

**Maintaining Cultural Identity in Design: Shape Grammar
as Means of Identifying and Modifying design Style**

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Abstract

This research is an attempt to find an objective system for maintaining cultural identity in design. The proposed framework will guide interior designers to identify the key features and design language of their traditional style, and then to modify it to give more variety to the developed style and to help it keep pace with fast developments in the field of design.

This work came from the need to find a solution to the fact that there is a lack of cultural identity in the field of design such as those of furniture, decor and facades, in particular in the state of Kuwait. The lifestyle of the people of Kuwait has changed dramatically since oil was discovered, the lifestyle of its people has changed dramatically. The development of its economy have resulted in a more wealthy and up-to-date society. Such a transformation was not imposed on them, but was rather their choice. The problem is not in modernisation, but in the rush towards it without comprehending its consequences.

There is no doubt that the traditional crafts are an important source of inspiration when generating new ideas, but what if the process of generation leads to cliché designs? The focus of this research involves the analysis of a popular traditional Kuwaiti product called Sadu.

Style in art and architecture is measured in terms of consistency over a series of artifacts which can be recognised through the similarity between them. The aim of this research is to create a link between consistency in style and the Kuwaiti style, and it does this by dividing the work into three sections, each with an associated milestone. The first employed focus groups to identify the Kuwaiti style. The results of the test clarified the most common features of geometric shapes and symmetry rules among the Sadu products that directly influence the approach which the study proposes. Then the shape grammar method was adopted as a means of identifying the Sadu design language.

The second section developed the traditional style using knowledge gained from the first step as a means of generating new designs. Seven design groups were created, each with a unique approach to creating patterns. The groups were tested to evaluate whether that the new designs had not lost their original identity, and to identify which method produces the most

recognisable patterns of the Kuwaiti Sadu style, and what are the common rules in the seven groups that successfully generate this Kuwaiti style. Also the test measured the likability of the design group amongst Kuwaitis.

In the final section, a design tool was created which incorporated features inspired by the data and evidence gathered throughout the study. The tool was then tested and evaluated to measure the consistency of the patterns it produced with the Kuwaiti cultural style. The tool produces inspirational designs that can be used for architecture or product design that has a theme of cultural identity, such as furniture, illumination, flooring and plan layout.

Methods of developing a Kuwaiti style whilst at the same time maintaining its original identity have been presented. The key to developing the original style was firstly to measure it by identifying the common style features. Sadu was used as a case study as this was deemed an iconic representation of traditional Kuwaiti style. Specific geometric shapes and symmetry rules were established among the tested designs and these features were found to capture the essence of the original style. Shape grammars were applied to explore the style and the results produced a set of rules that were indicative of that style. In the second step, Kuwaiti Sadu was developed by shape grammars and the common rules of the established style were augmented with new rules that would produce recognisable and likable patterns which were still of the Sadu style. The degree to which these were recognised and liked by a sample of Kuwaiti people was tested. The end stage of this research was to develop a software tool with features established from the data gathered in the previous stages that produced consistent Sadu patterns so that Kuwaitis and non-Kuwaitis would be able to produce designs that maintain the original style. The framework and design tool that were used to develop a traditional style proved to be successful. These were used to generate 2D developed style designs that were translated into 3D models, through action research from an interior designer. These were found to emulate the Kuwaiti style.

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Researcher's declaration

I declare that the work in this thesis was carried out in accordance with the regulations of Bournemouth University. The work contained in this thesis is the result of my own investigations and has not been accepted nor concurrently submitted in candidature for any other award.

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the University or other academic or professional institution.

Signature of Candidate: Abdulaziz Alsallal

Date: 07/07/2012

Type of Award: Doctor of Philosophy.

School: School of Design, Engineering and Computing.

1 Introduction

1.1 Background to the topic

This study is a continuation of a work started during an MA degree in interior design entitled “Colour and pattern as elements in the revival of Kuwait’s lost identity in interior design”. The aim of the research was to prove that there is an existing problem that needs to be solved in the built environment in the state of Kuwait, and also to find acceptable solutions to the process of combining artistic traditions with new products used in interior design.

The findings of the survey revealed that there is a lack of identity in the built environment in Kuwait, in particular in domestic designs such as those of furniture, decor and facades. They also helped to present a number of solutions for transforming traditional design to a more domestic feel with colour and pattern as the media for this transformation (see figure 1.1).



Figure 1.1: Deriving patterns and colour schemes from cultural Kuwaiti products and using them on walls, sofas and flooring to transform formal designs into traditional designs.

One of the conclusions of the MA thesis was that the study had addressed Kuwaiti culture and its revival from a certain angle - formation rather than development - where cultural elements (colour and pattern) are used and integrated into designs in their current form. It was proposed that an advanced study be undertaken to analyse the cultural features in depth, to understand how Kuwaiti style can be identified and measured. It is from these roots that the idea for this research project developed.

This research proposes methods which could assist interior designers in understanding the principles of their heritage of features, and to maintain their cultural identity. The design language which is represented in the traditional crafts are used to revive Kuwait's lost identity in the field of design by identifying the Kuwaiti style, then using the shape grammar to develop that style.

1.1.1 Research problem

In the middle of the twentieth century, following the discovery of oil and the accompanying changes in living standards for Kuwaiti citizens, there was a conflict between localisation and globalisation in the fields of the built environment and interior design. People began to adopt a more global stance towards design to the extent that the Kuwaiti identity became almost extinct. This transformation was a result of the sudden wealth and the desire of the Kuwaiti people to improve their standard of living and join the developed, modern world. As thoroughly documented by Saba George, "planning and construction of the modern city-state of Kuwait 50 years ago was a dramatic urban revolution that swept over Kuwait as a hurricane, leaving one dizzied and dazzled in its wake. ... Kuwait literally exploded from a small village to a fast-urbanizing regional metropolis in just over 12 years" (Shiber, 1964). Such a transformation was not imposed on them, but was rather their choice. The problem is not in modernisation, but in the rush towards modernisation without comprehending its consequences.

Culture is not, as it was in the past, subject to traditional publication and dissemination. It became largely affected by technology. Technology created cultural invasion and became the dominant power and the means of culture transmission. Culture is transferred by technology

and technology can disseminate the culture it desires. As Paul Oliver said: " the transmission of cultural forms across time and space is not a new phenomenon. The migration of people, political and economic hegemonies, and the impact of key individual thinkers, have all at time influenced the dissemination of culture. But this cultural dispersion has often been slow, and been limited by geographical and political boundaries. The significance of globalisation is that it has enabled cultural transmission to take place on a scale which would not be conceivable without contemporary technological infrastructures" (Cullingford & Gunn, 2005).

Attempts have been made to develop cultural products such in Figure 1.2, which illustrates modern bags inspired by traditional designs. The patterns were taken in their current visual form from cultural products such as Sadu and placed on the new wares. This process lacks an understanding of the design principles of the cultural style features and cannot explore the design language presented in the traditional crafts.



Figure 1.2: On the left-hand side is a handmade bag from the pre-oil era in Kuwait (before the 1950s). On the right-hand side is a recent bag inspired by the previous design.

1.1.2 Measuring the style

To maintain a cultural identity, the style of that culture has to be determined. This can be achieved by studying the features which reflect certain types of characteristics that illustrate cultural circumstances and social aspects. As Chan says, “historically, a style is identified by recognisable features (forms) that appear in certain products created by one person, by a group of persons, across some geographical areas, or through a period of time” (Chan, 2000). No doubt, the identity of a country lies in its people’s attachment to their traditional crafts and culture. Thus, the disappearance of the traditional crafts leads to the loss of the country’s heritage. Therefore, this study included an analysis of popular traditional Kuwaiti products known as Sadu.

1.1.3 Shape grammar

The design language of Sadu were analysed by investigating the shape grammar of that style. As Knight says, “defining a shape grammar in terms of the revived style is certainly the easiest and the most profitable means for exploring all possible variation within this style” (Knight, 1981).

A shape grammar is based on a vocabulary of shapes, a set of spatial relations defined by shape rules, and an initial shape made up of the shapes in the vocabulary. Stiny stated that “generation processes can be modelled on the transformation of shapes. Shape grammars are applications in which shapes are represented as design descriptions and transformed according to a role-based formalism” (Stiny, 1980).

A well defined shape grammar is able to capture the essence of a style, and encode it into a language of shapes. The constructional features of a style are denoted as a set of rules. A strong sense of style can be generated by repeatedly using certain rules and by applying rules in a consistent manner throughout the production process.

1.1.4 Summary

As mentioned previously, these two axes (style and shape grammar) are the main topic of the Literature Review. They were related to Kuwait and, in particular, the field of design (see figure 1.3).

The work is divided into three steps:

1. Measuring Kuwaiti style, which has two parts:
 - Determining the common features of traditional products.
 - Analysing the language of design.
2. Modifying the style; methods were used to generate patterns based on the analysed language of design. Then measurements of Kuwaitis response were statistically analysed to determine which group of developed patterns maintains the original identity, and which group made the Kuwaitis satisfied and willing to buy these patterns if applied to products (wallpapers, fabrics, rugs, flooring, and so on).
3. Developing a design tool, which produces different and consistent patterns.

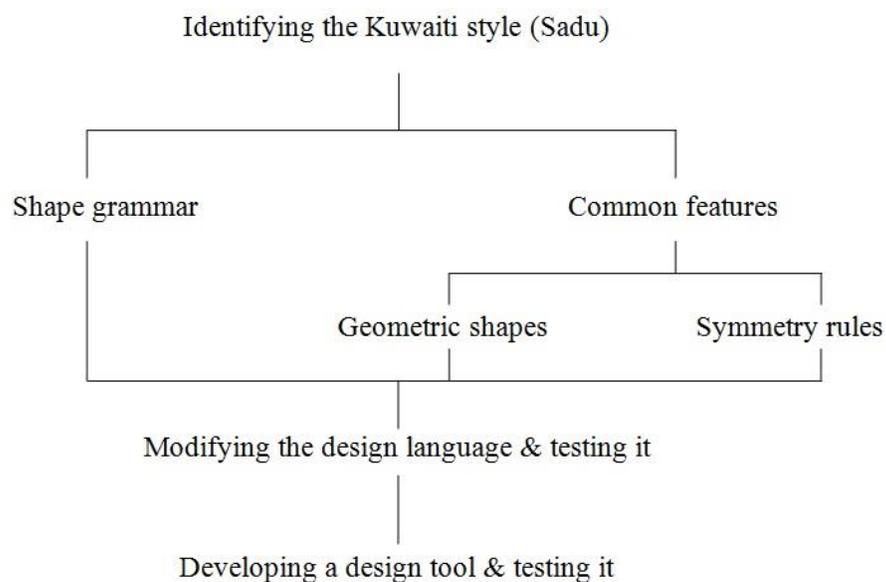


Figure 1.3: Methodology for the research process.

1.2 Aims and objectives

The aim of the research is to help designers to understand the principles of their heritage of features, and to maintain their cultural identity, and re- introduce it to the world in a form that matches the fast development in the field of design. Also of interest are the strategies that designers use in order to achieve success when developing and maintaining a constant style statement. The main objectives are:

- i. Identifying initial shapes and symmetry rules in traditional Kuwaiti products using the focus group method.
- ii. Exploring the spatial relationship in the designs by analysing the shape rules which construct that spatial relation.
- iii. Modifying the identified shape rules to create new spatial relations.
- iv. Using shape grammar method to generate a new language of design.

1.3 Research methodology

1.3.1 Primary research

A mixed method has been applied in this study, gathering data from a focus group and also from the formulation and analysis of a questionnaire survey. The research has a syntactic approach, which means that in-depth analysis has to be undertaken with regard to the shape grammar and common features of Sadu to identify the design language and style of Kuwaiti traditional products.

1.3.2 Secondary research

The secondary data was mainly been collected from the literature review. Other elements were gathered from reference books and journals which are related to the topic. Some electronic resources, such as e-journals and e-books, were also be used.

1.4 Research structure

In brief, the report will be structured as follows:

Chapter one: introduces the background to the research as well as the aims and objectives, and presents the methodology used in this thesis.

Chapter two: this is the main review; it includes sections on shape grammar, style, Kuwait's origins and one of the traditional crafts.

Chapter three: discusses the research methods, including primary and secondary data collection, the scope of the research, its limitations and problems.

Chapter four: deals with identifying style; exploring common features and shape grammar in traditional products.

Chapter five: looks at modifying style; proposing methods to develop the Kuwaiti style and testing the output to measure its recognition and likability among Kuwaitis.

Chapter six: discusses the creation of the design tool, and testing it to measure consistency in the developed patterns.

Chapter seven: a summary of the findings and conclusion.

2 Literature review

2.1 Introduction

This chapter describes the material used to establish a method of maintaining cultural identity in design. The covered topics were categorised into two themes: cultural identity and style.

Section 2.2 begins by presenting the definition of cultural identity and how it is shaped by the background of the people. It applies this concept to the origins of cultural identity in the State of Kuwait, compares old and modern Kuwait, and scopes the problem of future loss of identity in the design field. It also explores one of the traditional Kuwaiti crafts which inspired this research.

Style is presented in section 2.6 which clarifies concepts and definitions such as ‘measuring a style’ and ‘shape grammars’. The contribution of the measuring a style approach to exploring how traditional style can be analysed in terms of design elements (geometric shapes) and rules (symmetry) is discussed. Finally, the shape grammar method for defining the language of design is reviewed.

2.2 Defining cultural identity

In recent years, a form of identification has been established in which the individual as a whole can be broken down into a series of cultural identifiers. These include: location, gender, race, history, nationality, language, religions, beliefs, ethnicity, aesthetics and so on.

Also the culture of a nation comprises many aspects. It is moulded by the background of its people, their languages and beliefs. The anthropologist Edward Hall described culture as an unseen but powerful force that holds everyone captive: “Culture is not an exotic notion studied by a select group of anthropologists in the South Seas. It is a mold in which we all are cast, and it controls our lives in many unsuspected ways” (Hall, 1959).

Defining a national identity is not an easy task, especially if it is a nation made up of many cultural groups, with many different customs and traditions. As for the State of Kuwait, although the original citizens were groups which came from different places, such as Najd (Saudi Arabia), Iraq and Iran, with different backgrounds, they managed to unite and form strong bonds because the society was small. In the eighteenth century, this enabled them to develop their own new identity.

In all countries, there are influential factors that have an impact on cultural identity, and which lead either to its modification or replacement, and these factors vary from one country to another. The State of Kuwait is no exception, in fact there was one main reason for its dramatic change in the middle of the twentieth century, and that was the discovery of oil.

In order to appreciate the rate of change in Kuwaiti culture, its origins are explored below and a comparison is made with the modern-day State. What concerns us in this comparison are the changes in the population which evidence the fact that a method is needed to maintain the cultural identity, and to control changes in the built environment. This is the field of investigation to which the techniques for maintaining cultural identity will be applied.

Cultural practices, especially the purposeful making of things, embody the values which contribute to an individual and collective sense of identity and citizenship. The goal of the research is to use these traditional products as inspiration for creating new ideas that can be used in the built environment, embedding traditional features and maintaining a constant style statement. The problem, as Hall said, is that “culture hides much more than it reveals, and it hides most effectively from its own participants” (Hall, 1959). This is the role of this study; to investigate one of Kuwait’s popular traditional products, to link it to other studies that have measured style, then to focus on developing it to show the new generation of Kuwaitis and designers that there is still beauty in the traditional style but all that is needed is to develop and make it more suitable for modern use without losing its cultural identity.

2.3 General information about Kuwait

2.3.1 Origins of Kuwait

The whole of the eastern side of Kuwait overlooks the Arabian Gulf (Persian peninsula) and, since early times, there have been many ports along this coast. Goods from India and Yemen would arrive here, and were then transported west, to Najd (in the middle of Saudi Arabia) and surrounding towns. The sea has always been one of the factors which influence population in this part of the Arabian Gulf (see figure 2.1).



Figure 2.1: Gulf countries.

The eastern coast of the Arabian Gulf came under the authority of the Bani Khalid tribe after they overcame the Othman governor in the Al Ahsa area. They ruled the coast between Kuwait in the north and Qatar in the south, and all villages along this stretch fell under their control. One of these villages was known of Al-Qurain, or Kuwait, which at the beginning of the seventeenth century was a barren land whose inhabitants were dependent on the sea, fishing and diving for pearls.

During that period, one of the chiefs of the Bani Khalid established a small fort overlooking the coast (Al-Qurain). It was used as a store in which he preserved his supplies and ammunition, and as somewhere where he could take a rest in the good pastures nearby. The fort was named 'kūt', and it became the nucleus of the state that is today known as Kuwait.

From another quarter, at the end of the seventeenth century, a group of Arab tribes emigrated, in an escape from drought and famine, from the middle of Najd to the eastern coast of the Arabian Gulf. A group of them, called the Al Otob, settled in Qatar and pursued a life which was dependent upon the sea. They became divers, fishermen and ship manufacturers, picking up their maritime knowledge from the people around them in Bahrain, Oman and along the Arab coast.

Qatar at that time was under the reign of Al Musallem. Over the course of time, there was a disagreement between the Al Otob and Al Musallem, and the Al Otob were obliged to leave Qatar; according to local stories they sailed north. Opinions vary, but one view is that “the Al Otob reached Al Basra in Iraq in the year 1701, with 150 sailboats, and settled near the entrance to the Arab coast” (Slot, 1991). The ruler of Al Basra, Ali Basha, wanted to allow them to stay there so that he might benefit from their commercial and marine experience, but he could not convince the Ottoman empire that this was a good idea. Forced to leave because they were blocking the route for caravans and boats approaching the Arab coast, they sailed south to Al-Qurain, which was outside Ottoman sovereignty. The Bani Khalid welcomed the Al Otob to Al-Qurain because of the enmity between the Bani Khalid and the Ottoman authorities, and they allowed them to stay.

When the Al Otob reached Al-Qurain, they found it to be a small marine environment, the inhabitants of which resided around Al kūt. They settled into the area and their lives were linked to the sea like those of the original people of Al-Qurain. As the strength of the Bani Khalid decreased, the Al Otob grew into a position of strength in Al-Qurain and eventually became its governors.

In 1764, when Kuwait has ruled by Sheikh Abdullah, son of Sabah the first, the Kuwaiti people entered the first marine armed battle in their history, the battle of Al Regga. The maritime knowledge of the Kuwaiti people, and their small efficient ships were of great benefit in their victory over the Bani Kaab (Alreshiad,1926).

At the beginning of the nineteenth century, when Kuwait was under the reign of Sheikh Gaber the first, trade began to flourish to the extent that Kuwaiti ship manufacturers adopted the manufacture of ‘Al Baghla’ and ‘Al Batil for commercial transport (see figure 2.2). This was a

great turning point in their commercial and marine capabilities. They used these ships to reach the coasts of India and Yemen to transport goods in and out without any need to depend on the port of Muscat for commercial mediation. In 1816, the English explorer Buckingham described Kuwait port as “great”, and mentioned that its traders were dealing with other nations of the Gulf. He also wrote that the sailors of Kuwait were experienced and brave. Their ships numbered around one hundred and varied in size from small to large. At that time, Buckingham described the transportation of Arabic horses from Kuwait to India as brisk.

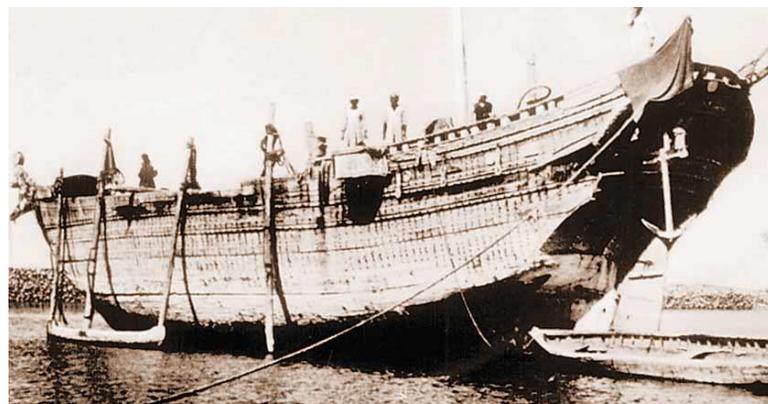


Figure 2.2: Albaghla (Alqabas, 2011).

Captain Brooks said in his 1829 report: “Kuwait was the main supplier of wheat and coffee in addition to other necessary products to northern and middle of Najd, they had 15 ships from the kind of ‘Al Baghla’, its cargo around between 100 to 400 tones, in addition to a lot of other ships that were used in diving, fishing, its number reached to 170 ships” (Alreshiad,1926).

He mentioned that Kuwait was exporting pearls, horses, and natural fats, and its ships travelled to the Indian and Red Sea harbours.

Also the famous English explorer William Palgrave who visited the Gulf area in 1862-1863 touched on the reasons for its fame. “Kuwait possesses a big harbour, which is considered the most suitable harbour in the Gulf for ships anchorage, and the low charges of tariffs on these different goods that come to this harbour. Moreover, the politeness of the Kuwaiti people to the newcomers” (Alturky, 1997).

In 1918, the people of Kuwait numbered 85,000, and in 1920 there were 900 ships. Kuwait was importing cloth, wood, rope, tea and spices from India whilst bringing in wood from eastern Africa that was used to roof its houses. Its traders were established importers of different materials from the two areas for ship building. Kuwait's approach to trading was to transport different goods on its commercial ships to and from India and Eastern Africa and to sell or barter for other goods throughout the journey. Moreover, the Kuwaiti people had a relationship with the Bedouin of Najd, who came to Kuwait to barter their sheep, sheep's milk, wool and other products in exchange for food and cloth.

Old Kuwait city was surrounded by a wall built in 1920. The wall had seven gates and protected the residents from outside attack (see figure 2.3).



Figure 2.3: The Kuwait wall.

2.3.2 Geography and weather

Kuwait is to be found at the north-western tip of the Arabian Gulf, bordered by Saudi Arabia to the south and Iraq to the north and west. It is approximately 17,820 sq. km in size and is almost entirely flat desert plain.

It has a desert climate and is hot and dry. In summer, high average daily temperatures range from 42 to 46 °C (see figure 2.4); the highest ever temperature recorded in Kuwait was 53.5 °C

at Kuwait International Airport on August, 2011. The lowest official temperature recorded was $-6.1\text{ }^{\circ}\text{C}$ at Kuwait City in January 1964 (Wikipedia, 2012).

Climate data for Kuwait													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	18 (64)	21 (70)	26 (79)	31 (88)	38 (100)	43 (109)	43 (109)	44.5 (112.1)	41 (106)	35 (95)	26 (79)	19 (66)	32.1 (89.8)
Average low °C (°F)	7 (45)	9 (48)	13 (55)	18 (64)	24 (75)	27 (81)	29 (84)	28 (82)	24 (75)	19 (66)	13 (55)	8 (46)	18.3 (64.9)

Figure 2.4: Monthly temperature in Kuwait (Weather, 2012).

2.3.3 Religion and language

“The first language for Kuwaitis is Arabic (official) and English is also widely spoken” (State, 2012). “Islam is the state religion, under the Constitution, Shari ‘a (Islamic law) is a main source of legislation” (Kuwait research group, 2000). Of the country’s total population of 3.6 million, approximately 85% are Muslims, including nearly all of its 1.18 million citizens. Among expatriates, there are an estimated 450,000 Christians, 300,000 Hindus, 100,000 Buddhists, 10,000 Sikhs, and 400 Bahai (State, 2012).

