for ensuring that all researchers abide by the above. It is anticipated that ethical approval will be granted by each Research Institute. Each Research Institute will give guidance and approval on ethical procedures and ensure they conform to the requirements of relevant professional bodies. As such Research Institutes are required to provide the University Research Ethics Committee with details of their procedures for ensuring adherence to relevant ethical requirements. This applies to any research whether it be, or not, likely to raise ethical issues. Research proposals involving vulnerable groups; sensitive topics; groups requiring gatekeeper permission; deception or without full informed consent; use of personal/confidential information; subjects in stress, anxiety, humiliation or intrusive interventions must be referred to the University Research Ethics Committee.

Research projects involving participants in the NHS will be submitted through the NHS National Research Ethics Service (NRES). The University Research Ethics Committee will normally accept the judgement of NRES (it will never approve a proposal that has been rejected by NRES), however NRES approval will need to be verified before research can commence and the nature of the research will need to be verified.

Where work is conducted in collaboration with other institutions ethical approval by the University and the collaborating partner(s) will be required.

The **University Research Ethics Committee** is a sub-committee of the Academic Board and is chaired by a member of the Vice Chancellor's Executive Group, appointed by the Vice-Chancellor and includes members external to the University

Research Misconduct: Allegations of Research Misconduct against staff or post graduate (non-taught) research students should be made to the Director of Research Development.

October 2014

UNIVERSITY OF BEDFORDSHIRE
Research Ethics Scrutiny (Annex to RS1 form)
SECTION A To be completed by the candidate

Registration No: 1121675

Candidate: Marwah Ibrahim

Degree of: PhD

Research Institute: **The design of an innovative automatic computational method for generating a geometric Islamic visual art with aesthetic beauty.**

Research Topic: The Relationship between Corporate Governance Mechanisms and Audit Quality: Jordan Evidence

External Funding: No
The candidate is required to summarise in the box below the ethical issues involved in the research proposal and how they will be addressed. In any proposal involving human participants the following should be provided:

- clear explanation of how informed consent will be obtained,
- how will confidentiality and anonymity be observed,
- how will the nature of the research, its purpose and the means of dissemination of the outcomes be communicated to participants,
- how personal data will be stored and secured
- if participants are being placed under any form of stress (physical or mental) identify what steps are being taken to minimise risk

If protocols are being used that have already received University Research Ethics Committee (UREC) ethical approval then please specify. Roles of any collaborating institutions should be clearly identified. Reference should be made to the appropriate professional body code of practice.

•Special considerations (ethical issues):
The ethical approval of this research will be sought from the Institute for Research Ethics Committee (HREC) at Bedfordshire University, UK. Once I have granted the permission of the HREC to undertake my fieldwork. This is to confirm that the potential participants will be protected from any harm and that their confidentiality will be respected.
•Inform participants about the purpose:
Participants who will take part in survey questionnaire or interview will be fully informed of the purpose, methods, and uses of this research. Potential participants will be provided with an information sheet about the research project.
•Consent form:
Regarding the two phases of this concurrent mixed method design, once the participants read the information sheet and agree to participate in the "questionnaire or interview", they will be asked to sign an Informed Consent Form (ICF). This will inform the person that their details will be confidential and that they can withdraw from the programme at any time. Furthermore, participants will be informed that any data or information used in any publications which arise from this study will be anonymous.

October 2014

Answer the following question by deleting as appropriate:

1. Does the study involve vulnerable participants or those unable to give informed consent (e.g. children, people with learning disabilities, your own students)?
   No

   If **YES**: Have/will Researchers be DBS checked?

2. Will the study require permission of a gatekeeper for access to participants (e.g. schools, self-help groups, residential homes)?
   No

3. Will it be necessary for participants to be involved without consent (e.g. covert observation in non-public places)?
   No

4. Will the study involve sensitive topics (e.g. sexual activity, substance abuse)?
   No

5. Will blood or tissue samples be taken from participants?
   No

6. Will the research involve intrusive interventions (e.g. drugs, hypnosis, physical exercise)?
   No

7. Will financial or other inducements be offered to participants (except reasonable expenses)?
   No

8. Will the research investigate any aspect of illegal activity?
   No

9. Will participants be stressed beyond what is normal for them?
   No

10. Will the study involve participants from the NHS (e.g. patients) or participants who fall under the requirements of the Mental Capacity Act 2005?
    * **No**

If you have answered yes to any of the above questions or if you consider that there are other significant ethical issues then details should be included in your summary above. If you have answered yes to Question 1 then a clear justification for the importance of the research must be provided.

*Please note if the answer to Question 10 is yes then the proposal should be submitted through **NHS research ethics approval procedures** to the appropriate **NRES**. The UREC should be informed of the outcome.