2.3.4 Currencies in Kuwait

Kuwait used many currencies in its commercial transactions with the surrounding area and more distant lands; these included the Golden Ottoman Lira, the English Pound, Austrian Schilling, the Iranian Guran and the Indian Rupee (see figure 2.5). Kuwaiti people agreed among themselves the exchange value of these currencies. It was likely that Kuwait used all of them at the same time and showed no preference for one over another. The situation changed after World War I, which witnessed the limitation of Ottoman sovereignty over the area and pushed Kuwaiti traders to prefer the Indian Rupee, unintentionally halting the use of other

currencies. This was partially a result of inherent relations between Kuwait and India, and the spread of this currency among surrounding Arabian Gulf emirates.



Figure 2.5: Currencies used in old Kuwait.

Usage of the Indian Rupee in Kuwait continued from that time until April 1959. At the same time, Kuwaiti officials devoted themselves to studying the monetary laws of different countries, with the help of international experts. By the end of 1959, they had reached the conclusion that they needed to issue a private local currency.

“Kuwaiti monetary law No. 41, of 19 Oct 1960, was issued to regulate the process of issuing a new Kuwaiti currency, the Kuwait Dinar” (Alturky, 1997). Immediately after issuing a Kuwaiti monetary fund, it was decided to withdraw the Indian Rupee from circulation in Kuwait. These were returned to the Indian government pursuant to an agreement that was entered into after negotiations between the governments of both Kuwait and India in March 1961, and the beginning of using the Kuwaiti Dinar in April 1961 (see figure 2.6).



Figure 2.6: The first Kuwaiti Dinar.

In fact the idea of issuing a local currency in the 1950s was not the first time this had been suggested. Kuwait had issued a private local currency more than a century previously in 1866,

in the reign of Sheikh Abdullah Al Sabah the second. It was a brass currency with the name Kuwait engraved on it together with the date of issuance. It did not last for long and was withdrawn from circulation.

2.4 Comparison between pre-oil and modern Kuwait

The lifestyle of the people of Kuwait has changed dramatically since oil was discovered, with oil bringing a change to the country's economy and to the way people lived their lives in a more modern, prosperous society. Cities are trapped between foreign and local forms of cultural identities, however, as a result of resurgence and the influence of globalisation. The implication of this is continued loss of urban heritage and local identities. One of these cultural identities that faced a major transformation in Kuwait is the built environment. Changes in population over the years are discussed below to demonstrate the size of the need to preserve the cultural identity before it is lost.

2.4.1 Built environment

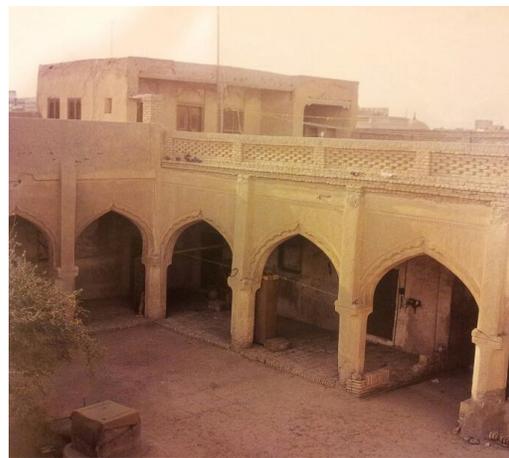
There is a profound difference in aesthetic style between traditional and modern Kuwaiti houses and the huge new construction developments. There was a consistency in the style of buildings in the old Kuwait city because the materials used for construction were mostly natural, and included mud, rock, palm tree trunks, and nails. Building materials were brought either by land or sea, or imported from abroad. As Ayyob describes it "Men of Kuwait travelled to India, Persia, and African countries where they learnt the art of building and interior design and merged it with their heritage to develop their own art in the built environment" (Ayyob, 1998).

Houses of the past were of a particular design. The courtyard was in the middle of the house, overlooked by all of the rooms. Almutawa explains this layout saying: "In that architectural design, the courtyard ventilated the house to find it cool at night and after sunset. This was due

to the exchange of radiation between the floor of the courtyard and the outer space” (Almutawa, 1994). Walls were built of rock and mud, and decorated internally with white gypsum, and they were high to ensure privacy. The ceilings consisted of rows of trunks, bamboo and straw mats, covered with a 30cm or a 40cm layer of mud. Columns in the courtyard had a sense of beauty and were decorated with Islamic or botanical drawings (see figures 2.7a, b, and c).

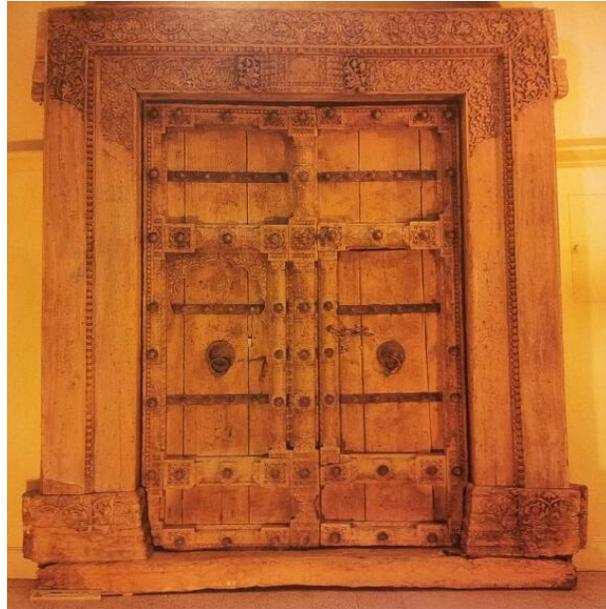


Figure 2.7a: Kuwait traditional house (t3as, 2008).



Figures 2.7b, and c: Kuwait traditional house (Tareq, 2005).

“Doors used to be made from wood imported from India. Whether cheap or expensive, the doors were distinguished by their particular shape. The large heads of the nails were visible on the surface of the door to give it both strength and beauty. Doors in general were characterised by large wooden locks” (Ayyob, 1998) (see figure 2.8).



Figures 2.8: Traditional door (Tareq, 2005).

The above are examples of characteristics of the Kuwaiti heritage in interior design and the built environment. They can still be seen in Al-Qattami House, which the government has turned into a museum of national heritage.

As for the built environment found in Kuwait today, it is a product of the decisions made during the early stages of planning and construction after the discovery of oil. Comprehensive documentation by Saba George says that: “planning and construction of the modern city-state of Kuwait 50 years ago was a dramatic urban revolution that swept over Kuwait as a hurricane, leaving one dizzyed and dazzled in its wake. ... Kuwait literally exploded from a small village to a fast-urbanizing regional metropolis in just over 12 years” (Shiber, 1964).

After the discovery of oil, the rulers of the country entered into contracts with British companies for planning of the new Kuwait City which was to make use of the best designs and building materials. However, prior to the execution of this project, the government purchased

the houses from their owners in preparation for demolition of the old Kuwaiti fence and traditional houses to provide land for building modern Kuwait City (see figure 2.9a and b). The Kuwaiti people headed towards the Western style neighbourhoods provided by the government.



Figure 2.9a and b: Demolition of the old Kuwaiti houses (Tareq, 2005).

Modern and international styles in interior design were introduced to the State of Kuwait in two ways. The first was the importation of large projects designed by Western companies without setting any economic or technical limitations on design (for example, banks, hotels, ministries). The role of local designers was very limited due to their lack of expertise in managing and designing such large projects.

The second way in which international designs were introduced to the State of Kuwait was when engineers and designers from other Arab and foreign countries (Egypt, Iran, India, Iraq and Syria) came to Kuwait due to the availability of work opportunities. Naturally, they brought with them different design styles from their homelands, and new ideas that were positively received in Kuwait. The citizens obtained the help and advice of such specialists in building their houses where there was no law constraining the aesthetics of the styles. That, during the sixties and seventies, was the beginning of the loss of Kuwaiti identity in the built environment, and it continues to this day.

The arrival of this new attitude in design has significantly shaped the appearance of Kuwait cities, leading to a loss of Kuwaiti identity. Nevertheless, there is a clear need for Kuwait to build new cities in the future to accommodate the demands of its dramatically increasing population. The public authority for housing welfare is in charge of providing Kuwaitis with land to build their houses. Projects such as Almetla'a City which will have 25,000 houses and Alkheran City which will have 35,530 houses (PAHW, 2012) are plans that the government is currently working on and which should be completed in the near future. These and other long term projects, like the Silk City, mostly adopt the use of modern, international materials and styles of design, making use of glass, curtain wall construction and concrete (see figure 2.10).



Figure 2.10: Future dream of Kuwait Silk City (E-architect, 2012).

This transformation is also applied to the interior design of Kuwaiti houses and commercial spaces (see figure 2.11a and b). Manuel Castells claims that cultural identity is not something that originally existed, that is now threatened by globalisation. Instead, he says, there is a dual shaping approach, linking both nations: “Our world and our lives are being shaped by the conflicting trend of globalisation and identity” (Castells, 2010). So focusing only on the manufacture and import of different international interior design styles in the State of Kuwait generates disorder in the identity of a country and makes Kuwaitis forget about their past. There is no fault in heading toward international designs and global trends, but there must be a

balance between globalisation and cultural identity, by providing a market that contains the successful alternative of the traditional style which is characterised by consistency, to match the demands of the local people and at the same time compete with the global market. A more formed and structured, detailed analysis of the Kuwaiti design style is required. This is in order to establish fundamental style features from which to generate new, emulated designs that retain the Kuwaiti style identity.



Figure 2.11a and b: Sample of the interior design styles in Kuwait today (Omarker, 2011).

2.4.2 Population

Since 1965, the population of Kuwait has been increasing significantly. According to an annual Statistical Abstract produced by the Ministry of Planning in 2007 (Central Statistical Office, 2007) which compared changes in population every 10 years from 1965-2005, in 1965 the population was 467,339, with a density of 26.2 residents per km². In 1975, this number had grown to 994,837 and the density doubled to 55.8. Approximately half of the people living in the country at this time were non-Kuwaitis. The population density in 1985 reached 95.3 residents per km² and the total population climbed to 1,697,301 million, of which 470,473 were Kuwaitis and 1,226,828 non- Kuwaitis.

In 1995, with the invasion of Kuwait by Iraq, the population density fell to 88.4 residents per km², at which point there were 1,575,570 residents; 653,616 Kuwaitis and 587,101 non-Kuwaitis. The non-Kuwaiti population was more than halved in 1995 compared to a decade earlier. Then, by 2005, its population again increased massively to 2,410,829, made up of 944,758 Kuwaitis and 1,446,071 non-Kuwaitis.

Another statistical Abstract produced by the Ministry of Planning on the labour force in Kuwait shows that employment is dominated by non-Kuwaitis. In 2001, 1.214 million of Kuwait's population were gainfully employed, with the majority of Kuwaitis working for the government (almost 93%), and most non-Kuwaitis (90%) in non-government rolls. By December 2006 the population of 3,182,960 comprised approximately 1 million Kuwaiti citizens and 2 million non-Kuwaitis. Labour force statistics for 2004-2008 indicate that "the Asian countries come first, followed by the Arabic countries, North America, the European countries, the African countries, Australia and New Zealand, and then the South American countries" (The Ministry of Planning in Kuwait, 2007 and 2008). By 2011, the population of Kuwait had increased to 3,697,292, made up of 1,183,185 Kuwaitis and 2,514,107 non-Kuwaitis.

It can be seen from the above that the population of Kuwait, which has only a small land mass, has expanded rapidly. In 2006, there were twice as many non-Kuwaitis as Kuwaitis and this had an inevitable impact upon the country, not least in terms of its cultural identity. Kuwaitis need to take steps to ensure that they retain their culture, especially in the field of design.

2.4.3 Handicrafts in Kuwait

Old Kuwaiti society was full of handicrafts that were linked to the history and nature of the country and which emerged to fulfil its needs. Handicrafts were linked to the Kuwaiti dependence on pearls, fishing and travelling for trade. The state was famous for ship and boat manufacturing and these were the tools used by the Kuwaiti people to establish their position not only in Kuwait but in the whole of the Gulf area. The people were concerned with the manufacturing of fishing nets as much as with ship building, and they produced many shapes and kinds of net. In addition to these crafts, there were numerous others including the products

of blacksmiths, carpenters, goldsmiths and weavers. All of these depended on fundamentals acquired by practice and passed on from father to son or mother to daughter. In addition to all these, there was the craft of Sadu weaving which was one of the crafts that helped to form Kuwaiti cultural identity in the field of art and design.

As mentioned previously, in modern Kuwait, good salaries and secure futures have attracted the majority of indigenous people to work in the government sector, leaving behind the traditional crafts which enabled their predecessors to form and develop their identity.

2.5 Inspired by traditional crafts: Bedouin weaving

Having explained the research problem and the fear of losing cultural identity in the built environment in Kuwait, a solution was sought to help designers to maintain the cultural identity in their work. But providing designers with methods and tools for understanding and developing a style is not enough without inspiration to produce work which possesses an identity. What better source of inspiration than the traditional crafts that were created by the local people, for they have exclusive features and a strong identity that express the characteristics of that society. One such craft is known as Sadu, and it is the focus of inspiration for this research (see figures 2.12).



Figure 2.12: Examples of Sadu.

Sadu is the term used by the Bedouin (desert dwellers) of Kuwait and the Arabian Gulf countries to refer to the weaving process, the woven objects themselves, and the horizontal

loom on which they are produced. As Altaf described it in her book; "Sadu is an old Arabic term that evokes images and meaning that derive from the desert environment and Bedouin traditions" (Alsabah, 2001).

2.5.1 Historical perspective

Weaving has been an essential part of human life going back thousands of years to the domestication of animals by men. It is an important practical skill, "weaving is not only one of the oldest crafts but also a highly developed one allowing a great deal of creative and artistic expression" (Alsabah, 2001).

Bedouin women learn weaving from an early age, assisting their mothers in spinning, dyeing and weaving. Before they reach the age of 18, girls are able to weave almost all the patterns characteristic of their tribe. A skilled weaver traditionally accorded great respect and praise among the Bedouin of Kuwait.

Weaving was part of the range of essential skills proper to women but it was not a full time job. It was the custom that the women of the tribe would work collectively on tent parts, cooperating from start to finish (see figure 2.13). However, Altaf says "for the more intricate designs such as shjarah or midkhar, each weaver would work alone, reflecting in the process her own individual skill and ability" (Alsabah, 2001).



Figure 2.13: Bedouin women.

2.5.2 Techniques

"The weaving of a textile piece involves various initial stages: Shearing the wool, cleaning the wool, spinning and dyeing. Each step is necessary and vital to the quality to the finished product" (Alsabah, 2006). The wool for weaving came from the family's sheep, camels and goats. Goat's hair was used for the roofs of tents because it is the strongest of the three and the most waterproof (see figure 2.14a, b and c).

In the springtime, men sheared the sheep, then the women teased out the wool by hand and then combed it with wooden carders. Spinning was then carried out on a spindle, using a variety of techniques: "Some would hold the spindle between their hands while tending to their flocks; others spun it against their thighs" (Alsabah, 2006).



Figure 2.14a, b and c: Sadu weaving.

2.5.3 Dyes

"Red is the dominant colour used in the weavings of the Bedouin of Kuwait and is associated with the joy and prosperity, which might come from red being the colour of blood, therefore life" (Alsabah, 2001). In counterpoint to the austerity of the desert, Bedouin women used colours to liven up their monotonous surroundings. Before chemical dyes became known, wool was used in its natural colours or coloured with dyes produced from desert plants (as shown in figure 2.15). "Women also used other natural substances for their dyes such as henna, safflower, pomegranate skin and turmeric, which they bought from the markets of Saudi Arabia and Iraq" (Alsabah, 2001).



Figure 2.15: Wools are coloured with dyes from natural sources.

2.5.4 Patterns and motifs

The technology of the loom and its limitations dictate the largely geometric designs. Dots, stripes, squares and triangles are simple designs combined to flow together in rhythmic repetition and symmetry. "Designs and decorative patterns found in Bedouin weaving reflect the austerity of the desert environment and are governed by the principles of Islam which restrict the representation of the human figure" (Alsabah, 2001). These patterns are not kept within a closed frames, but rather stretch on as endlessly as the desert before them (see figure 2.16a, and b).



Figure 2.16a and b: Sadu patterns.

Geometric shapes are popular in Sadu and are referred to differently depending on the design. "Bedouin women weavers do not yield much information with regard to the meaning of the designs, nor are they aware of the significance of all these patterns. However, they continue to copy them in their weaving, passing them on from one generation to another depending on memory and deeply rooted traditions" (Alsabah, 2001).

2.6 Style

2.6.1 Definitions of style

Style is a widely adopted concept and exists in a broad range of fields. "The definition of style varies throughout academia, literature, linguistics, musicology, visual art and architecture" (Chen and Owen, 1997).

From measuring a style point of view, style is defined as any distinctive and recognisable mode of design that is repeatedly manipulated in the design process and thus generates certain common features across designed products (Chan, 1995). This definition regards the forming of a style from two perspectives. From the process point of view, a style reflects a designer's method of operating a set of factors and procedures repeatedly. From the object perspective, the set of common features that appears in a group of designs is considered to be a style.

Style in art and architecture is the consistency of a series of artifacts, which can be recognised through the similarity between them. Art historians defined style as "the constant elements and expression in the art of an individual or a group" (Shapiro, 1953). Here are some examples of well known styles that made an impact in the design field and were recognised by the common features of their products:

I. Rococo (c.1715-70)

Originally started in France in the first half of the 18th century, Rococo style is characterised by its organic patterns and the curving, serpentine movement of its composition. "The motifs used are based on shell and rockwork. In addition, there are

suggestions of wave or flame motifs that often create a sense of flickering movement and symmetry” (Noel and Patricia, 2003). Essentially this style is associated with interior decoration rather than with architecture. Rococo patterns were highly dependent upon personal interpretation by designers and craftsmen.

Products such as tables and chairs were designed to be part of the interior, and were built to reflect the motifs and shapes of the panelling. Comfort was a key issue in Rococo designs, and chairs of the period were characterised by the cabriole leg, and by decorative shell motifs and C-scrolls. The 1740s were the years when chair arms emerged from the frame in one continuous movement (see figure 2.17).



Figure 2.17: Rococo furniture (Gailingis, 2011).

II. Modernism (1920-1945)

The phrase ‘Modernism’ refers to the global style trend from the 1920s to the 1945s. Modernist objects look very different to those that came immediately before them: “they have no ornament and no overt reference to historical style and they tend to

emphasize the materials and processes of their construction” (Noel and Patricia, 2003). In Germany and France, modern designers were inspired by lightweight folding furniture (see figure 2.18).



Figure 2.18: Modernist furniture.

These pieces were meant for use outside the home so they broke all the rules of decorum and craftsmanship. Modernism presents the apparent paradox ‘less effort produces better design’. Designers in Sweden, Finland and Denmark aimed for softer effects in material and colour, although their best pieces were no less strict in eliminating visually confusing or overdone construction and the consistency of the style can be seen throughout the products (see figure 2.19).



Figure 2.19: Scandinavian furniture of the Modernist era.

III. The space age (1960-69)

“There was a strange movement around the mid-sixties when designers became more important in producing ‘want’ products rather than ‘need’ products” (Noel and Patricia, 2003). Function, economy, reliability and longevity were no longer the only concerns of designers, but equally they embraced impact, identity and stylishness.

The space age was represented by politicians such as Harold Wilson; the period in which we landed a man on the moon was concurrent with a time of penetration into an exciting and wonderful era in the history of mankind; a time in which all could and must take part. Young men and women in particular, had in their hands the power to change the world. It was a time that expanded our moral codes and practices. By 1963, the media had become obsessed with youth’s values, trends and idols.

Design expressed the decade perfectly. The social and cultural forces of the times helped to form and shape them. The spirit of novelty and the mood of youthfulness were portrayed in the colour supplements. “It was inevitable that the young who bought fashionable clothes and went to discos would want furniture in up-to-the minute colours, pop shapes or wild floral patterns: stuff which is cheap enough to repaint with aerosol spray or throw away when a new style, pattern or colour appears” (Noel and Patricia, 2003). An example of the trend for less formal, cheaper forms of furniture was the bean bag. These were chairs that contained millions of plastic granules or polystyrene beads, which adjusted to the shape of the sitter’s body (see figure 2.20).



Figure 2.20: bean bag (Greatbeanbags, 2013).

So, from the examples, it can be said that a style creates consistent images and visual impressions. Extensive research into style was found in the architecture literature, and studies into the subject approach it from two different points of view: recognition of style and generation of a style.

This chapter presents two research approaches, measurement of style and the shape grammar approach. To illustrate the science of these approaches, the similarities and differences between them are discussed, providing insight into the analysis and production of Kuwaiti cultural style.

2.7 Measuring the style

Style can be identified by features which present certain types of characteristics, used to illustrate cultural identity and social aspects. “If there are some attributes that have magnitude which can serve as common denominators to theoretically represent a style, then a style can be detected as an entity that possesses some basic properties” (Chan, 2000). These attributes can be used to measure how strong a style is and the degree of similarity between two styles. According to Schapiro, “style means the constant form and sometimes the constant elements, qualities, and expressions in the art of an individual or a group” (Schapiro, 1961). The common features in objects are the fundamental units of style measurement which are used to categorise a style.

Chan’s approach gives an explanation of the cause of a style. In his view, a style results from the constant application of certain factors in a design process to generate common features. The term features covers many meanings of patterns (detail treatments), physical forms (materials) or characteristic (textures and colours). Thus, any legitimate features to be regarded as stylistic should have the following properties (Chan, 2000):

- i. They should have a form or composition distinguished by some particular configuration, and a contextual relationship with other features;
- ii. They should be generated originally by a designer through creative processes, or adapted or copied by a designer from other sources with certain functionality achieved;

- iii. They should be members of a set of prominent forms repeatedly used by the designer.

The perception of a style is affected by the number of features appearing in an object. The results of psychological experiments (Chan, 1994) regarding the definition of style suggest that features can be registered as common if they appear in three products. Also, if there are less than three common features in a product, its style is barely perceptible. So the greater the number of common features the easier it is to perceive the style (see figure 2.21).

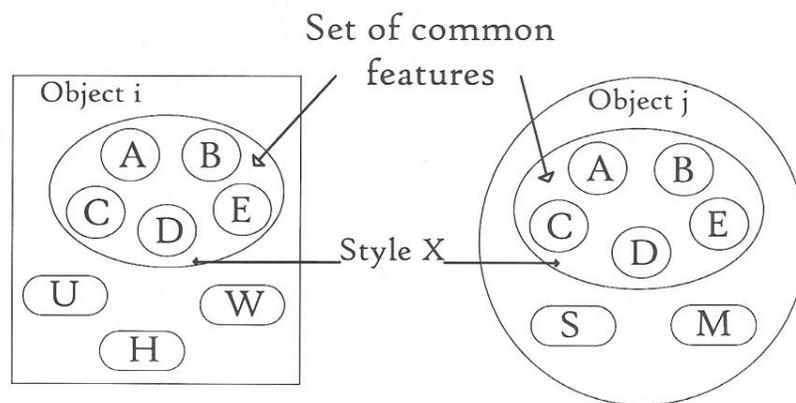


Figure 2.21: Objects i and j of the style X share the same set of features.

2.7.1 Similarity between styles

Similarity plays an important role in theories of behaviour. As Tversky describes it, “it serves as an organizing principle by which individuals classify objects, form concepts, and make generalizations” (Tversky, 1977). Some objects look more similar together than others, thus, they more strongly represent the style than others. The similarity model, based on the theory of feature matching (Tversky, 1977), contains a combination of the measures of common and distinctive features existing in objects, and is written as follows:

$$S(A,B) = f(A \cap B) - f(A - B) - f(B - A).$$

Where, $S(A, B)$ is the similarity between object A and B; $f(A \cap B)$ represents the common features in both A & B; $f(A - B)$ represents the distinctive features in A but not in B; $f(B - A)$ represents the distinctive features in B but not in A (see figure 2.22).

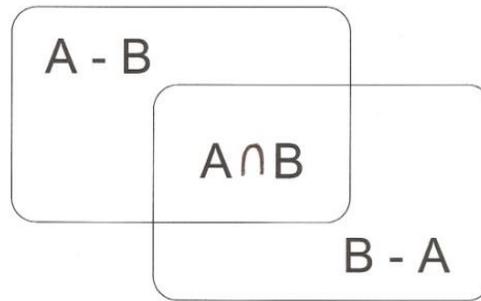


Figure 2.22: The relationship between two feature sets.

An increase in the number of common features increases similarity and decreases difference, whereas an increase in distinctive features decreases similarity and increases difference. So, if $S(A,B)$ is bigger than 0 then the similarity is greater than the distinctive features; if $S(A,B)$ is equal to 0 then similarity equals distinctiveness; and if $S(A,B)$ is less than 0 then similarity is less than distinctiveness.

Chan's theory explains how a style can be analysed and generated, and thus accomplishes half of the mission for styling studies. In order to support designers in understanding the design language of style and then modifying it, shape grammar approaches are needed to help designers in practice.

2.8 Shape grammars

A shape grammar characterises the abstract spatial form of designs in a particular style or language. As Knight describes it: "It is based on a vocabulary of shapes and a set of spatial relations that correspond to different arrangements of shapes in the vocabulary. A set of shape rules defined in terms of these spatial relations, together with an initial shape, comprise a shape grammar" (Knight, 1993).

Geometric shapes are one way we begin to understand the real world our visual sense brings to us. They act as a medium for perceiving and representing the physical world. In vision, the role of shapes is in processing external images in our mind for recognition and understanding. In design, shapes are employed as symbolic abstractions for conceiving design ideas and physical forms.

Conventional drawings use shapes to represent physical objects, such as geometric form, materials and special relations. A higher level of visual abstraction uses shapes to represent design concepts (Oxman, 2002). Manipulation and transformations with shapes are the fundamental medium in design for interacting with a designer's imagination. They have broad impact for visual reasoning and design emergence.

The concept of shape grammar was first developed by Stiny and Gips in the 1970s (Lauzzan and Williams, 1988). Since then, many research projects have been conducted in that field to generate a language of design. Grammars have been developed to generate and understand languages of Chinese ice ray lattice designs (Stiny, 1977), Palladian villas (Stiny and Mitchell, 1978), Hepplewhite chairs (Knight, 1980), Queen Anne houses (Flemming, 1987) and many other kinds of design.

Over the years, two fundamental concerns in design were addressed:

1. The analysis of past styles of design. This can be undertaken by taking into consideration the following steps: Distinguishing the vocabulary of shapes and a set of spatial relations which is common to design in the style; defining the shape rules that fix the appearance of spatial relation in the design; defining an initial shape from which to begin generation; and specifying an appropriate grammar in terms of rules and initial shape.

The design language is constructed in five stages, as explained by Stiny (Stiny, 1980). They are:

- i. A vocabulary of shapes: This is a limited set of shapes no two of which are similar.
- ii. Spatial relation: Exists whenever any collection of shapes is considered to form a recognisable form.

- iii. Shape rules: They incorporate the constructive mechanisms used in the procedure. The way spatial relations recur is fixed by the shape rules.
- iv. Initial shapes: Are formed by combining the vocabulary of shapes.
- v. Shape grammars: Are specified in terms of shape rules and the initial shapes.

Individual possibilities in one stage may lead to multiple possibilities in a succeeding stage. For example, a single vocabulary can support a variety of spatial relations, and a single spatial relation can support the basis for a variety of shape rules.

2. The creation of completely new and original styles. Generally, this involves creating a vocabulary of shapes and spatial relations from scratch, then defining initial shapes and rules based on the vocabulary and spatial relationships. After that, a shape grammar can be formed by combining these variables in various ways.

This research is concerned with the analysis of past styles of design and the development of a structured method. The process adopted to achieve the research aims is as follows (see figure 2.23):

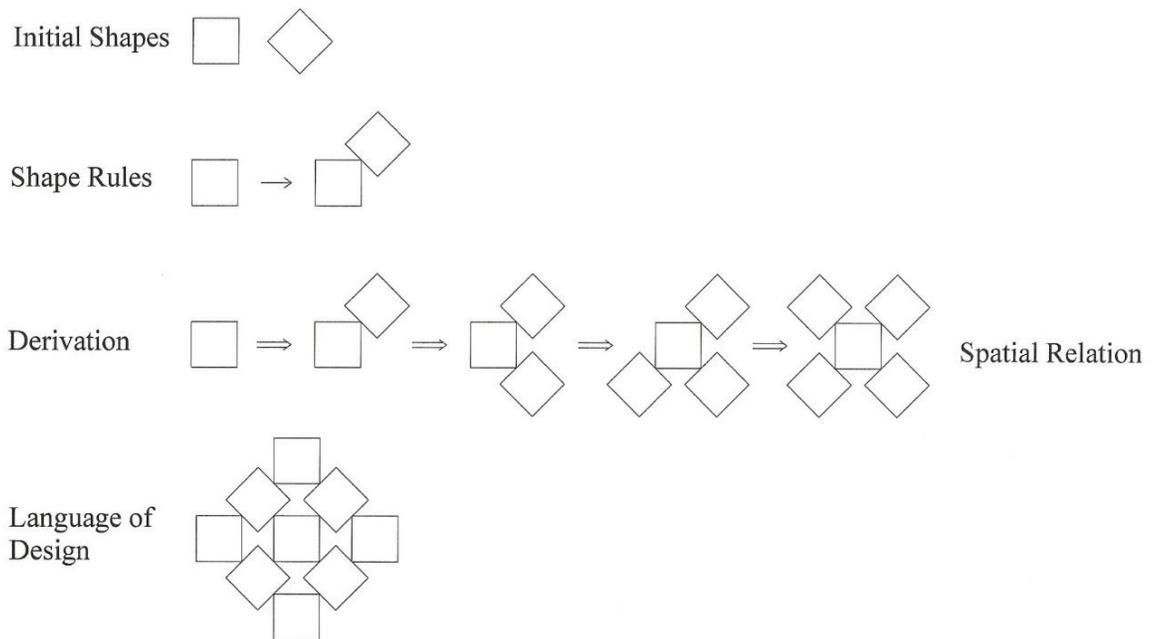


Figure 2.23: The development of shape grammar.

2.8.1 Shape grammar applications

Architectural grammars focus on shapes and their spatial relation. They were used to generate and analyse design styles. An example on this is Palladio's villas (see figure 2.24). The grammar for Palladio style is the most comprehensive. It consists of three academic papers which were written to construct a grammar which captures a style, deriving room layouts and evaluating plans. The first paper presented a grammar that was constructed and grouped into stages (Stiny & Mitchell, 1978a). Each stage responds to a construction procedure, from ground plan framework to detailed ornamentation design, from defining exterior walls to interior walls. The second paper used rules to construct room layouts. A catalogue of all possible layouts was enumerated and counted (Stiny & Mitchell, 1978b). The third paper applied aesthetic criteria to evaluate the grammar generated designs (Stiny & Gips, 1978).

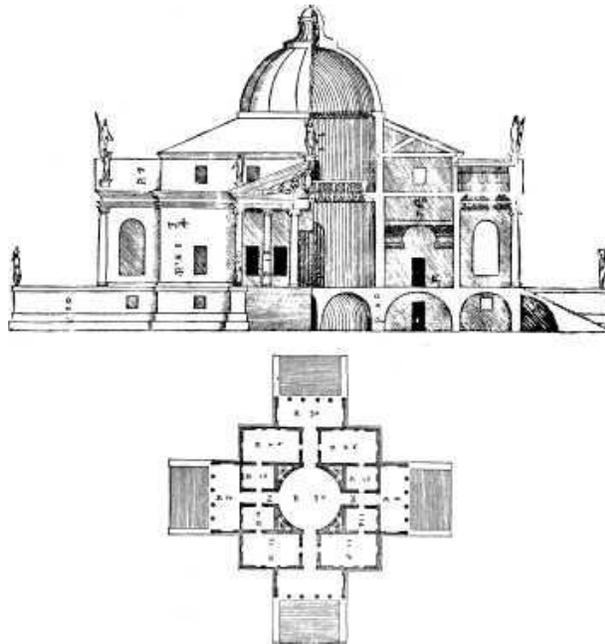


Figure 2.24: Palladio's villas (PlayTechs, 2008).

Another example is Knight's work on the Meander Motif on Greek Geometric Pottery, demonstrating that style can be transformed by adding, reducing and modifying rules (Knight, 1986).

Inspired by architecture shape grammars, researchers from engineering backgrounds made attempts to explore logical structures for engineering synthesis. One example of shape grammars for product design is the Buick grammar, which was identified by Cagan and McCormack who worked on constructing grammar for brand identity. They focused on automotive styling design and put together a Buick grammar (McCormack & Cagan, 2004). Their paper presented shape grammars as a method for encoding the key elements of a brand into a repeatable language, which can be used to generate products consistent with the brand. The front views of Buick vehicles were analysed, in particular, and categorised into periods of several years separated by a year of more prominent change (see figure 2.25). The characteristics of the brand were captured in two dimensional sketches, and the essential features of the Buick were encoded in shapes and rules. This method was used to ensure that no changes were made unless they were captured in the grammar on the basis that this would enable the company to understand how far its brand can be stretched without losing the core brand statement. Their suggestion opened up further research on the integration of shape grammar into the design processes.

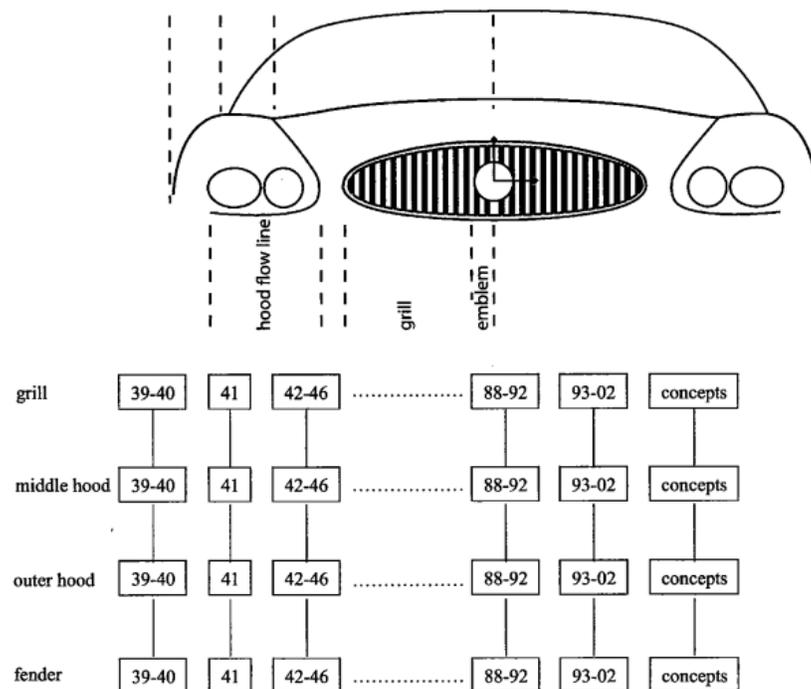


Figure 2.25: Summary of the key elements of the Buick brand for each thematic form era (McCormack & Cagan, 2004).

2.8.2 Shape grammar interpreter:

SGI is a robust tool used to define shape grammars and generate new designs. It facilitates the easy manipulation of shape grammars: creation of shapes, rules and generation of designs. The developed shape grammar framework allows the user to obtain automatically generated patterns and to participate in the design process (see figures 2.26).

The user creates shapes by drawing them on canvas using a mouse. Rules operate in a similar manner; the user creates rules by specifying the spatial relation among shapes either parametrically or by mouse. Existing shapes are used to create rules of a shape grammar. (Trescak & Rodriguez & Esteva, 2009).

After decomposing the Kuwaiti Sadu style into basic elements, this tool allowed the researcher to test the proposed design language rules that built this style. The process in detail is demonstrated in chapter four.

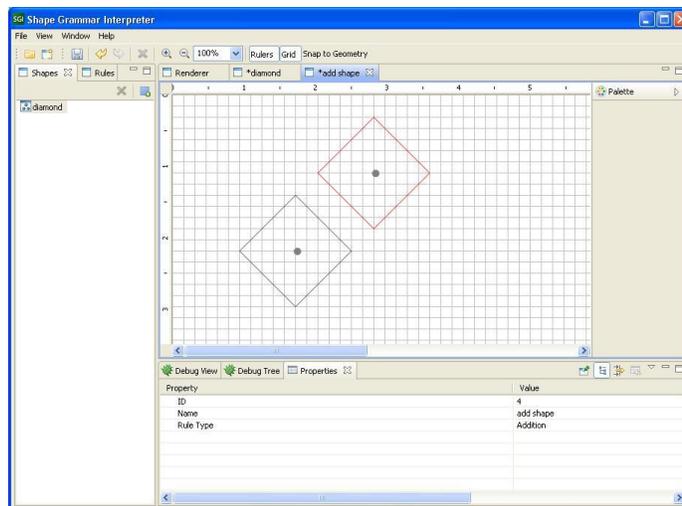


Figure 2.26: The interface of the SGI tool.

A common conclusion was reached although the recognition and representation of style was approached differently in the studies; and that was that ‘a style can be recognised through consistent elements or expressions appearing on a group of objects’. The common approach in their studies of style was that they broke down their particular style into basic elements that have a strong impact on that style.

Chan (1995) proved that a style consists of common features, and can be constructed by the constant application of certain factors to generate common features. In shape grammars, a style is encoded into a set of shapes and rules, and generated by repeatedly applying certain rules in a consistent manner.

Transferring the common agreement to the context of maintaining the cultural identity, a style can be decomposed into a set of elements which relate to product features. In the case of the State of Kuwait, there are elements and rules that can be seen consistently in traditional Sadu products, and these are what makes Sadu unique in the region and framed the national identity. These features are geometric shapes and symmetry.

2.9 Symmetry

Whilst diversity is apparent in the decoration of Kuwait's textiles, it would seem that there are also common characteristics, which are in some way a manifestation of Kuwaiti identity. One of these characteristics is the symmetry rule. So part of the analysis process in this research will focus on understanding the various aspects of repeating patterns as well as their classification.

Symmetry is defined as the proportionality between the constituent elements of the whole. Therefore, it incorporates the properties of balance, harmony, regularity and order. The concept of geometric symmetry was discovered and developed within the sphere of mathematics. As Escher pointed out, "Crystallographers have put forward a definition of the idea they have ascertained about which and how many systems or ways there are of dividing a plane in a regular manner. In doing so, they have opened the gate leading to an extensive domain, but they have not entered this domain themselves. By their very nature they are more interested in the way in which the gate is opened than in the garden lying behind it" (Escher, 1986).

Some archaeologists and art historians have applied symmetry classification to analyse patterns of decorated items in addition to the customary categorisation by reference to media, style, cultures and periods. As Hann stated, "A means by which textile and other surface patterns can be classified by reference to the symmetry characteristics of their underlying structures is

developed and shown to be an objective, systematic and reproducible means providing meaningful and standardised descriptions of regular symmetric patterns” (Hann, 1991). “Patterns from each different culture setting exhibit their unique symmetry preferences evidenced by non-random distributions of the symmetry classes employed. This non-randomness is of importance, for it indicates that symmetry classification is in some way culturally sensitive” (Hann, 1992).

Washburn and Crowe pointed out that people used symmetry to diagnose feature in the perception of design (Washburn and Crowe, 1988). A regular repeating pattern may be constructed by using a combination of one or more of the four symmetry operations. These are:

1. Translation (slide an object): In geometric symmetry, translation means the motif undergoes repetition in any direction at regular distances, while retaining the same orientation (see figure 2.27).

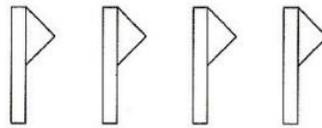


Figure 2.27: A letter P is repeated horizontally by shifting it from the initial position on the left-hand side to its congruent copies on the right-hand side.

2. Rotation: The motif undergoes repetition about a fixed point through a certain fractional angle of 360 degrees, which leaves the motif exactly coinciding with its original position. n-fold rotation refers to the order of rotation (see figure 2.28).

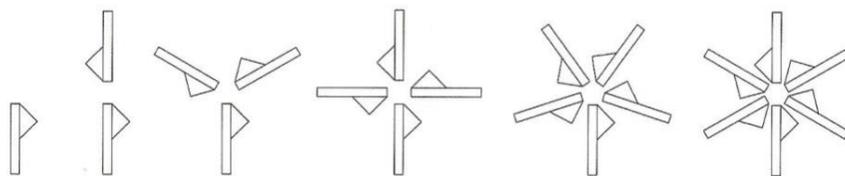


Figure 2.28: n-fold rotations, where $n = 1 - 6$.

3. Reflection or mirror: Is an axial symmetry by which a motif is repeated by producing its mirrored image across an imaginary straight line, known as a reflection axis (see figure 2.29).

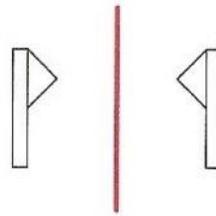


Figure 2.29: A letter P is mirrored horizontally on the right-hand side with respect to a vertical reflection axis.

4. Glide-reflection: Is a combination of translation and reflection in association with a glide-reflection axis (see figure 2.30).

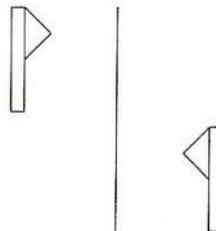


Figure 2.30: A letter P is mirrored horizontally onto the right-hand side of a vertical reflection axis followed by a translation which is parallel to the reflection axis.

There are three categories of design recognised by their symmetry group arrangements. A design that exhibits symmetry about a fixed point with no translation is known as a finite design. A design which undergoes repetition in one direction is regarded as a band pattern. A design which is translated successively in two non-parallel directions is regarded as an all over pattern.

2.9.1 Classification of finite design

A finite design acknowledge reflection and/or rotation about a fixed point but no translation and hence glide reflection in it symmetry group. Therefore, it has no sense of forward and backward or right and left. There are two categories of finite design, and they are:

- i. Cyclic groups: which exhibit a design with n -fold rotational symmetry and are denoted as a finite design of class cn , where c stands for a cyclic group and n stands for the order of rotation (see figure 2.31).

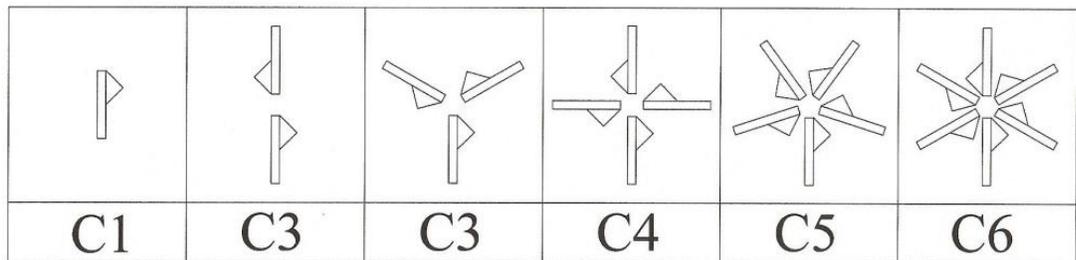


Figure 2.31: Schematic illustration of finite design of class cn , $n= 1- 6$.

- ii. Dihedral groups: which present a design having n distinct reflection axes and n -fold rotation, and are known as class dn , where d refers to a dihedral group and n stands for the order of rotation as well as the number of reflection axes (see figure 2.32).

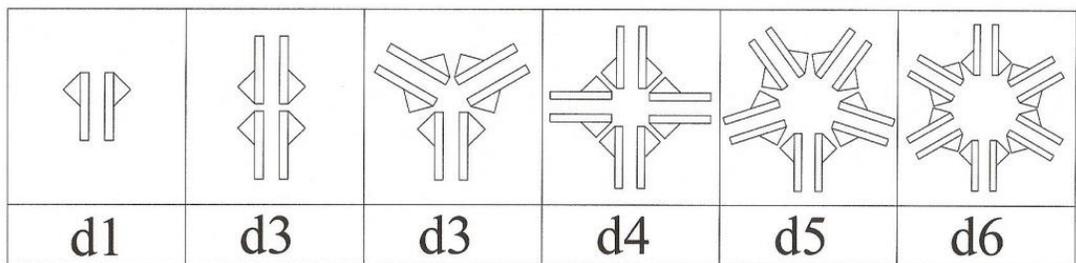


Figure 2.32: Schematic illustration of finite design class dn , $n= 1- 6$.

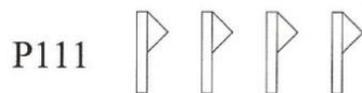
2.9.2 Classification of band patterns

Because of the design language nature of the Kuwaiti style, this research is concerned with the band pattern which is generated by repeating motifs along a longitudinal axis between parallel sides (see figure 2.33). One dimensional patterns, frieze groups, border patterns and line groups are all other terms for band patterns.

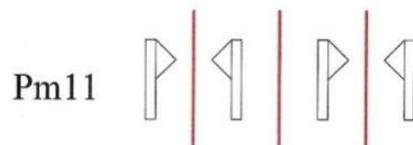


Figure 2.33: Band pattern.

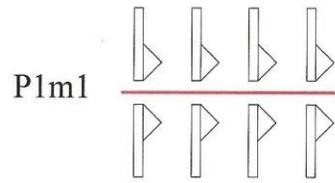
In the generally accepted notation, there are seven classes of band pattern based on a four-symbol combination of the form $pxyz$, as explained by Washburn and Crowe (1988). They are, $p111$, $pm11$, $p1m1$, $p1a1$, $p112$, $pmm2$ and $pma2$ (see figures 2.34a and b). The p symbol refers to the band pattern class; x is replaced by m (for mirror) when a vertical reflection occurs, otherwise x is 1; y is replaced by m when a horizontal reflection occurs, or a where a glide reflection occurs, otherwise y is 1; z is 2 whenever rotation occurs, otherwise z is 1.



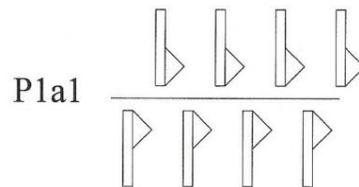
Band pattern class $p111$ has translation only along a longitudinal axis of the band.



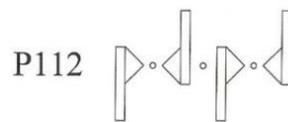
Band pattern class $pm11$ has vertical mirroring only.



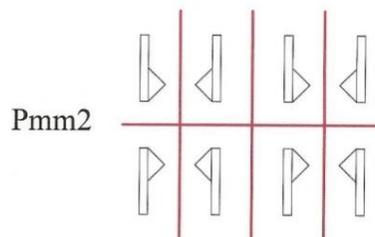
Band pattern class p1m1 has horizontal mirroring only.



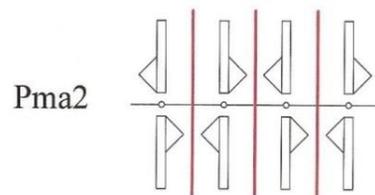
Band pattern class p1a1 means there is only glide reflection.