Checklist of documents which should be included:

Project proposal (with details of methodology) & source of funding	Enclosed
Documentation seeking informed consent (if appropriate)	Enclosed
Information sheet for participants (if appropriate)	Enclosed
Questionnaire (if appropriate)	Enclosed

(Tick as appropriate)

Applicant declaration
I understand that I cannot collect any data until the application referred to in this form has been approved by all relevant parties. I agree to carry out the research in the manner specified and comply with the statement of ethical requirements on page 1 of this form. If I make any changes to the approved method I will seek further ethical approval for any changes.

Signature of Applicant:  Date: ...19/10/2016.....

Signature of Director of Studies: ..... Date: ....19.11.16.....

This form together with a copy of the research proposal should be submitted to the Research Institute Director for consideration by the Research Institute Ethics Committee/Panel

Note you cannot commence collection of research data until this form has been approved

SECTION B To be completed by the Research Institute Ethics Committee:

Comments:

✓ Approved

Signature Chair of Research Institute Ethics Committee:

Date: 22/11/16

This form should then be filed on the student's record

If in the judgement of the committee there are significant ethical issues for which there is not agreed practice then further ethical consideration is required before approval can be given and the proposal with the committees comments should be forwarded to the secretary of the UREC for consideration.

There are significant ethical issues which require further guidance

Signature Chair of Research Institute Ethics Committee:

Date:

This form together with the recommendation and a copy of the research proposal should then be submitted to the University Research Ethics Committee

APPENDIX E : INFORMATION SHEET FOR PARTICIPANTS IN SURVEY

University of Bedfordshire

Information Sheet for Participants in Survey

Invitation

My name is Marwah and I am a PhD research student at the University of Bedfordshire, in the UK. I am conducting research on Islamic Geometric Patterns. This sheet provides you with information about my research and invites you to participate in the study.

The title of my study is:

'The design of an innovative automatic computational method for generating a geometric Islamic visual art with aesthetic beauty"

Before you decide to participate in this study, it is important to understand why the research is being conducted and what it will involve. Please take time to read carefully the following information and discuss it with friends and family before deciding whether or not you wish to take part. Please do not hesitate to ask if anything is unclear or if you would like any further information.

1. Purpose of the research

The purpose of this research is to develop an innovative and automatic algorithm for generating geometric Islamic patterns based upon pre-defined rules that guarantee the quality of the produced pattern and which also considers the involvement of aesthetics metrics. Investigation of previous and similar approaches will be conducted in order to understand the limitations.

2. Selection of participants

You have been selected to participate in this study because you met all of the following criteria:

2.1 Inclusion criteria

- Aged 18-and over
- Has experiences more than 3 years in his/ her field (artist, architectural engineers).

3. **Procedures and time involved:**

If you choose to participate in this study, we will provide you with our project package, including an Information Sheet, an Informed Consent Form (ICF), and a Survey Questionnaire. Subsequently, you will be asked to complete a questionnaire, to which there are no correct or incorrect answers. You may answer the questionnaire yourself or you give your responses to the companion who will note them down this is only ,in case if the potential participant is illiterate.

4. **Benefits of participating in this study:**

You will not benefit directly from taking part in this study. The benefit will reflect on the ministry of higher education through developing the new subjects in the curriculum for both undergraduate and post graduate studies. In addition, massive interventions of designs will be added to this art in this field due to the outcome of this study which may be enhanced such designs in diversity places such as mosques, schools houses and public places.

5. **Risks or discomforts of participating in this study:**

There are no risks or personal discomfort anticipated from participating in this study. If you feel uncomfortable with any of the questions, you can leave out that question or withdraw from the study altogether. If you decide to give up at any time before you have finished the questionnaire, your questionnaire will be destroyed.

6. **Anonymity and confidentiality:**

Any information you provide will not be shared with anyone outside of the research team. This information will be kept confidential and will not be released to other parties without your written permission, unless compelled to by law.

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7. **Ethics approval:**

Ethics approval has been sought and acquired from:

- The Research Ethics Committee (REC) at Bedfordshire University, in the UK.

8. **Right to withdraw**

If you decide to take part you are still free to withdraw at any time and without giving a reason..

9. **Compensation**

We will not offer any monetary compensation or other incentives for people who participate in the questionnaire at the first phase of this study.

10. **Participant responsibilities**

Your participation in this study is voluntary. If you choose to participate, the responsibilities to which you will commit are as follows:

- You will be asked to sign the Informed Consent Form (ICF)
- Complete the survey questionnaire (approximately 20 minutes).