Band pattern class p112 designs involve only rotation.



Band pattern class pmm2 involves vertical- and horizontal-mirror and rotation.



Band pattern class pma2 involves vertical mirroring, glide reflection and rotation.

Figure 2.34a: Seven classes of band pattern.

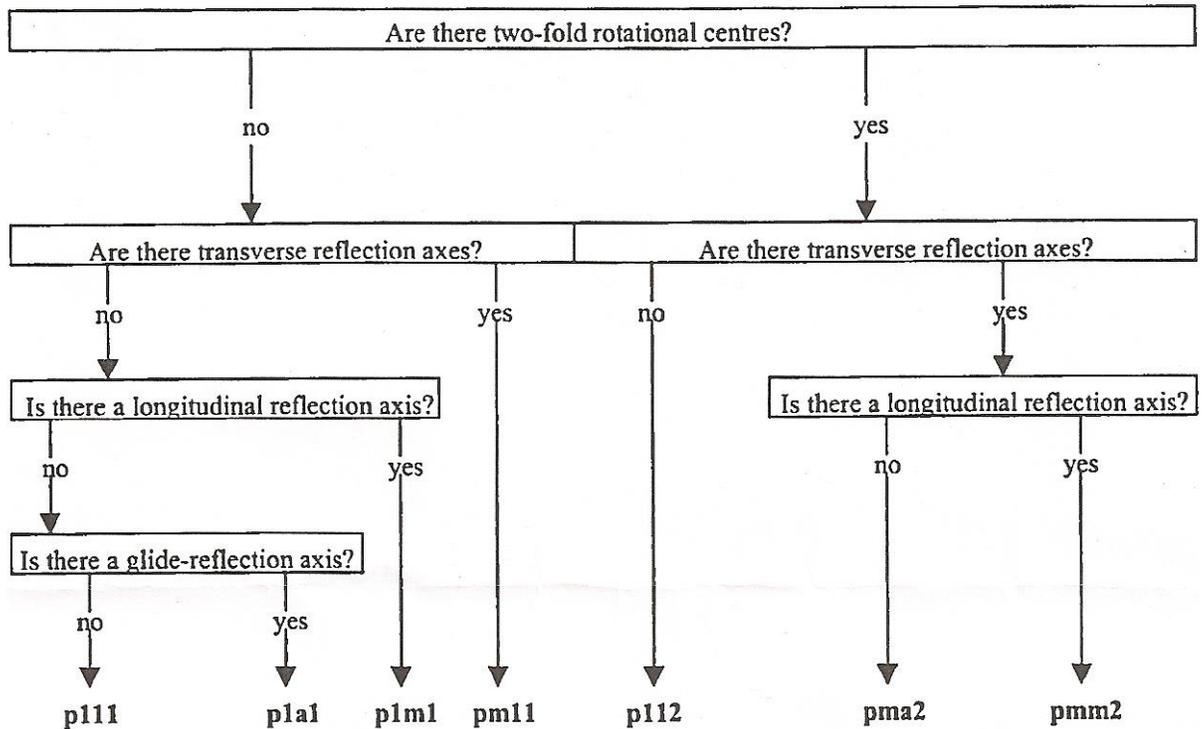


Figure 2.34b: A flow-diagram aiding the identification of seven symmetry classes of band pattern (Horne, 1997).

2.9.3 Classification of all-over pattern

“An all-over pattern exhibits regular repetition in which a motif or motifs is/are translated in two independent directions across the plane” (Hann and Thomson, 1992). A total of seventeen distinct symmetry groups of all-over patterns may be generated by combining one or more of the four symmetry operations. Other terms for all-over pattern classes are a two dimensional pattern, wallpaper group, plane group and periodic pattern.

There are various notations used by mathematicians and crystallographers to identify the seventeen classes of all-over pattern, and the widely accepted crystallographic notation consists of four symbols which identify the conventional by chosen unit cell. Further explanation of the four symbols is provided by Washburn and Crowe (1988) and Hann and Thomson (1992).

2.10 Elements of visual communication

The visual impact of every design, sketch, drawing or construction is composed of a basic list of elements. “The visual elements are the basic substance of what we see, and they are few in number: The dot, line, shape, direction, tone, colour, texture, dimension, scale, movement” (Dondis, 1973).

The basis of Gestalt theory is “The belief that an approach to understanding and analysing all systems requires recognition that the system as a whole is made up of interacting parts, which can be isolated and viewed as completely independent and then reassembled into the whole” (Dondis, 1973). Therefore, interpretation of the basic components as a means of understanding a visual language or individual work is a method of exploring its potential.

Shapes are made by joining lines together and can be classified as “geometric, organic, rectilinear, irregular, hand-draw and accidental” (Wong, 1972) (see figure 2.35). They can be defined as “enclosed areas that are identifiably distinct from their background and other shapes” (Pipes, 2003). In this research the element of interest is the geometric shape, which considered a main characteristic in the Sadu design language.

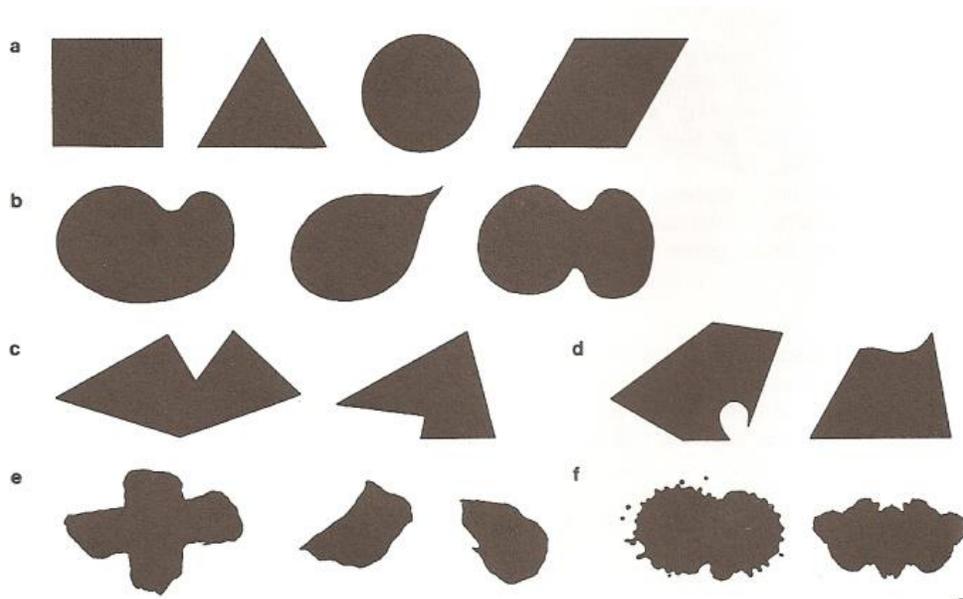


Figure 2.35: Shape classification (a) geometric (b) organic (c) rectilinear (d) irregular (e) hand-draw (f) accidental.

2.11 Summary

In this chapter the literature reviews on various topics in relation to the research scope were presented. Topics were categorised into cultural identity and style. The reviews explored research development on these categories, identified their research deficiencies and extracted concepts and methods that can be used for this research.

Topics regarding cultural identity were presented in section 2.2.

“Culture refers to the customs, practices, languages, values and world views that define social groups such as those based on nationality, ethnicity, region or common interests. Cultural identity is important for people’s sense of self and how they relate to others” (Molina, 2006). Therefore the message of this research is important for the State of Kuwait because of the changes which have occurred since the discovery of oil which have led to a loss of identity in the built environment. The styles of other developing countries also need to be maintained and developed in the design field.

The origin of Kuwait was explored along with its cultural identity in terms of geography, weather, population, religion, language, currencies and the built environment. Then a comparison between the old and modern built environment was made together with the reasons for change. A comparison between the population of Kuwait before and after the discovery of oil was made to indicate the size of the problem and the need to find a solution. The traditional crafts were presented and one of these crafts was chosen to be the inspiration for maintaining cultural identity in design because of its popularity among Kuwaitis - that craft is Sadu.

Topics regarding style were presented in section 2.6.

Chan presented a series of papers on his study of style. His research focuses on measuring the style studies that detect designers’ thinking and behaviour during the design process. Chan asserts that style is reflected in design thinking and should be approached from a cognitive point of view (Chan, 1995). He defines style as a function of common features and common factors; features such as geometric shapes in patterns or horizontal board siding in the design of house interiors. Factors include goals and the sequential order in which they are applied.

Research into shape grammar provides a rule based system for generating a style. In shape grammar, a style is considered as a language of design. Style elements are represented as shapes, and their relationships are constructed using rules. The generation of a style is a computational process that manipulates shape and sub shape through the application of rules.

In order to measure a style, the elements and rules of design must be investigated. In this research, the symmetry rule and geometric shapes are chosen in analysing the Kuwaiti style because they are considered an important visual characteristic of that style.

The research questions are:

- What is the Kuwaiti style and how can it be measured?
- What are the common features of Kuwaiti style?
- How is it possible to develop the traditional designs without losing their identity, and at the same time not turn them into cliché designs?
- Is there a consistency in the proposed design tool?

3 Research methodology

3.1 Introduction

In this chapter, the methods used in collecting the relevant data, and the evidence required to achieve the research objectives are outlined. In order to carry out the project, both primary and secondary data collections were used in this research. The primary data collection consisted of three tests conducted during the study, and the data gathered from each test formed the basis for further investigation in each subsequent test. The research methods gathered data in numerical form which then was put into categories, rank order and then statistically constructed graphs and tables that produced measurable results. Also, as part of a practice to inform interior designers, the Kuwaiti Sadu style was used as a case study, to show how such a style could be developed whilst still maintaining the original Kuwaiti identity.

The first test involved the measurement of style by locating the common shape and symmetry rule features using a focus group method to analyse the Kuwaiti Sadu. This approach had two parts; i) to establish the common geometric shapes in the designs: and ii) to find the symmetry rules that shaped that style.

The second test employed a questionnaire to establish the cultural recognition and likability of the newly developed patterns from the opinions of the Kuwaiti participants. The aims were: to evaluate whether or not the new designs had retained their original identity; to identify which method produced the most recognisable patterns of the Kuwaiti Sadu style; and to determine what were the common rules in the new patterns that successfully generate this Kuwaiti style.

A software tool was then developed to enable both Kuwaitis and non-Kuwaitis to produce consistent Kuwaiti Sadu patterns. The third test used the questionnaire method to measure whether the tool produced patterns which were consistent with the Kuwaiti cultural style.

3.2 Research approach

This section describes the methods selected for this research. The selection was based upon the issues being addressed and to achieve the research aim. This study is based on exploration, understanding and measurement of the Kuwaiti style. The methodology needed for this research to achieve its aim involved: data collection, statistical analysis, and the development of an understanding (as part of design practice) through action research. Therefore, the research requirements helped to define the research model which is a mixed methods approach, in order to answer the research questions.

According to Creswell, “Mixed methods research provides more comprehensive evidence for studying a research problem than either quantitative or qualitative research alone. Researchers are given permission to use all of the tools of data collection available rather than being restricted to the types of data collection typically associated with qualitative tools, open-ended questions, emerging approaches, text or image data, or quantitative tools, closed-ended questions, predetermined approaches, and numeric data” (Creswell, 2007). Johnson et al. define mixed methods as follows: “Mixed methods research combines elements of qualitative and quantitative research approaches for the purposes of breadth and depth of understanding and corroboration” (Johnson, Onwuegbuzie, and Turner, 2004).

The data in qualitative research is typically descriptive data, in which the voices of participants are directly heard. Quantitative research, on the other hand, gathers data in numerical form which can be measured in units of measurement. Mixing the data from both methods helps to provide a better understanding of the research problem. To Creswell (2007), “there are three ways in which data mixing occurs: merging or converging the two datasets by actually bringing them together, connecting the two datasets by having one build on the other, or embedding one dataset within the other so that one type of data provides a supportive role for the other dataset” (see figure 3.1).

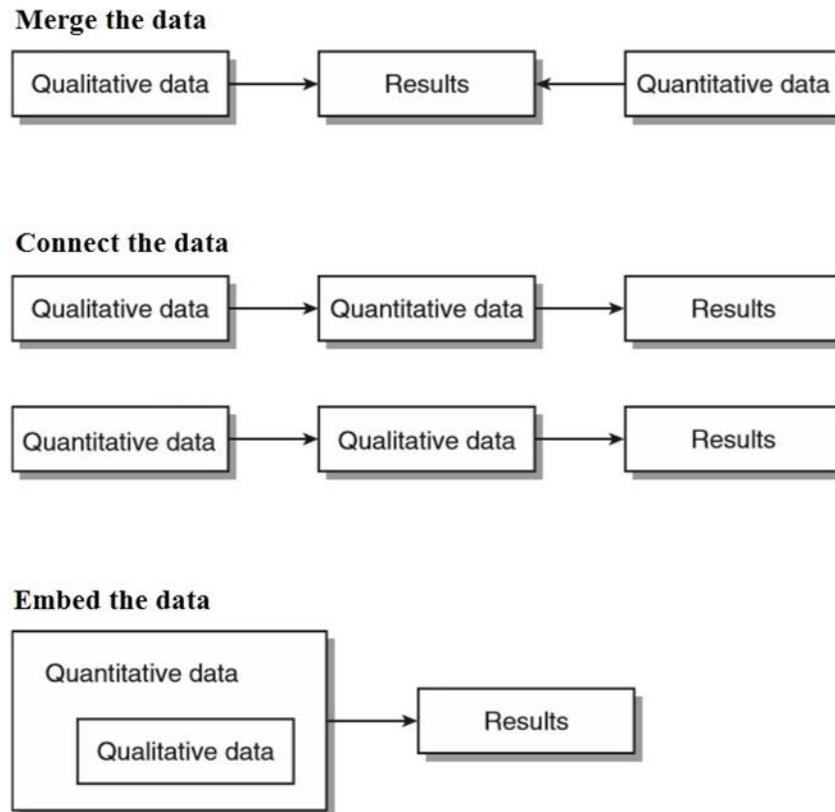


Figure 3.1: Three ways of mixing quantitative and qualitative data.

The priority in the first part of this study was to collect and analyse data to address the research questions. The second phase then built upon these results, by testing and generalising the initial findings. This ‘embedded’ style of analysis produces credible data and a more coherent understanding of the problem, and was thus an appropriate mixed methods approach for this research.

During the process of this research several tests were undertaken; each had its own goal, but they all built upon each other in order to achieve the project aim. The methods of data collection in this work were selected based upon the requirements of each task. The first test was designed to measure the Sadu style by locating the common geometric shapes and the symmetry rules in the tested designs. The focus group method was chosen for this task because it focused on a specific area of interest which allowed the designer participants to probe the topic in greater detail. As a research method, “focus groups are valuable because they offer the

researchers a means of obtaining an understanding of a wide range of views that people have about a specific issue” (Conradson, 2005). The area of interest was introduced to the participants who gave their responses accordingly.

The results of the test were analysed and showed that the designs have strong shape and symmetry features in common, and that these features give Sadu its distinguished style. As mentioned in the review chapter, shape grammars consist of rules that are applied to initial shapes to create the language of a design style. The next step was to identify the rules that generate the language of the Sadu style by the shape grammar method. The design language was analysed using Shape Grammar Interpreter and the design rules table as tools. This helped to propose new modified designs that were tested for recognition in the second test.

The second test was designed to explore the recognition and likability of the developed Kuwaiti Sadu patterns, and this required a large number of participants to achieve measurable and reliable results. The survey method was used in this task to collect quantitative data because of its advantages. According to Creswell (2009), “a survey design provides a quantitative or numeric description of trends, attitudes or opinions of population by studying a sample of that population”. The data collection for this task was the questionnaire because it simplifies the collection of a large amount of data in a short period of time, and enhances the collection of objective data.

In the third test, two methods were used to collect the data. Firstly Kuwaiti and non-Kuwaiti designers were asked to use the developed software tool and to evaluate the strengths and weaknesses of the software in a qualitative focus group method with open ended questions. Then the recognition of the produced designs by the designers was tested using a questionnaire method to Kuwaiti nationals to measure whether the tool produces consistent developed Kuwaiti patterns.

Regarding populations of participants, Basha and Harter (1980) state that “a population is any set of persons or objects that possesses at least one common characteristic”; so for each conducted test in this study, the population had at least one common characteristic. For example, in the first test the participants shared the same educational design background and

age. The second test was conducted among Kuwaiti nationals. In the third test, the users of the tools were all designers, and the questionnaire was made for Kuwaitis.

The methods in this research involved both quantitative and qualitative approaches. A focus group and questionnaires were the means used in this study to collect data which was then statistically analysed to provide a solid base from which to maintain the cultural identity of design. Added to that, action research was applied (to the design tool that was developed) to add understanding and to strengthen the claims to new knowledge made by this work. Action research is a quantitative research method, and it brings about action in the form of change. “Action research is a method used for improving practice. It involves action, evaluation, and critical reflection – based on the evidence gathered – and changes in practice are then implemented” (Koshy, 2010). This tested knowledge that was gathered from the framework that was used in developing the Kuwaiti traditional style and successfully generated 2D developed style designs that were translated into 3D models by an interior designer.

In order to develop an understanding as part of design practice in this research and to demonstrate how the knowledge gathered from previous steps can help interior designers to create a design that captures cultural identity (and at the same time allows for design creativity), a case study of a hotel lobby and counter were created using 3D MAX software. The inspiration for the overall theme of the hotel came from the tools that the researcher had developed which represent the Kuwaiti culture, and in particular the Sadu style.

All the furniture and decorations presented in the case study are original designs produced especially for this work by the researcher. Benefiting from the proposed framework that first identified and then modified the style, tools were built to produce inspirational designs that can be used for any project that has a theme of cultural identity. These designs were tested and then the case study in chapter six was validated by the action research method.

Figure 3.2 is a diagram of the research process. It shows how the applied studies built upon each other and how the results and outcomes of each stage were employed in the next study in order to achieve the main research aim and objectives.

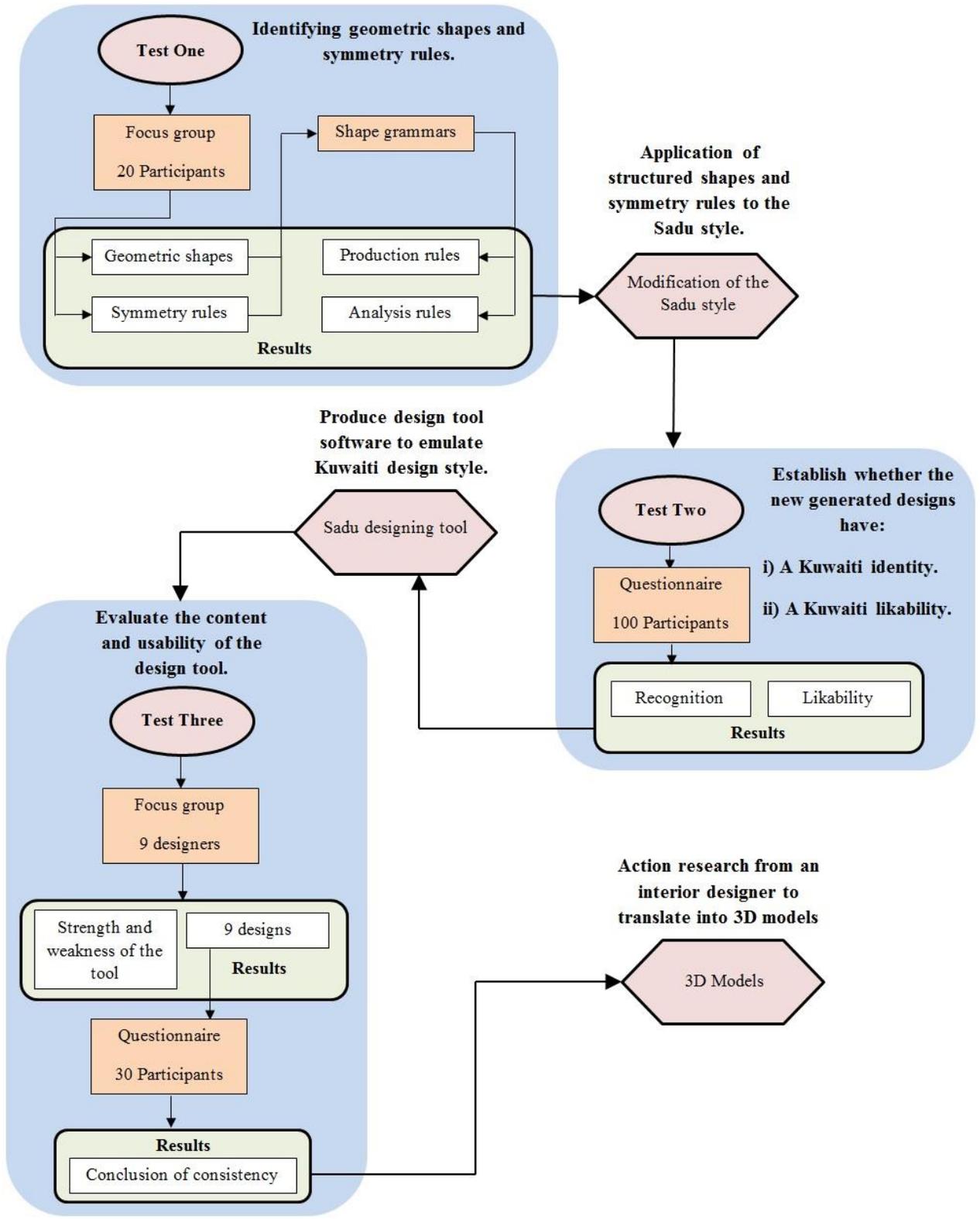


Figure 3.2: A diagram of the research process.

3.3 Primary data collection – test one

The focus group, which was designed to measure the common features of traditional Kuwaiti products in order to measure their style, consisted of two parts (see appendix A).

Part one

The first part focused mainly on identifying the common basic shapes pattern amongst the products. Based on the education level of the participants in the selected group, questions were targeted to explore Kuwaiti style and the respondents' perception of that style.

The question in the first part involved finding out which were the most repeated shapes in the designs. This was to provide the study with clear data concerning the features which could be used as a basis for generating new designs. The participants were given a chart of numbered shapes and, when they recognised any one of those shapes on a product, were asked to write its number on an answer paper (see figure 3.3).

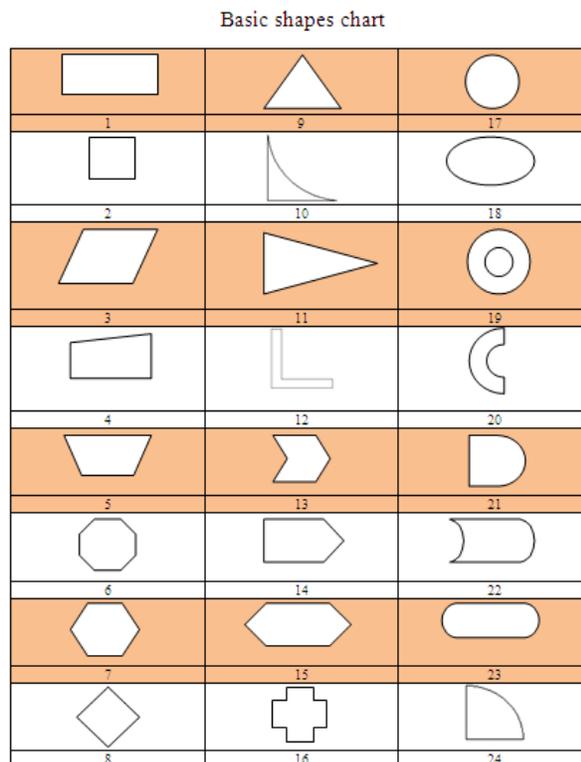


Figure 3.3: Shapes Chart.

The chart was derived from Sadu designs which contain geometric patterns. After pre-testing the chart several times (the first time without a chart, the second with only five shapes), to choose these 24 shapes. Although there are more shapes (for example, the star), they are not presented in Sadu designs.

Part two

The second part of the focus group was about the rules of symmetry. In this second part of the focus group meeting, the researcher was keen to explain the symmetry rule to the groups because the participants' answers would be more reliable if they had first understood this, and the final recommendation and solutions would consequently be well founded. The aim was to find out what type of symmetry rules are involved in Sadu and which are the most common. Each border of the ten designs was analysed individually. So the borders were coloured in different colours to make sure that the focus groups would not become confused (see figure 3.4).

The participants selected the appropriate symmetry rules for each border by ticking the boxes on the answer sheet. these rules were: vertical mirror, horizontal mirror, rotation and glide reflection (see table 3.1). The focus groups had four rules to choose from, the border could have only one rule or it could have all four rules together depending on the visual analysis of the participants. Then the class of symmetry was specified for each border based on the focus group's answers. For example, if the border had vertical mirror symmetry only, then it was of class Pm11 as explained in the literature review chapter.

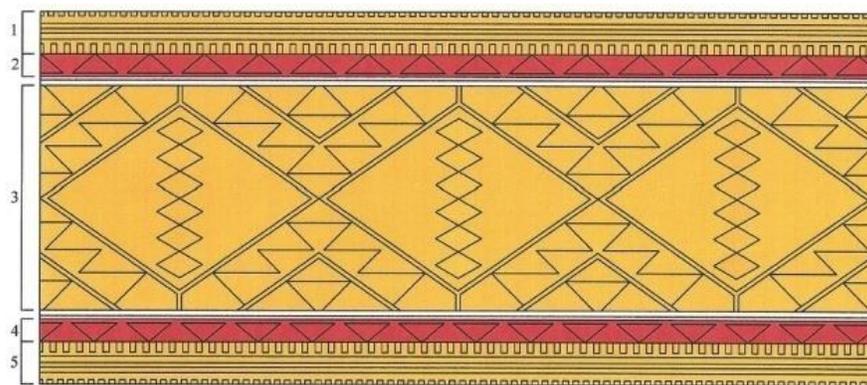


Figure 3.4: Sadu.

Product A							
Border 1	Vm		Hm		Gr		R
Border 2	Vm		Hm		Gr		R

Table 3.1: Sample of the symmetry rules answer sheet.

3.3.1 Initial pilot study

The research has a syntactic approach, which means in-depth analysis has to be undertaken with regard to the rules and elements of design to identify the style DNA. To achieve this, ten popular Sadu pieces which were the products most frequently found in Kuwaiti museums, were chosen, installed into AutoCAD software and traced to facilitate more accurate analysis and to control the quantity of copies (see figure 3.5).

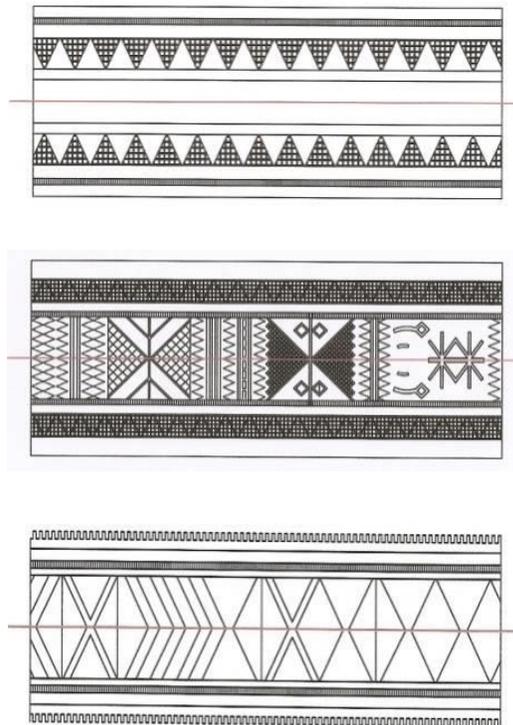


Figure 3.5: Sadu drawings by AutoCAD.

3.3.2 The scope of the research area

Twenty people participated in the test and they were divided into two groups based on their level of design education. The first group, of ten people, consisted of first year design students. This group represented the customers because of their lack of design knowledge. The second group were final year design students and they represented the designers. This approach was devised to measure the similarities between the two, with the help of a similarity model based on the theory of feature matching, and then to compare the answers with the researcher's analysis. The outcomes were expected to give an idea of the differences between customers and designers in terms of the visual analysis of Sadu.

The participants were all Kuwaitis because the test was related to Kuwaiti culture and they would be the most appropriate people to answer the questions. All were male. Each person was given an answer sheet and was asked to share the ten AutoCAD drawings of the Sadu with another participant, to save paper and ink.

3.3.3 Test one limitations

- i. First, the time factor. Since the test consisted of an analysis of ten products, and the researcher had to explain the symmetry rules, each focus group took between thirty-five and forty-five minutes; a heavy task for both the participants and the researcher.
- ii. Second, the researcher had to design the test, and re-design it twice more to obtain reliable answers, because many faults were exposed by the pre-test. The participants thought it was too difficult and did not understand what they had to do. For example, in the first test, the participants were asked to find the basic shapes in the ten Sadu products without showing them what the basic shapes were. In the second attempt, only five basic shapes were given. This time, the problem was that many participants could not break down the complex designs into these five basic shapes. All of this produced extra work and was also time consuming.

3.4 Primary data collection – test two

Seven developed design groups based on the knowledge gained from the previous test were created, each with a unique approach to creating patterns. This test helped the researcher in identifying which method produces the most recognisable patterns of the developed Kuwaiti Sadu, and what are the common rules in the seven groups that successfully generate this Kuwaiti style. Also the test measured the likability of the design group amongst Kuwaitis.

3.4.1 The scope of the research area

A questionnaire was conducted among the Kuwaiti public to explore the rules that can be used to generate a developed Sadu style. One hundred Kuwaitis participated in this test, and they were given seven groups of Sadu drawings, each group containing four examples (see figure 3.6). These groups represent the methods of developing a style. The participants were then asked two questions:

- Is this a Kuwaiti Sadu style?
- Do you like it?

The answers were written on the answer sheet using Likert scale, varied between 1, which was strongly disagree, and 5, strongly agree.

Based on the results, and from comparison of the groups, the researcher can decide which methods to use in order to make a tool that will help designers to efficiently maintain the cultural identity of the Kuwaiti traditional style, and to produce developed and consistent patterns.



Figure 3.6a: The developed Kuwaiti Sadu designs.



Figure 3.6b: The developed Kuwaiti Sadu designs.

3.4.2 Test two limitations

Printing the questionnaire consumed a large amount of paper. The test was printed on hard copies which amounted to over two hundred sheets. Posting the questionnaire on the Internet would have been ineffective because, from previous experience, a large number of participants would not have completed the test. Therefore, the researcher had to produce hard copies and put extra effort into persuading people to take part and complete the test; this was both time consuming and costly.

3.5 Primary data collection – test three

The aim of testing the design tool was to prove that the method used in developing a traditional style is successful and to find out whether the tool produces consistent Kuwaiti style patterns. The focus group consisted of two parts. First, the users had to spend some time using the tool to familiarize themselves with its functionality, then they were asked to write their opinions about the strengths and weaknesses of the software. Second, each user had to draw at least one pattern design. These were to be gathered together on a single sheet, and then incorporated into a questionnaire to be conducted on Kuwaitis, the purpose of which was to measure whether these

drawings could be recognised as Sadu style, and to find out whether there was consistency in the outcome (see figure 3.7).

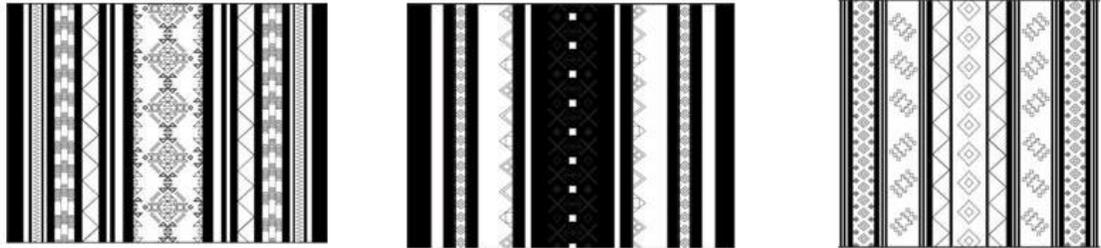


Figure 3.7: Pattern drawings.

3.5.1 The scope of the research area

Nine designers of different nationalities participated in the test, the non-Kuwaiti designers were not familiar with the Sadu style. That was important for this part of the research because the aim is not to create a tool that can only be used by Kuwaitis, but one that also non-Kuwaitis can use and still produce a developed Sadu style. The outcomes were expected to give an idea of the strengths and weaknesses of the software. The test was also expected to indicate whether the tool produces consistent developed Kuwaiti patterns by showing the drawings created by the designers to the public. Thirty Kuwaitis, with a range of ages, participated in the questionnaire, and for each drawing they were asked one question:

- Is this a Kuwaiti Sadu style?

The answers were written on the answer sheet and varied between 1, which was strongly disagree, and 5, strongly agree.

3.5.2 Test three limitations

First, the time factor. Since the researcher was unable to gather all the designers together in one focus group because of their dissimilar time schedules, he had to divide them into two groups,

explain the tool, and encourage them to use it. This process took forty-five to sixty minutes on each occasion, which required considerable effort and was time consuming.

Second, programming skills. The software is a prototype, which means that it is not a completed tool and it has flaws regarding functionality. This can be attributed to the researcher's lack of programming skills, since this is not his field.

3.6 Secondary data collection

Secondary data was obtained from previously published soft and hard copy materials, such as books, magazines and journals. Bournemouth University library was an important resource for secondary data collection including books, thesis and e-books (<http://prism.talis.com/bournemouth-ac/home>). Also some authorised websites were used to download journals such as Science Direct (<http://www.sciencedirect.com>), and theses were sourced from sites such as the British Library EthOS service (<http://ethos.bl.uk/Home.do>). The keywords that helped to find the published materials and define the project search process were: style, shape grammars, design rules, design elements, flash software, cultural identity and Kuwait. In addition, the materials related to Kuwait which were used to explore the origin of the state and its cultural identity were obtained either from Kuwaiti public libraries or bought from bookshops.

3.7 Summary

This chapter has discussed primary and secondary data collection methods. In primary data collection, the three tests were necessary in order to achieve the research objectives.

The first test were presented in section 3.3 which was intended to explore the common geometric shapes and symmetry rules in the traditional Sadu style. The test investigated one element and one rule of design for the following reasons:

- The aim of the research was to find a framework for designers to guide them in understanding and developing their cultural identity in design. When the proposed methods are established and their efficiency proved, then the other elements and rules of design can be applied to this system.
- The geometric shapes element and symmetry rule are the most important characteristics in Traditional Kuwaiti Sadu, as mentioned in the literature review chapter.
- Shape grammars consist of shapes, rules and the relationships between them. Thus it is important to identify the popular geometric shapes and symmetry rules in Sadu as a first step in determining the design language of that style.

The second test in section 3.4 was about measuring the seven developed design groups based on the knowledge gained from the previous test. This test helped to identify which method produces the most recognisable patterns of the developed Kuwaiti style. It also measured the likability of the design groups amongst Kuwaitis. Also the common rules in the seven groups that successfully generate this style were explored.

The third test, presented in section 3.5, was designed to test the tool and prove that the method used in developing a traditional style was successful. The test was also expected to indicate whether the tool produces consistent developed Kuwaiti patterns, and to give an idea of the strengths and weaknesses of the software.

In collecting the secondary information, the British and Kuwaiti libraries were used to make use of as many resources as possible to enrich the research. The sample of participants selected for the research was also explained and introduced and finally the drawbacks of the study were presented.

4 Identifying the style: measuring the style and shape grammar approach

4.1 Introduction

Chapter Four presents and analyses the results of elements and rules of design, generated from the first test in this study to achieve the aforementioned goals. The results of the test clarified the most common features of geometric shapes and symmetry rules among Sadu products and that directly influenced the methods which the study proposes. Then the design language of Sadu was explored using the shape grammars approach. These all fall within the scope of developing a traditional Kuwaiti pattern and finding out which method of pattern generation is most acceptable as a replacement for the traditional cultural style.

4.2 Test one feasibility

The questions in the focus group test were based on the problem presented in the previous chapters and on the points raised in the Literature Review. Those questions can be divided into two parts: 1.) those that aim to identify the most frequently repeated basic shapes amongst products that generate the complex designs of Sadu; and 2.) those that focus on the rules of symmetry, aiming to explore the types of symmetry in the products and to determine which are considered common features.

4.3 Data analysis

The questionnaire was distributed to 20 Kuwaiti citizens with ages ranging between 17 and 22.

10 persons were between 17 and 18 years.

10 persons were between 20 and 22 years.

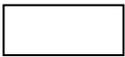
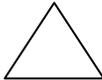
Kuwaiti citizens were selected to answer the questions because they are the subject of the study. All respondents were students and their opinions were obtained based on their education level.

4.3.1 The first test part one

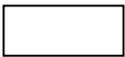
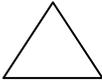
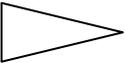
The participants of the two groups were given a chart of numbered shapes and when they recognised one of those shapes on a design, they were asked to write its number on the answer sheet.

Results:

- Strong common geometric shapes were identified amongst the ten designs - these were the most repeated shapes (see table 4.1a,b and c). For example; if the ten participants saw the rectangle in each product of the ten, then the number of repetition of that shape is one hundred.
- The top five common shapes in the first year design students' group were:

Shapes					
Number of repetitions	68	60	53	44	26

- The top five common shapes in the final year design students' group were:

Shapes					
Number of repetitions	92	76	60	52	49

- The researcher's top common shapes were as shown below. Answers were multiplied by ten so that they could be compared with those from the other two groups:

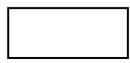
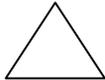
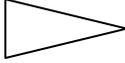
Shapes						
Number of repetitions	90	80	70	60	40	40

Table 4.1a, b and c : The common geometric shapes in the Sadu style.

The results show that some shapes are repeated more than others across products. By applying a similarity model based on the theory of feature matching it can be seen that there are common features between the focus groups (see figure 4.1). The model is:

$$S(A,B) = f(A \cap B) - f(A - B) - f(B - A).$$

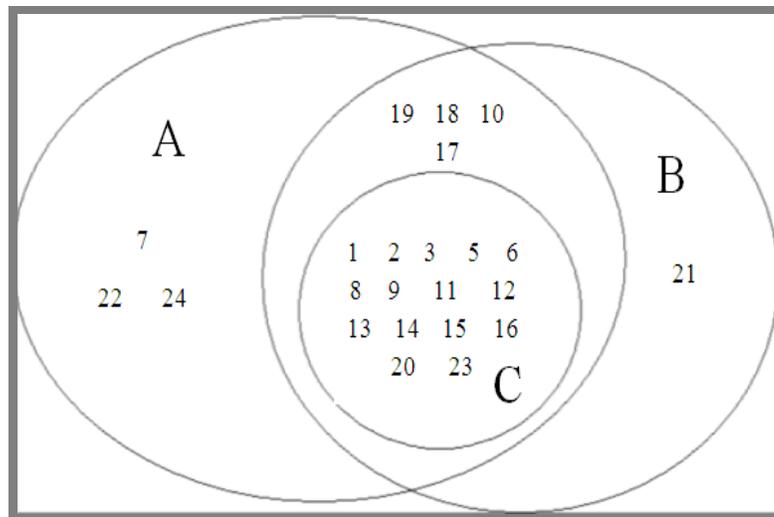


Figure 4.1: The diagram shows that there are fifteen common geometric shapes between the three groups. (A) first year design students, (B) final year design students, and (C) the researcher.

- $S(A,B) = 19 - 3 - 1 = 15 > 0$
- $S(B,C) = 15 - 5 - 0 = 10 > 0$
- $S(A,C) = 15 - 7 - 0 = 8 > 0$

Since all the results are positive, then there is similarity in the visual analysis of Sadu between the three groups. They also show that the researcher's answers have more in common with the designers than with the customers. This was done to ensure that the researcher does not analyse the style based purely on personal preference, failing to appreciate what participants see in it. Where the participant's perceptions are not taken into account, the outcome of the style revival process may not be considered a continuation of the original style.

4.3.2 The first test part two

The second part of the test, which involved finding the rules of symmetry in the product, was conducted on the same groups. Based on an explanation of the rules and what was to be analysed, the results show that there are some strong features which have been repeated in almost all the products (see table 4.2a,b and c), and there is similarity between the focus groups' answers (see figure 4.2).

Results:

- The top three common symmetry rules in the first year design students' group are:

Symmetry group	Pmm2	Pm11	P1m1
Number of repetitions	444	100	72

- The top three common symmetry rules in the final year design students' group are:

Symmetry group	Pmm2	Pm11	Pma2
Number of repetitions	410	96	81

- The researcher's top common symmetry rules are:

Symmetry group	Pmm2	Pm11	Pma2	P1m1
Number of repetitions	410	130	80	80

table 4.2a,b and c: Top common symmetry rules in the Sadu style.

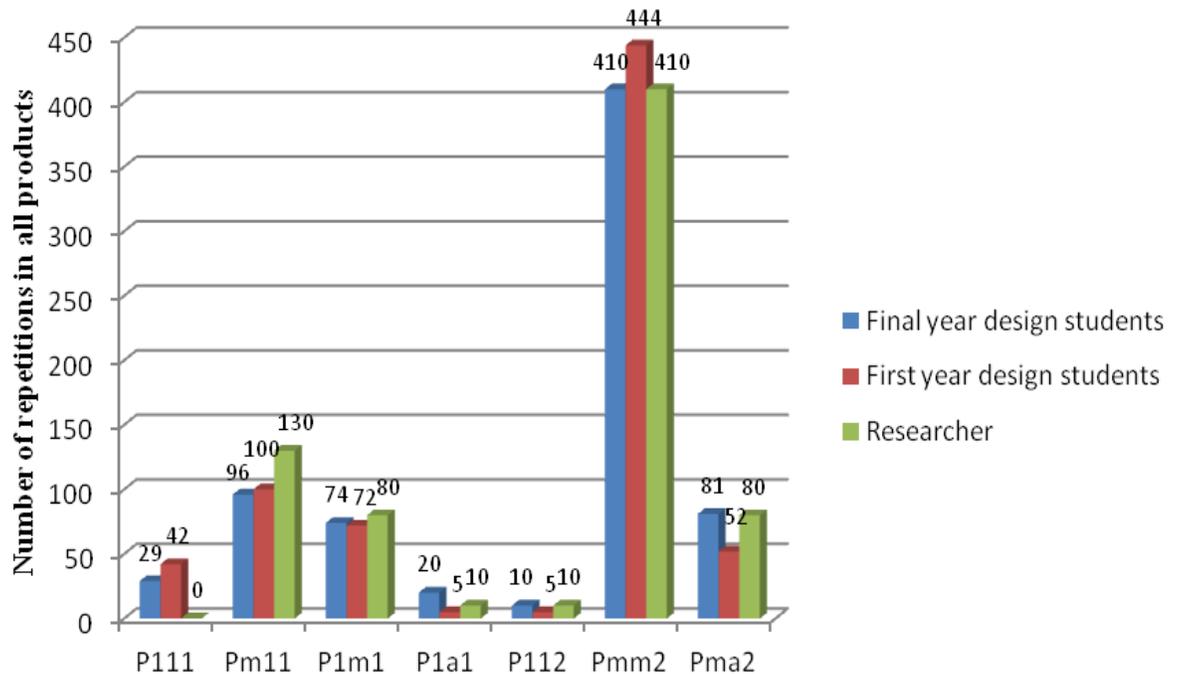


Figure 4.2: Diagram of the common symmetry groups in the ten products. Note: the researcher multiplied his answer by ten.

From the findings, and comparison of the researcher's answers with the two groups, it is easy to identify the symmetry rules of many borders and most participants were able to do this correctly. In the case of a few borders, neither of the two groups were able to identify the rules (see appendix A).

4.4 Shape grammar analysis

As mentioned in the review chapter, shape grammar consists of rules that are applied to initial shapes to create the language of design. So far, the common shapes for various Sadu have been identified. The next step is to identify the rules that generate the language of the Sadu style. A table was created which was used as a model for recognising and modifying the spatial relationships between the designs in this research (see table 4.3).

Shape Rules (production- analyse- modify)			Symmetry categories					
Attach	Reflection Horizontal	Reflection Vertical			S *632	S 4*2		
Not attach	Rotation $\Theta=45^\circ-360^\circ$	Cut			S 632	S *442	S 2*22	
Overlapping	Glide- reflection	Bend		S pma2	S **	S 442	S *2222	
Proportion Up	Move	Change angles		S plm1	S pmm2	S *X	S 3*3	S 22*
Proportion Down	Add	Change outline Length	S dn n=1-∞	S pm11	S p112	S XX	S *333	S 22X
Substitute	Delete	Change outline Width	S cn n=1-∞	S p111	S p1a1	S O	S 333	S 2222

Table 4.3: Design rules table.

The table consists of rules that are divided into two categories:

1. Shape rules, whose main function is to create and develop the patterns. They are:

- Attach: the initial shape is attached to another shape.
- Not attach: there is distance between the shapes.
- Overlap: one shape covers part of another.

- Proportion: proportion is linked to ratio. When scaling up or scaling down an image, the change occurs within the dimensions, preserving the ratio between the width and the height.
- Substitute: replacing one shape with another.
- Reflection: is an axial symmetry by which a shape is repeated by producing its mirrored image across an imaginary straight line, known as a reflection axis.
- Rotation: is a movement of an object around a centre of rotation.
- Add: adding a new shape to the existing ones.
- Delete: removing a shape from the group.
- Cut: deleting one or more vertices from the shape.
- Bend: making the lines and angles curvier.
- Changing angles: moving the vertices from one place to another.
- Changing outline: manipulating the width and length of the shapes.

Figure 4.3 demonstrates the generation process of traditional Kuwaiti Sadu using design rules table. The starting point of the design is the choice of the initial shape. Then the shape rules specify the type of original design that is generated.

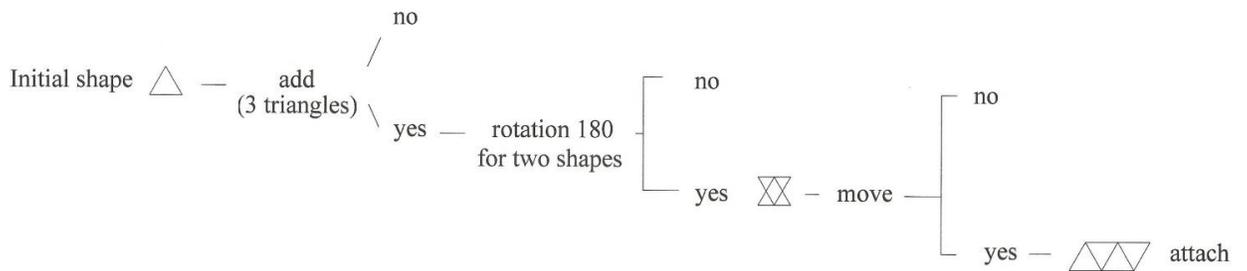


Figure 4.3: Generation process.