Contact detail

If there are any issues regarding this research that you would like to discuss further, please do not hesitate to contact to

Marwah

Email: marwah.ibrahim@study.beds.ac.uk

Dated: 1 October 2016

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APPENDIX F : INFORMED CONSENT FORM FOR QUANTITATIVE STUDY



University of Bedfordshire

Partic [0 0 0] tification Number:

Informed Consent Form for Quantitative study

Title of study: "The design of an innovative automatic computational method for generating a geometric Islamic visual art with aesthetic beauty"

	Please
1. I confirm that I have read and understood the research Information Sheet for the above study.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time.	☐
3. I understand that only the above researcher, Mrs Marwah and her supervisory team from the University of Bedfordshire, will have access to the data that I provide.	☐
4. I understand that any data or information used in any publications which arise from this study will be anonymous.	☐
5. I consent voluntarily to take part as a participant in this research.	☐

Signature of Participant Date

Name of Researcher Signature of Researcher Date

Dated: 1 October 2016

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APPENDIX G: INFORMATION SHEET FOR PARTICIPANTS IN INTERVIEW

University of Bedfordshire

Information Sheet for Participants in Interview

Invitation

My name is Marwah and I am a PhD research student at the University of Bedfordshire, in the UK. I am conducting research on Islamic Geometric Patterns. This sheet provides you with information about my research and invites you to participate in the study.

The title of my study is:

'The design of an innovative automatic computational method for generating a geometric Islamic visual art with aesthetic beauty"

Before you decide to participate in this study, it is important to understand why the research is being conducted and what it will involve. Please take time to read carefully the following information and discuss it with friends and family before deciding whether or not you wish to take part. Please do not hesitate to ask if anything is unclear or if you would like any further information.

1. Purpose of the research

The purpose of this research is to develop an innovative and automatic algorithm for generating geometric Islamic patterns based upon pre-defined rules that guarantee the quality of the produced pattern and which also considers the involvement of aesthetics metrics. Investigation of previous and similar approaches will be conducted in order to understand the limitations.

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2. Selection of participants

Eligibility criteria for participating in the semi-structured interviews:

Being selected as an interviewee in this study, as a potential participant you should be expert in Islamic Art.

3. Procedures and timescales

Participant will be provided with the Information Sheet, an Informed Consent Form (ICF), and then you will be asked to participate in an interview with the researcher, lasting approximately 30 minutes.

4. Benefits of participating in this study

You will not benefit directly from taking part in this study. The benefit will reflect on the ministry of higher education through developing the new subjects in the curriculum for both undergraduate and post graduate studies. In addition, grand interventions of designs will be added to this art in this field due to the outcome of this study which may enhance such designs in diverse places such as mosques, schools houses and public places.

5. Risks or discomforts of participating in this study

There are no risks or personal discomfort anticipated from participating in this study. If you feel uncomfortable with any of the questions, you can leave out that question or withdraw from the study altogether. If you decide to opt out at any time before completing the questionnaire, the questionnaire will be destroyed.

6. Anonymity and confidentiality

Any information you provide will not be shared with anyone outside of the research team. The data will be kept confidential and will not be released to other parties.

7. Ethics approval

Ethics approval has been sought and acquired from:

The Research Ethics Committee (REC) at Bedfordshire University, in the UK.

8. Right to withdraw

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Participation in this study is completely voluntary. You are free to withdraw at any time without giving an explanation.

9. Participant responsibilities

Your participation in this study is voluntary. If you choose to participate, the responsibilities to which you will commit are as follows:

- You must currently work as member of staff at the Art faculty
- You will be asked to sign the Informed Consent Form (ICF)
- You will be asked to participate in a semi-structured interview, lasting approximately 30 minutes.
- **Contact detail**
- If there are any issues regarding this research that you would like to discuss further, please do not hesitate to contact to

Marwah

Email: marwah.ibrahim@study.beds.ac.uk

Dated: 1 October 2016

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APPENDIX H: INFORMED CONSENT FORM (ICF) FOR QUALITATIVE STUDY



Participant Identification Number: ☐

Informed Consent Form (ICF) for Qualitative Study

Title of study: "The design of an innovative automatic computational method for generating a geometric Islamic visual art with aesthetic beauty"

Please

- I have been informed of and understand the purposes of the study. And I understan the interview will last approximately less than one hour. ☐
- I understand that my participation is voluntary and that I can refuse to answer certain questions. ☐
- I am aware that in order to facilitate the research, the interview will be recorded using a digital voice recorder, transcribed by the researcher and subsequently translated by certified Saudi translators. ☐
- I am informed that completely interview data will be dealt with securely in order to protect participant confidentiality. I understand that anonymity will be ensured in the thesis by disguising my identity; no names will be mentioned and the data will be coded. ☐
- I understand that disguised extracts from my interview may be quoted in the thesis and any subsequent publications. ☐
- I understand that the researcher, Marwah, and her supervisory team will access the information I will provide. ☐
- By signing below, I agree to participate voluntarily in this research study (without coercion). ☐

Signature of Participant Date _____

Name of Researcher Signature of Researcher Date _____

Dated: 1 October 2016

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