2. Symmetry rules, which consist of finite patterns, band patterns, and all-over patterns. This second set of rules follows the creation of the new design language and is concerned with space filling. Each of the three types of symmetry rule will provide a unique filling for the developed design. Here is an example (figure 4.4) of symmetry space filling based on the outcome of figure 4.3.

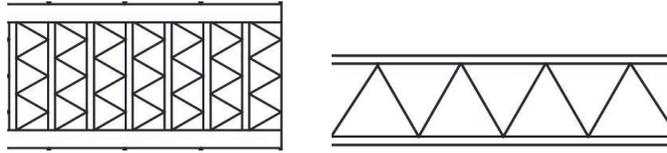


Figure 4.4: On the left-hand side is a band pattern design class p1m1, which has horizontal mirroring only. On the right-hand side is a band pattern design class pma2, involves vertical mirroring, glide reflection and rotation.

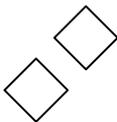
Now, to test the efficiency of the design rules table, it was necessary to construct the original Sadu designs using the shape grammar process. If the shape rules employed manage to create the original design, this constitutes proof that the table works. If not, then more rules need to be added.

Figure 4.5 presents the process of generating one original Sadu design, and is divided into the following steps:

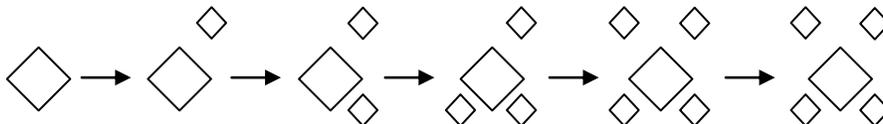
1. Choosing one of the strong geometric common shapes as a first step in the shape grammar process. That shape is a diamond;

Initial shape 

2. Using shape rules to create the spatial relationship of the design. These are known as the production rules, and they are;

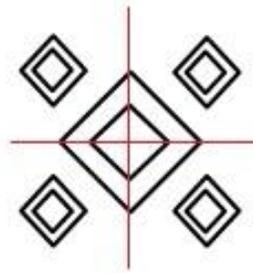
- Add  , move  , proportion and not attached 
 - Add  , proportion and overlap 

3. Applying the rules within the shape grammar software (SGI), to obtain all possible derivations;



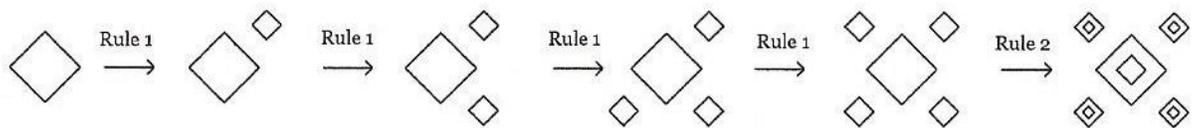
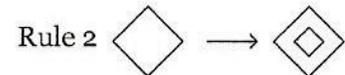
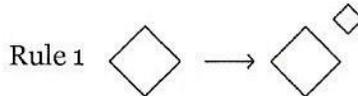
4. Analysing the final design and finding out what rules it has. These are known as the analysis rules, and they are one of the key aspects of modifying the style and comparing between the designs. The analysis rules for the design in step three are: not attached shapes, overlap, proportion, vertical reflection, horizontal reflection and S_{dn} , where $n=4$ (finite design). Note that the design has a glide reflection but the author did not include it in the analysis rules because when a vertical and horizontal reflections appear in a design they do the same functionality as glide reflection.

The final design

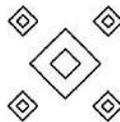


Initial shape 

Production Rules :



Analysis Rules for the final design :



Not attach shapes, Overlapping, Proportion, Vertical Reflection, Horizontal Reflection and S_{dn} , where $n=4$

Figure 4.5: The process of constructing the original Sadu design.

Table 4.4 gives more examples of the process of generating original Sadu designs using the shape grammar method:

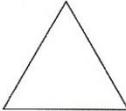
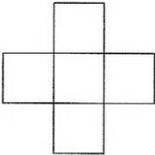
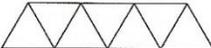
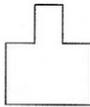
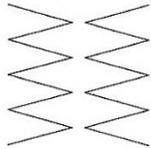
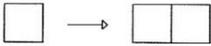
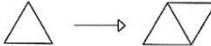
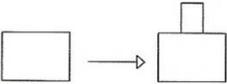
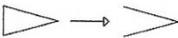
Shape grammar of designs based on one initial shape				
	1	2	3	4
Initial shapes				
Designs				
Production rules	Add, Move, Attach	Add, Move, Rotation 180 degree, Attach.	Add, Move, Proportion, Rotation 90 degree, Attach, Cut.	Add, Move, Cut, Attach, Not attach, Reflection.
Shape rules			 attach → cut	  
Analysis rules	Attach, Reflection v, Reflection h, Sdn _{n=4}	Attach, Reflection v, Glide-reflection	Reflection v	Not attach, Reflection v, Reflection h, Sdn _{n=2}

Table 4.4: Shape grammar tables.

This table contain designs created from one initial shape and they are distinguished by their simple form. Here is an example to presents the process of generating the design language for design number two in the above table by the following these steps:

1. The first step is choosing the initial shape. That shape is a triangle;

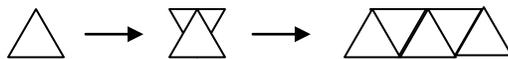
2. Initial shape 

3. Using shape rules to create the spatial relationship of the design;

Production rules: Add and rotation 180 degrees. 

Then move and attached. 

4. Applying the rules within the (SGI) software, to obtain all possible derivations.



5. The analysis rules for the design in step three are: attached shapes, vertical reflection and glide reflection.

After identifying the process for generating the shape grammar in the Sadu designs, twenty designs of the Sadu style were analysed which categorised into two groups; ten designs created from one initial shape, and ten designs created from multiple initial shapes (see appendix B). The designs with one initial shape have simple forms, whereas those with multiple initial shapes have a more complex appearance. This step was taken to explore the production and analysis rules in the two groups and to find the strong design rules that shaped the style. By ‘strong rules’ we mean those which are most repeated among the designs. For example, if a rotation rule were present in nine designs out of ten, then the weight of that rule would be nine which would make it a strong rule. The weight of the production and analysis rules will play a significant role in the next chapters especially when developing the design tool.

So after specifying the production and analysis rules for each design in both groups, the weight of the design rules is clear. Having in mind that Chan (Chan, 2000) has proved that the number of common features and rules required to identify a style should be three or more, the researcher has discarded those rules that are weighted less than three and kept those that are repeated three times or more among the designs.

The shape grammar for the Kuwaiti Sadu style shows that the original designs with one initial shape mostly using the following production rules (see figure 4.6a and b): Add, Move, Attach, Not attach, Cut and Rotation. Whereas the analysis rules which are found most often are: Vertical reflection, Horizontal reflection, Attach, Not attach and Sdn.

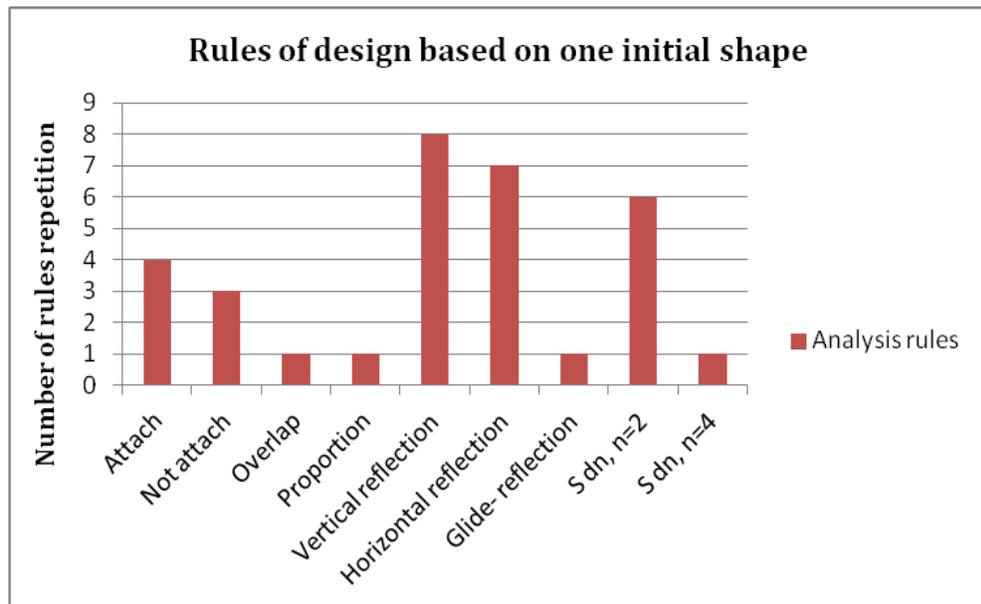
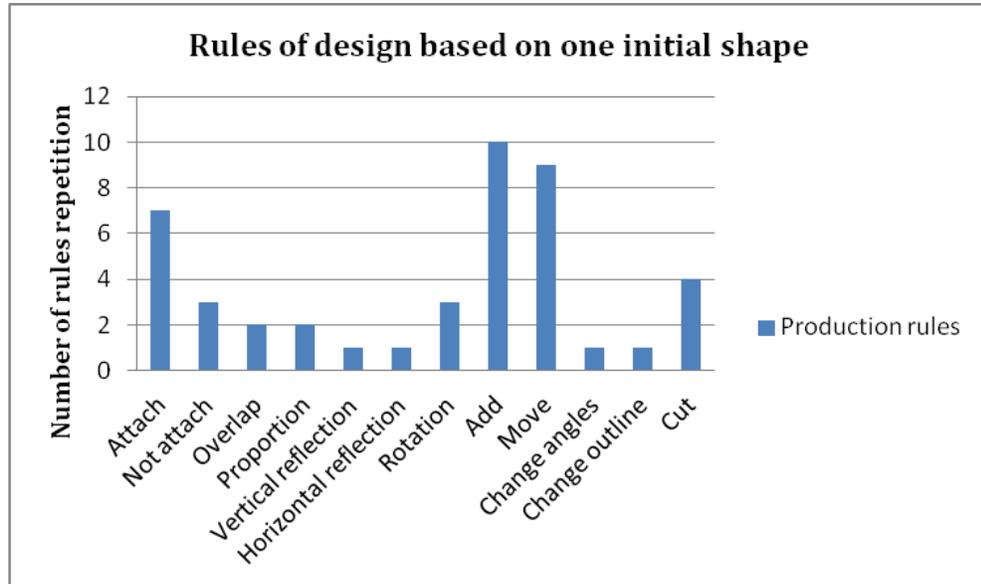


Figure 4.6a and b: The strength of the production and analysis rules in the Sadu designs created from one initial shape.

The original designs with multiple initial shapes are related to these production rules (see figure 4.7a and b): Add, Move, Cut, Proportion, Attach, Overlap, Vertical reflection and Horizontal reflection. Whereas the analysis rules which are found most often are: Vertical reflection, Horizontal reflection, Overlap, Proportion and Sdn.

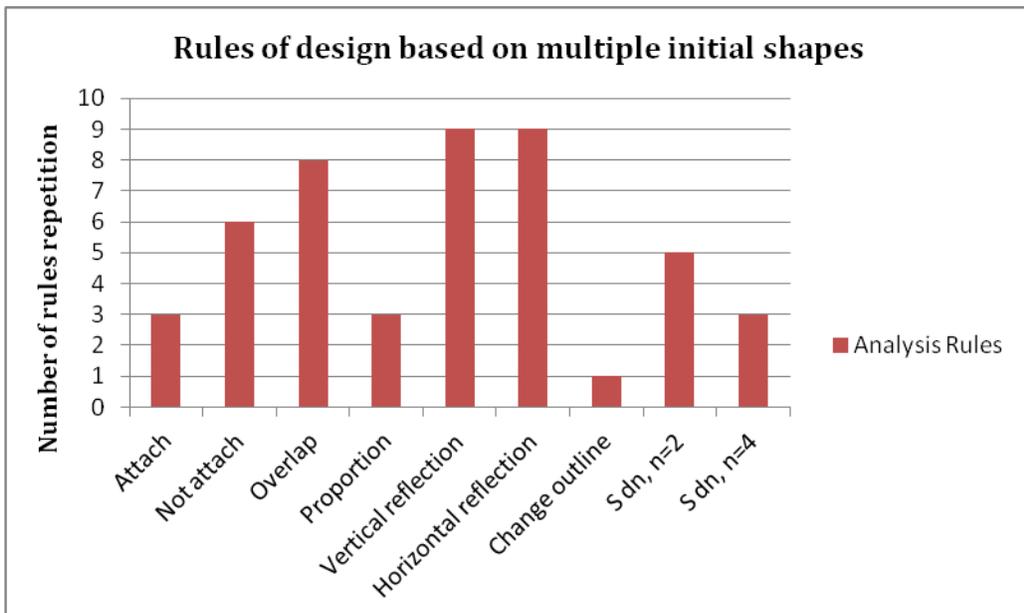
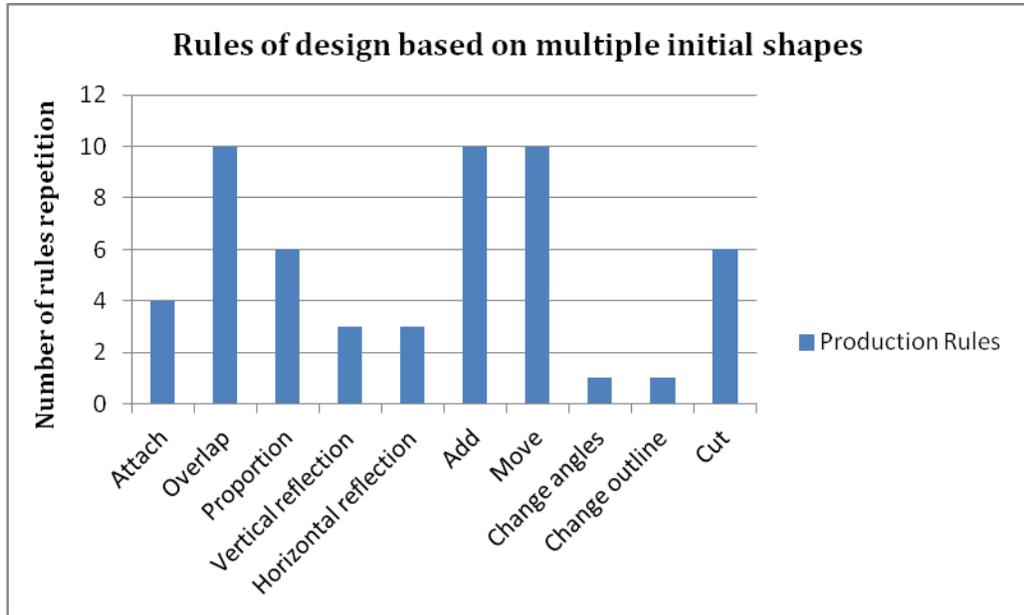


Figure 4.7a and b: The strong production and analysis rules in Sadu designs created from multiple initial shapes.

4.5 Modifying the shape grammar

After identifying the style and its spatial relations, the next step is to modify it. The method considered in this research was to manipulate the shape rules to create new spatial relations which would lead to a new design language. There are three possibilities, and they are:

1. Changing the production rules.
2. Changing the analysis rules.
3. Adding new rules.

Here are some examples (figure 4.8a, b and c) of how the new patterns could be generated based on figure 4.5:

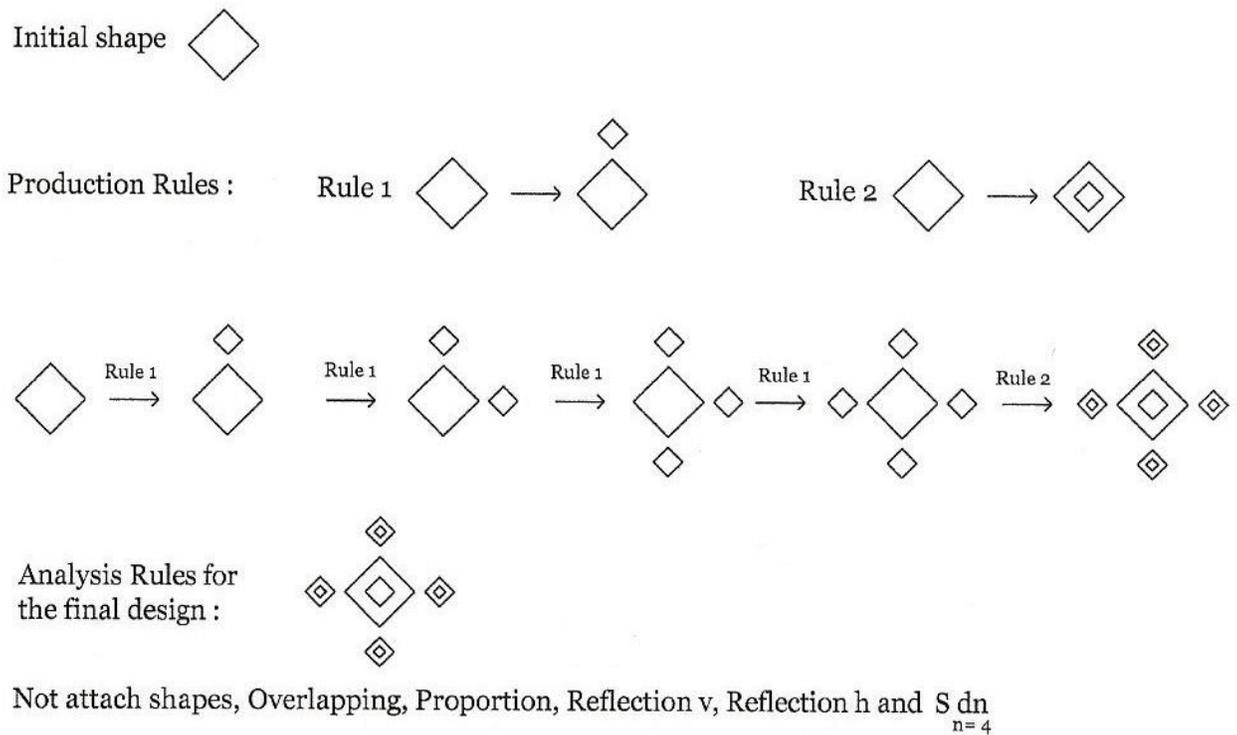
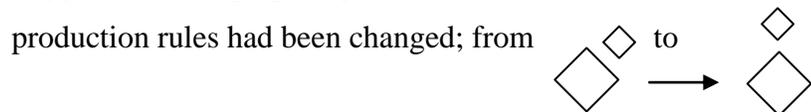
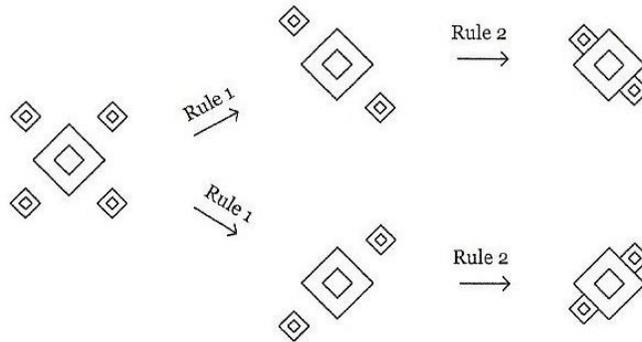


Figure 4.8a: Modify type one; Changing the production rules. The first rule in the original



Rule 1 : $S_{n=4}^{dn} \longrightarrow S_{n=2}^{dn}$

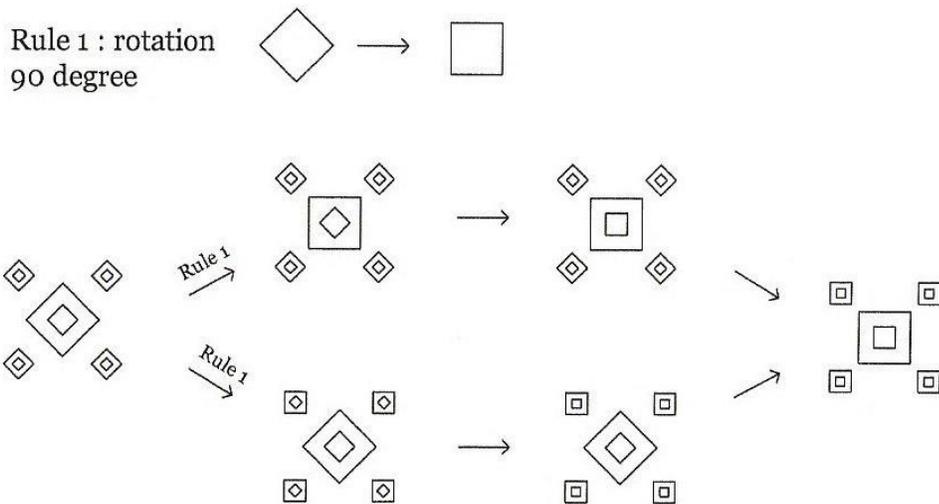
Rule 2 : not attach \longrightarrow attach



Analysis Rules for the final design :

Attach shapes, Overlapping, Proportion and $S_{n=2}^{dn}$

Figure 4.8b: Modify type two; Changing the analysis rules of the final design.



Analysis Rules for the final design :

Not attach shapes, Overlapping, Proportion, Reflection v, Reflection h and $S_{n=4}^{dn}$

Figure 4.8c: Modify type three; Adding new rules in the process of production.

The production rules specify the type of design that is generated. Changing these rules or adding new ones creates new spatial relations which will lead to a new design language. In figure 4.9, each level in the design tree contains numbers that represent the rules applied in that stage. This method will help in writing the formulas of the required design language, and to organize the process of patterns development. For example, the formula of the second design in table 4.4 is; 1,1,2,2.

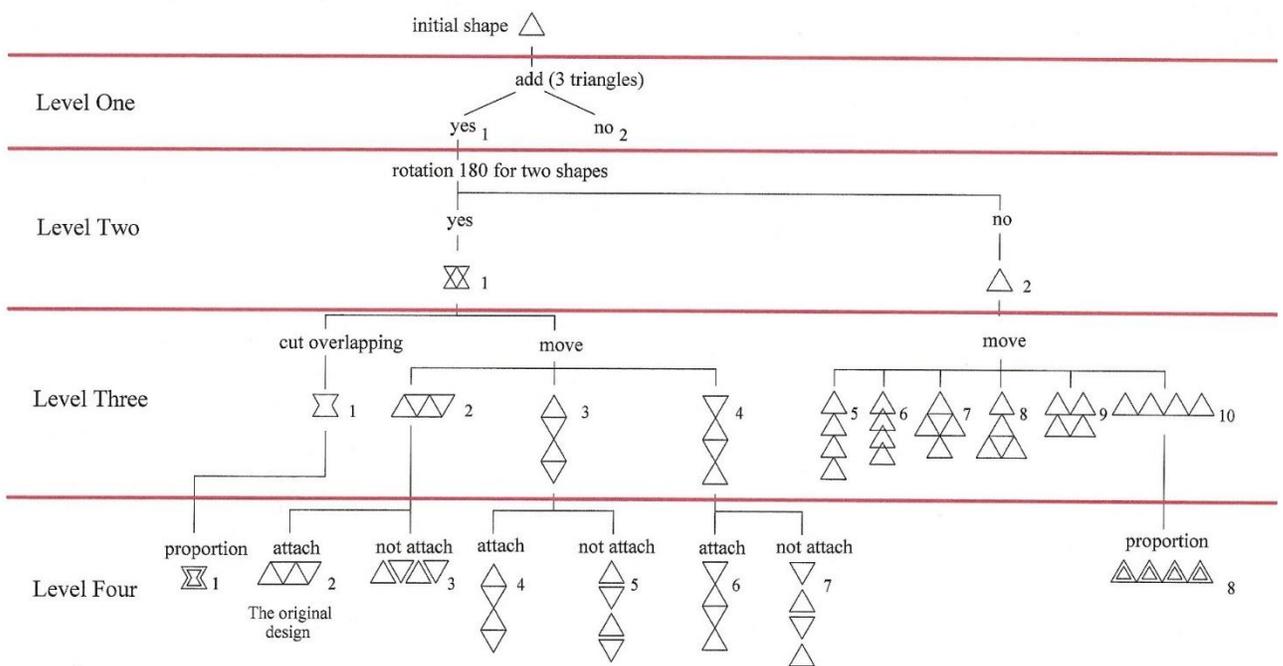


Figure 4.9: Design tree.

4.6 Summary

In this study, the Kuwaiti Sadu style was defined by exploring the common features. There was a specific set of shapes and symmetry rules which appeared in the majority of the tested products. Finding these features was the first half of identifying a style. The second half was exploring the spatial relationships between the shapes and design rules in the designs. The

shape grammar of the products was determined by creating a table that contained rules for constructing and modifying the language of the Sadu design.

In the next phase of the research a test is conducted amongst Kuwaitis to determine whether the method used has produced recognisable new Sadu patterns. The results will give a clear idea of the stage of the modification process at which the design lost or maintained its original identity.

5 Modifying the style

5.1 Introduction

Many researchers have discussed the issue of developing style to prevent it from been forgotten. Among other things, they have considered how to analyse style by exploring common features (Chan, 2000), and how to analyse and develop shapes using shape grammar as a means of identifying and modifying the design language of the style (Knight, 1981; Stiny, 1980), and how to retain aesthetic style brand DNA in a new design concept (Eves and Hewitt, 2009). In this chapter, all of this knowledge has been used and implemented it in a test that tries to develop a certain style and at the same time maintain its cultural identity.

5.2 The seven design groups

Seven design groups were created, each with a unique approach to creating patterns. The groups will help to identify which method produces the most recognisable patterns of the Kuwaiti Sadu style, and what are the common rules in the seven groups that successfully generate this Kuwaiti style. Also the test will measure the likability of the design group amongst Kuwaitis, because there is no point in investing in a method that produces Kuwaiti patterns which people do not like, or choosing a method where people like the patterns but where the original style is lost.

The first three groups are methods of generating new Sadu style by using the original designs but with different arrangements using symmetry rules. The next two groups are created by changing the design language of the original style using the shape grammar method. The last two groups are a combination of two styles, Kuwaiti and Islamic. The rules in the design rules table were used to create the designs in the seven groups.

5.2.1 Group A: designs created from one initial shape

In this group the patterns are created from one original design that is repeated based on symmetry rules. These designs are made by one initial shape and that is what gives them their simple form. There are four examples of this method, and each one contains unique features regarding the design or the symmetry rule (see figure 5.1). What follows is an explanation for each example:

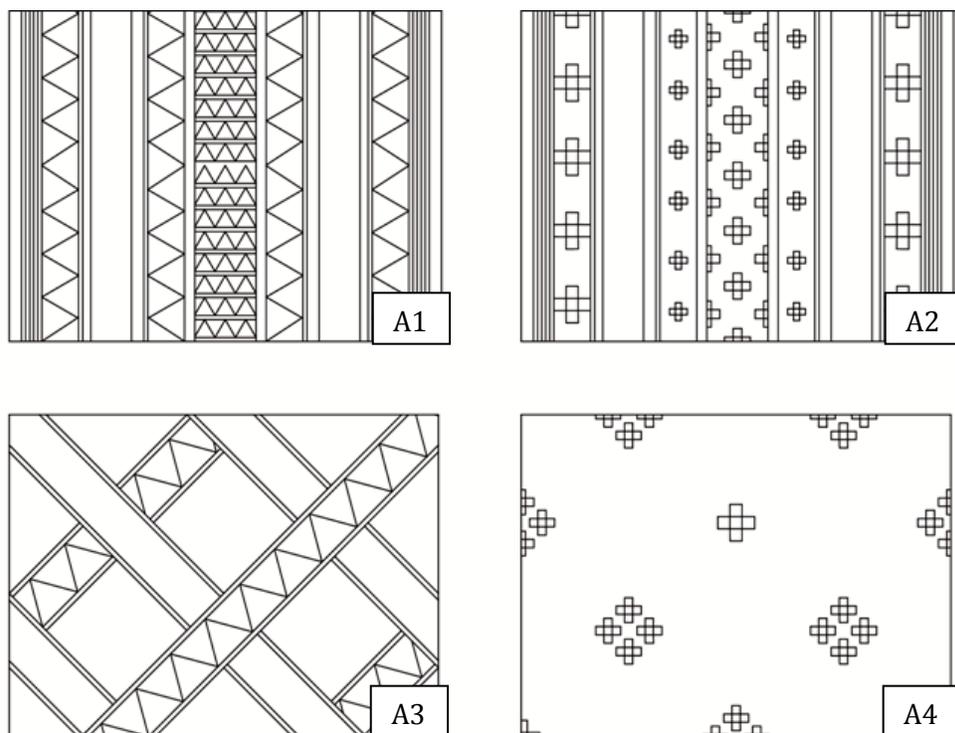


Figure 5.1: Group A.

- A1: this is a popular design created from the triangle as an initial shape. The researcher then applied the production rules from the design rules table using shape grammar interpreter software to generate the original design (see table 5.1). The twist in this example is that the researcher applied non-popular symmetry rules in the Kuwaiti Sadu style based on the result of the first test that the researcher conducted. So in four borders used the rule Pma2 which has a vertical reflection, glide reflection and rotation. On the border in the middle he used P1m1 which contains only a horizontal reflection (see figure 5.2).

For designers who are not experienced in using symmetry rules, there is software available which they can use to apply the rules to their designs, such as Symmetry Works for illustrator (see appendix C).

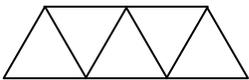
Initial shape	Design	Production rules	Shape rule
		Add, Move, Rotation 180 degree, and Attach.	

Table 5.1: Shape grammar.

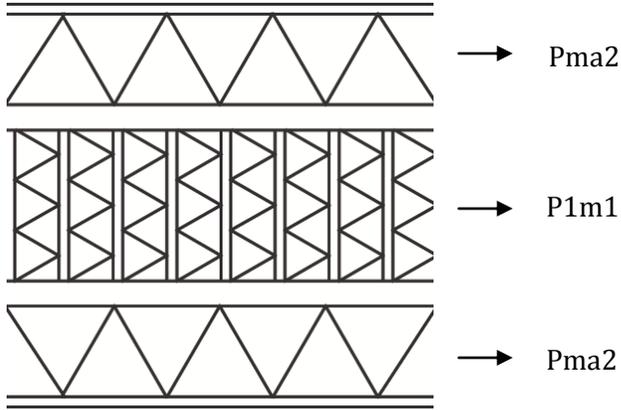


Figure 5.2: Symmetry rules.

- A2: the design used in this example is seen in some Sadu parts and it is not as popular as the previous design. The initial shape of this design is the square and the production rules are add, move and attach (see table 5.2). In here the most powerful (most seen by participants in the first test) symmetry rule in Sadu was used, which is Pmm2 and has vertical reflection, horizontal reflection and rotation, and he applied it to the five borders (see figure 5.3).

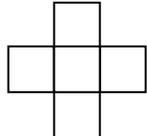
Initial shape	Design	Production rules	Shape rule
		Add, Move, Attach.	

Table 5.2: Shape grammar.

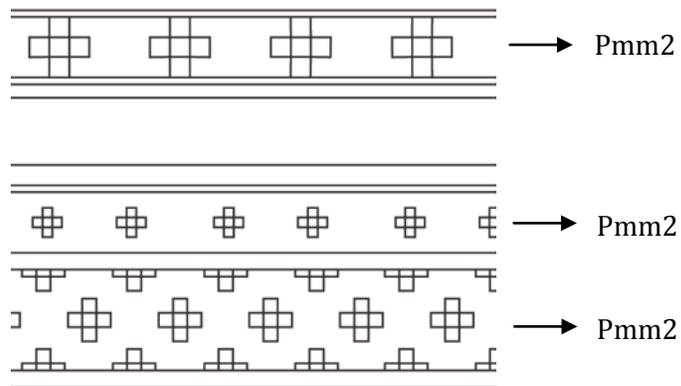


Figure 5.3: Symmetry rules.

- A3: the borders of this design use the Pma2 rule as in example A1 but by changing the borders' angle, instead of making them vertical, they lean by 45 degrees. This was done to measure whether changing the angle of the borders affects the perspective of the Sadu style.
- A4: in this example the researcher used the design in A2 but did not apply any borders. Instead he used the all-over patterns rules (symmetry rules) and in particular the rule P4m.

5.2.2 Group B: designs created from multiple initial shapes

When compared with group A, this group consists of more complex original Sadu designs, due to the use of multiple initial shapes in their creation. Only a single design is applied to the four examples but with different arrangement (see figure 5.4), and here is an explanation of them:

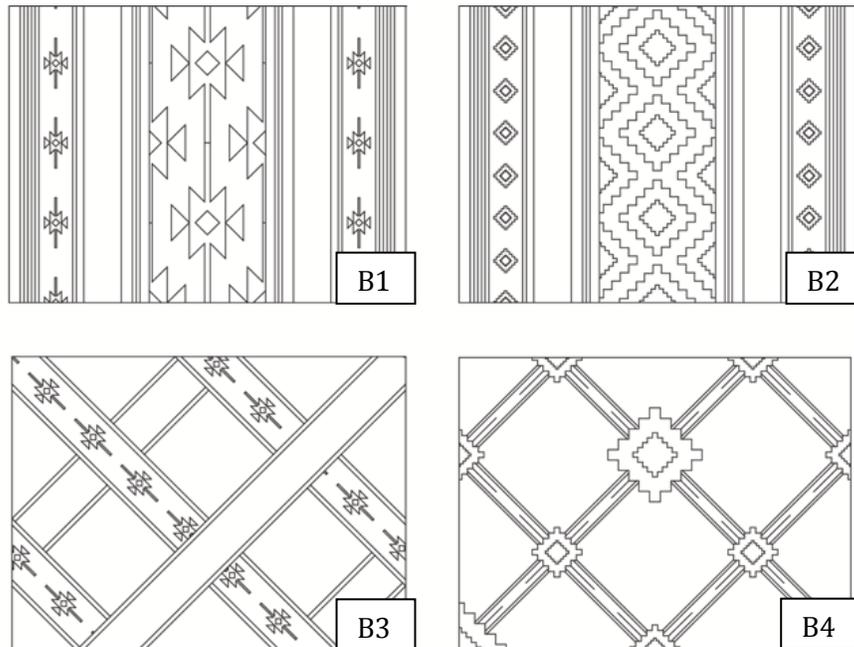


Figure 5.4: Group B.

- B1: the initial shapes that created this design are the triangle and rectangle, to which the production rules were applied to generate the original design (see table 5.3). The symmetry rule used in the three borders is Pmm2, and this is one of the popular designs of the Sadu style (see figure 5.5).

Initial shape	Design	Production rules	Shape rule
		Add, Move, Reflection, Proportion, Cut, Overlap	

Table 5.3: Shape grammar.

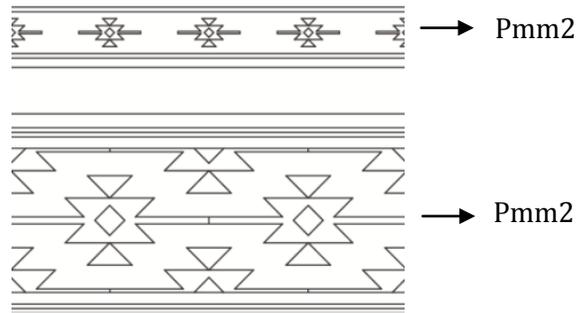


Figure 56: Symmetry rules.

- B2: the design in this example is also a popular design in Sadu and is created initially from the diamond and square (see table 5.4). The rule used to fill the borders is Pmm2 (see figure 5.6).

Initial shape	Design	Production rules	Shape rule
		Add, Slide, Proportion, Attach, Cut, Overlap.	

Table 5.4: Shape grammar.

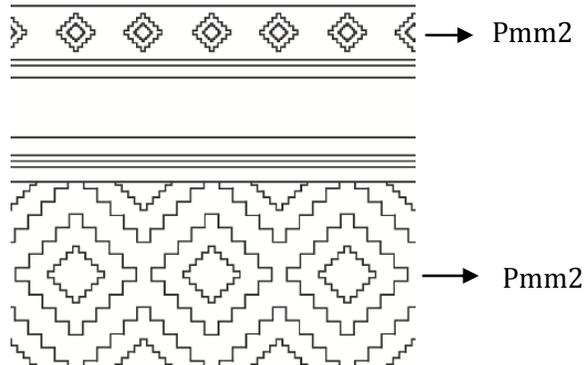


Figure 5.6: Symmetry rules.

- B3: this example has the same border design as B1 but the border angle is changed. Instead of 90 degree angles they are 45 degree angles.
- B4: the design here is taken from B2 and it is placed outside the borders. The borders are used as background for the design.

5.2.3 Group C: this group is a combination of groups A and B

In this group the researcher combined methods from groups A and B using four designs as a maximum to create the examples. The first two drawings have vertical borders, the third and fourth are combinations of diagonal borders and the all-over pattern style (see figure 5.7). This method produces patterns similar to the original style but the difference between them is that the original Sadu contain more than seven designs per piece whereas in this group the maximum is four. Note also that the way of arranging the designs inside the borders is different; Group C depends mainly on repeating each design in a separate border, whereas in the original Sadu more than five designs are placed inside one border.

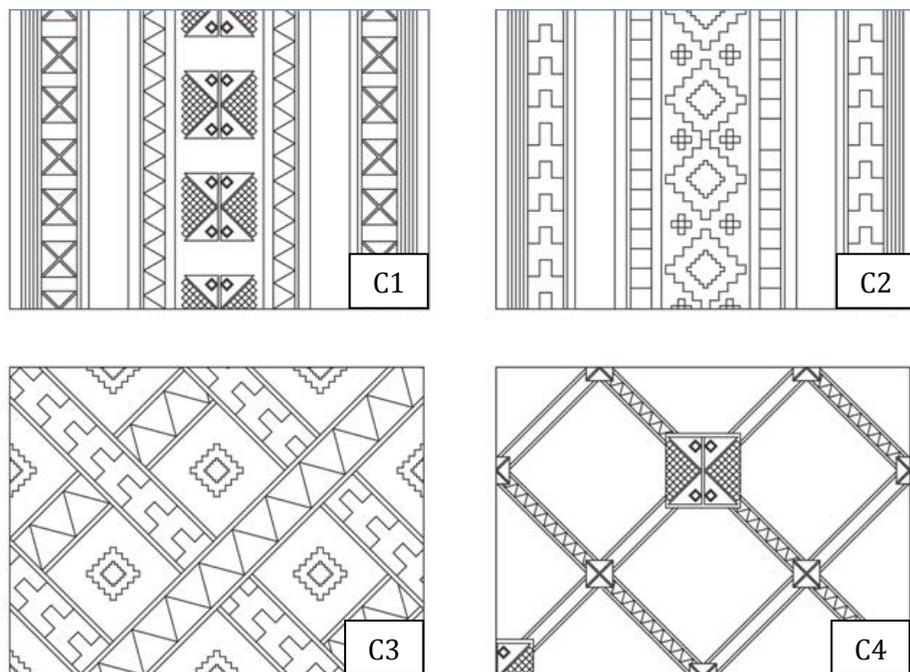


Figure 5.7: Group C.

- C1: this example contains one design created from one initial shape and two designs created from multiple initial shapes. The symmetry rules in the borders are Pmm2 and Pma2 (see figure 5.8).

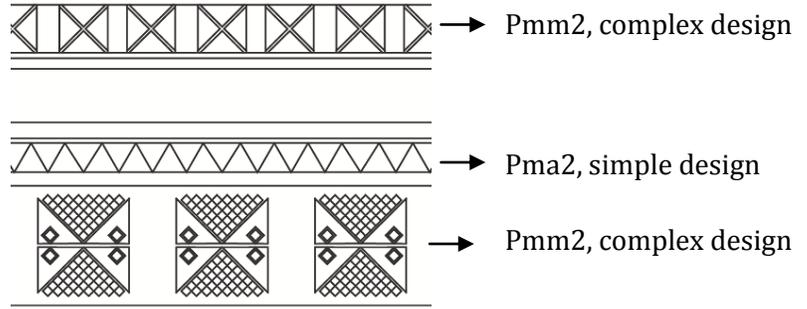


Figure 5.8: Symmetry rules and design type.

- C2: three designs created from one initial shape and one design created from multiple initial shapes are used in this example. There are two symmetry rules in the borders; P1m1 and Pmm2 (see figure 5.9).

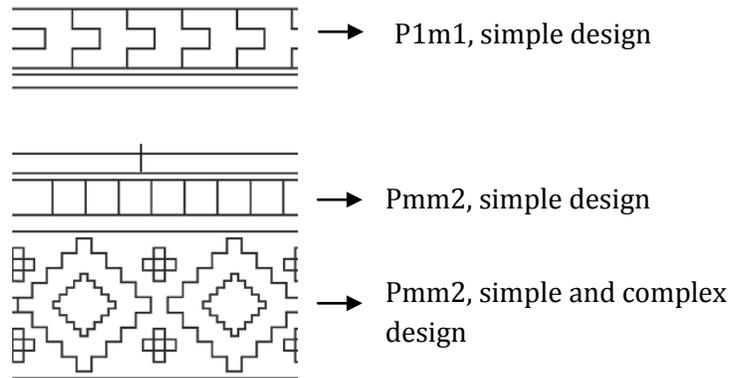


Figure 5.9: Symmetry rules and design type.

- C3: the example here is created from one simple design taken from C1 and two designs from C2. One of them is simple and the other is complex. Also two types of space filling were used, all-over patterns P4m and border pattern rules Pma2, P1m1.
- C4: the example here is created from the designs in C1. The two designs made from multiple initial shapes are placed without borders using all-over pattern rule Pmm, and the design with one initial shape is used inside the borders in the background.

5.2.4 Group D: designs created from a single design tree

The method used for this group was to change the shape grammar of the original style by using the design rules table, either by changing the production rules or adding new rules. Then the different possibilities of the modified process were used to form a design tree that would help in creating new design languages. Contrary to the first three groups, which were based on creating patterns by using the original designs and setting aside personal preferences, groups D & E are based mainly on the designer preferences to combine designs from different production process stages in the design tree and generate new designs. This will allow the researcher to measure how much the design can be stretched without losing its identity (see figure 5.10).

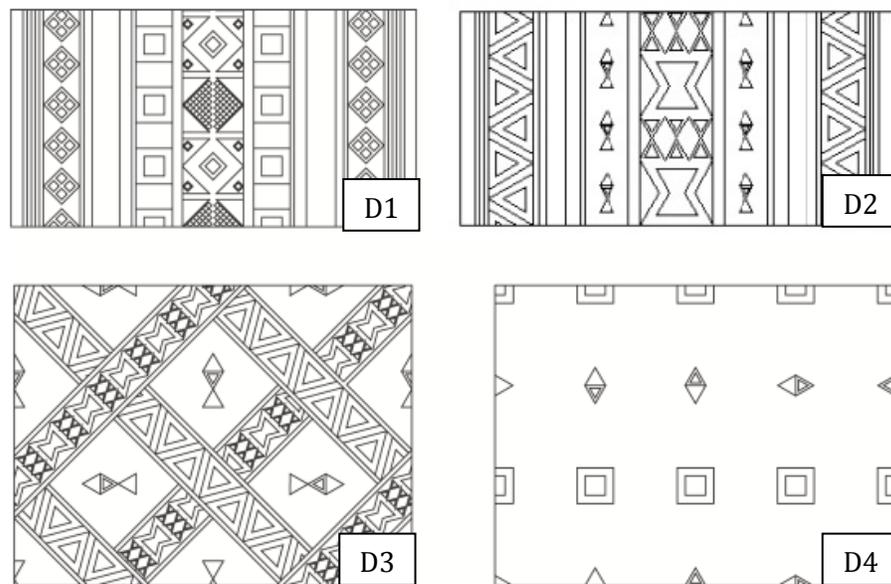


Figure 5.10: Group D.

- D1: all the patterns in this example are created from one design tree. In each border there is either a design taken from the process of creating the design language of the Sadu style or a combination of two designs (see figure 5.11). For example:
 1. The design in the first border has the code (Level three 1) from the design tree in figure 5.11.
 2. The second border has a design with the code (Level three 5).

- The centred border contains two designs. One of them has the code (Level three 2) combined with (Level six 2), and the second design has the code (Level two 7) combined with (Level four 1).

The symmetry rule used in all borders is Pmm2. Although the original design from which the researcher created the design tree has multiple initial shapes, the designs used in the first two borders are designs created from one initial shape whereas the centred border contains designs made from multiple initial shapes. This gives a sense of variety to simple and complex patterns (see figure 5.12).

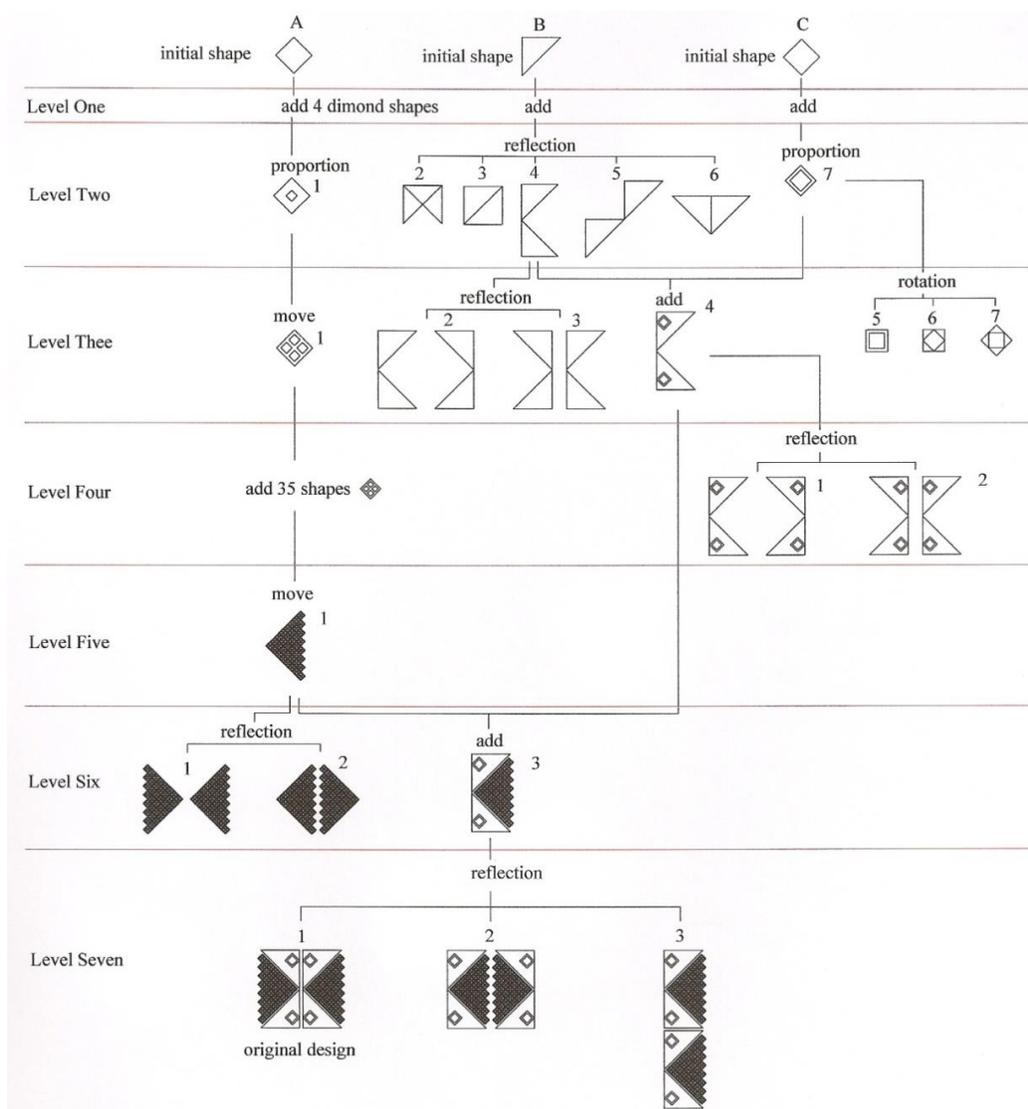


Figure 5.11: Design tree.

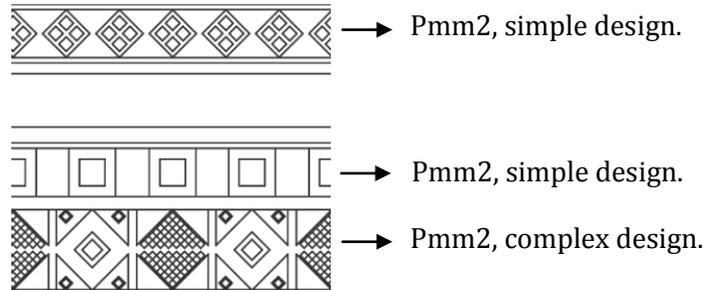


Figure 5.12: Symmetry rules.

- D2: the design tree for this example is created from one initial shape and that gives the designs a sense of unity and consistency since they all share the same initial shape which is a triangle. As in example, in D1 the patterns in the borders are designs taken from different stages of the production process, and the symmetry rules used are Pma2, P1m1 and Pmm2 (see figure 5.13).

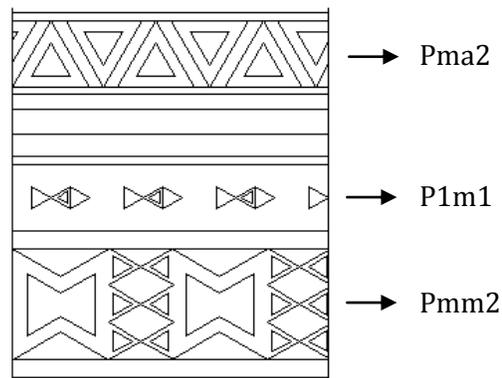


Figure 5.13: Symmetry rules.

- D3: this example contains the designs of D2 but the angle of the borders is changed, so that they are diagonal. Thus the symmetry rules in the borders are the same as those of D2 and the design that is not inside a border follows the P4g all-over pattern rule.
- D4: this example contains designs taken from a tree with multiple initial shapes. The symmetry rule used here is Pmg which is an all over pattern.

5.2.5 Group E: designs assembled from different design trees

In this group the method used to produce the Sadu style is similar to that of the previous group, which is to create a design tree that contains modified designs via shape grammar, and then to combine the designs from different production stages and place them in the borders. Now, however, we are using multiple design trees to produce a single sophisticated design (see figure 5.14).

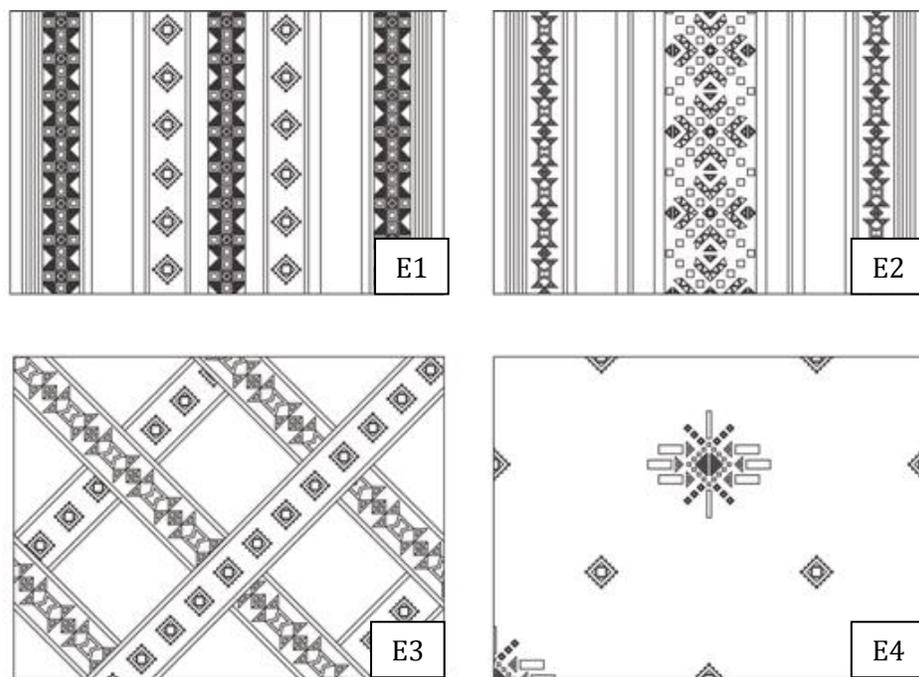


Figure 5.14: Group E.

- E1: the designs in this example are produced by combining designs from two different design trees. For example, for the pattern in the central border, the researcher used both the tree used in figure 5.11 and the one used in figure 5.15. The designs taken from figure 5.11 are (Level two 7, Level four 1 and Level five 1), and the design taken from figure 5.15 is Level four 2). Then these designs were combined to form a sophisticated design (see figure 5.16). The symmetry rule used in the borders is Pmm2 (see figure 5.17).

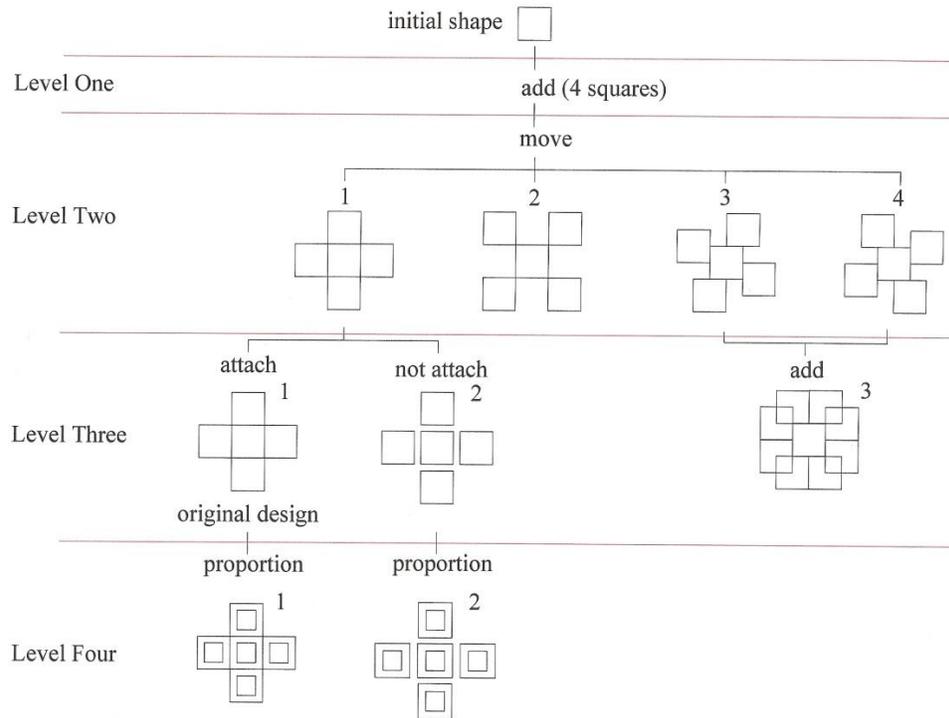


Figure 5.15: Design tree.

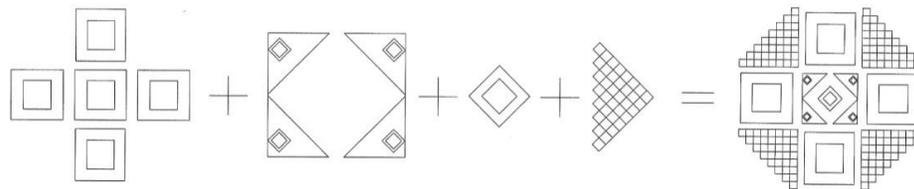


Figure 5.16: The bases of the new design.

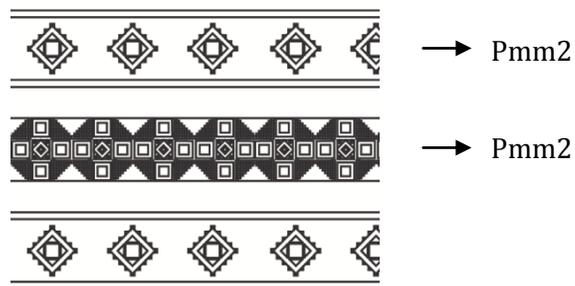


Figure 5.17: Symmetry rules.

- E2: in two borders of this example, the design is created from two design trees, whereas the design in the central border is created from more than three trees (see figure 5.18). The symmetry rule used here is Pmm2 (see figure 5.19).

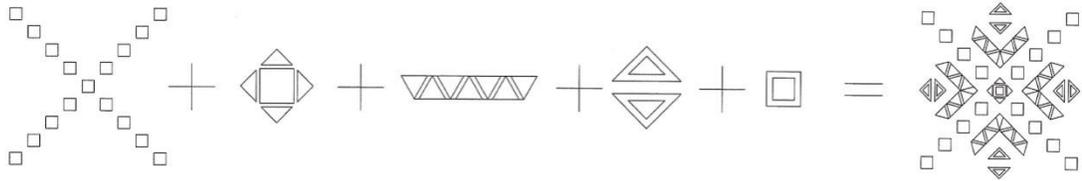


Figure 5.18: The bases of the new design.

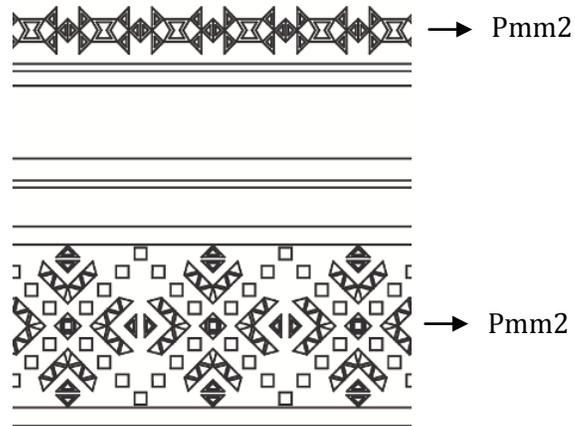


Figure 5.19: Symmetry rules.

- E3: the diagonal borders contain one design from E1 and the other from E2 and they are both created from two design trees.
- E4: the large design in this example is a sophisticated one that is created from more than three design trees, whereas the small one is created from two. The symmetry rule used here is Pmm .

5.2.6 Group F: combining two styles (same common features)

This group is an attempt to combine two different styles with the same characteristic to test whether this method will produce a notable and likable Kuwait Sadu design. The two styles are Kuwaiti Sadu and geometric Islamic designs (see figure 5.20).

Geometric patterns are a prominent and fundamental element of Islamic culture and its architecture and are to be found in materials such as carpets, tiles, doors, wood and bricks. Islamic patterns come in three types: Kufic calligraphic designs, arabesque (leafed and floral form) and geometric space filling patterns.

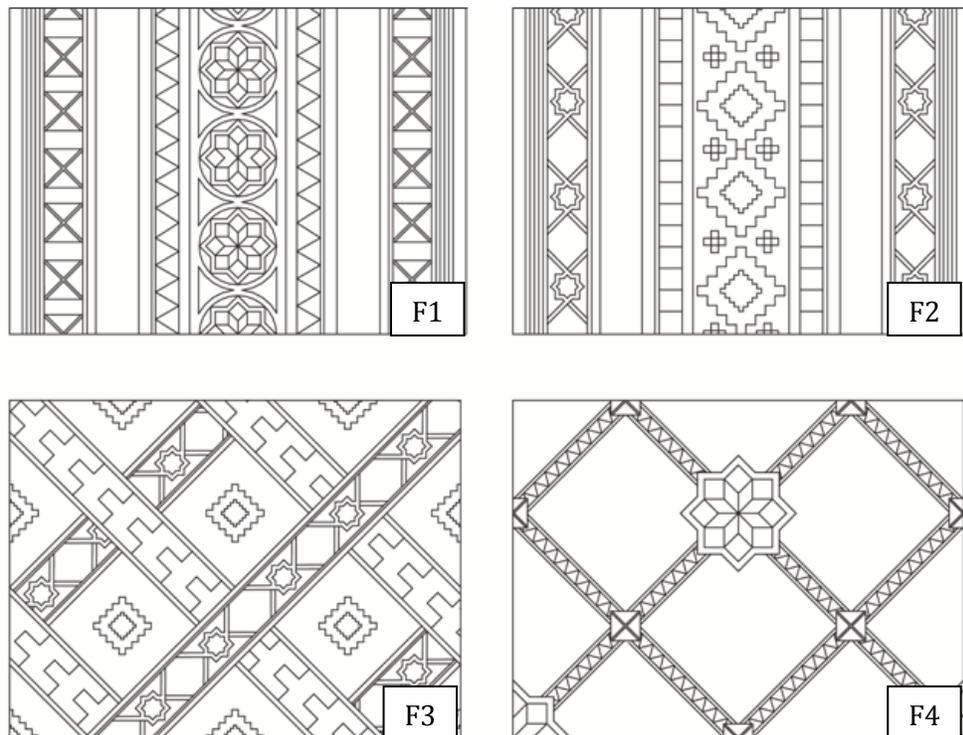


Figure 5.20: Group F.

- F1: in this example two original Sadu designs were used, one of them simple and the other complex, and placed them in separate borders. An Islamic design, which is created by combining a horizontal square with a diagonal one and placing a small design made of diamond shapes in its centre, is located in the central border and repeated using the Sadu popular symmetry rule Pmm2 (see figure 5.21).

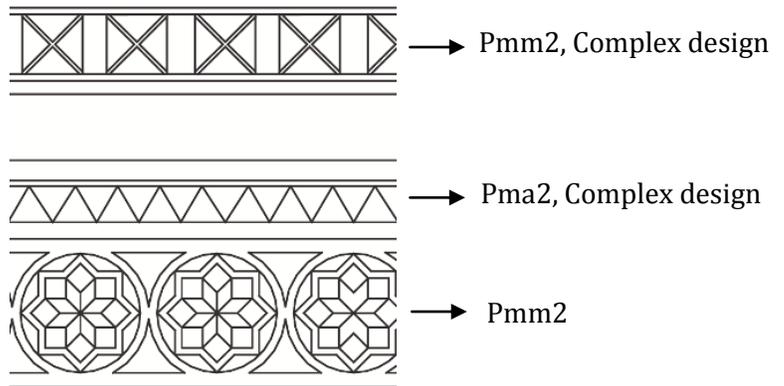


Figure 5.21: Symmetry rules.

- F2: the same concept as used in F1 is used here (see figure 5.22).

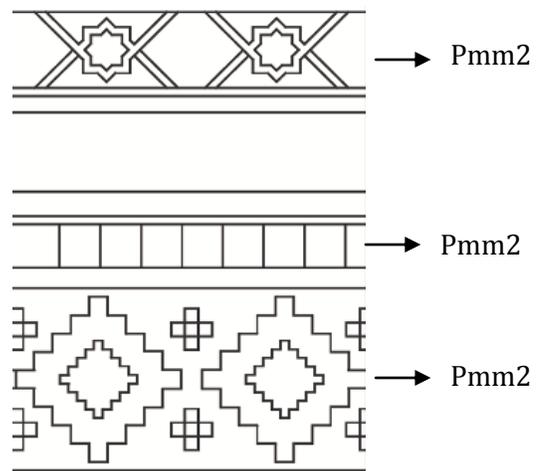


Figure 5.22: Symmetry rules.

- F3: one of the diagonal borders contains a simple original Sadu design, the other contains Islamic design, and the background contains a complex original Sadu design repeated in accordance with symmetry rule P4m.
- F4: the Islamic and Sadu patterns outside the borders are repeated using rule P6m and the pattern inside the border is repeated using Pma2.

5.2.7 Group G: combining two styles (different features)

The method used here to develop the Kuwaiti style is the same as in group F but using a style with different characteristics. The Islamic designs were also used but this time he chose the organic arabesque (see figure 5.23).

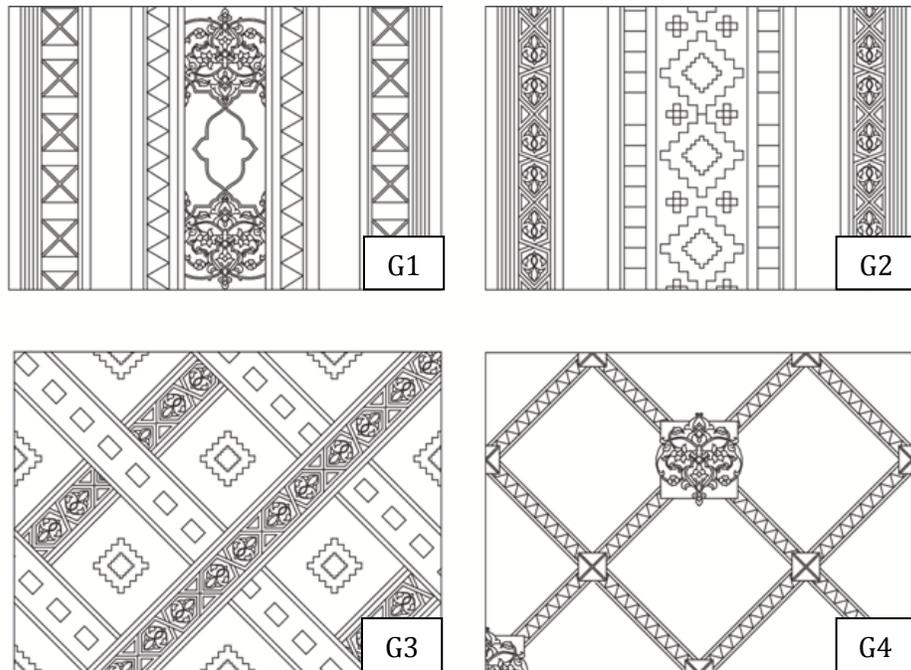
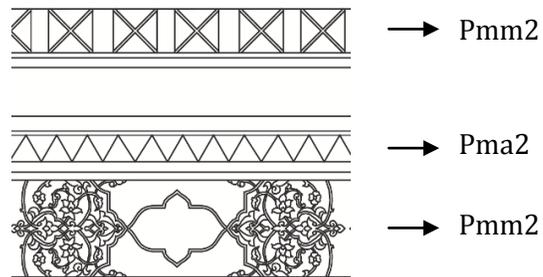


Figure 5.23: Group G.

- G1, G2, G3 and G4: the researcher used the same borders that contain the original Sadu style from group F, and placed the new Islamic organic patterns in the place of geometric Islamic ones. The symmetry rule for the new Islamic design is Pmm2 in the first three examples (see figure 5.24a and b).



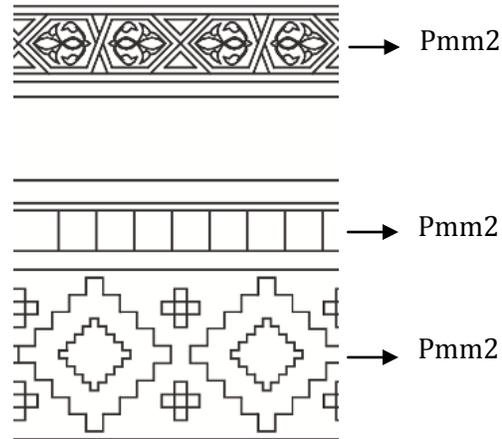


Figure 5.24a and b: Symmetry rules.

5.3 Testing the seven design groups

A questionnaire was conducted among Kuwaitis to explore the rules that can be used to generate a developed Sadu style. One hundred Kuwaitis participated in this test; forty-nine women and fifty-one men (see figure 5.25). Their ages ranged between eighteen and over sixty (see table 5.5).

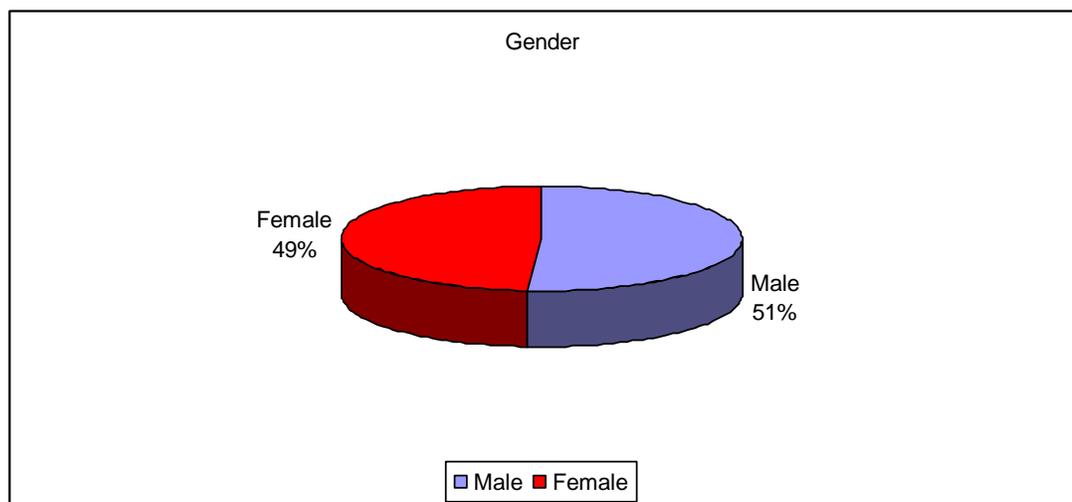


Figure 5.25: Gender category.

Age range	Number of participants
18- 30	49
31- 40	32
41- 50	15
Over 60	4

Table 5.5: Age range and the number of participants.

The participants were given seven groups of Sadu drawings, each group containing four examples. These groups represent the methods of developing a style. The participants were then asked two questions:

- Is this a Kuwaiti Sadu style?
- Do you like it?

The answers were written on the answer sheet and varied between 1, which was strongly disagree, and 5, strongly agree.

5.4 Test results

5.4.1 Reliability test

The patterns were evaluated for style reliability using Cronbach's α (alpha) method (Allen and Yen, 2002). Cronbach's α (alpha) is a coefficient of reliability. It is commonly used as a measure of the internal consistency or reliability of a survey for a sample of respondents and can be computed with the aid of SPSS Software. Internal consistency measures whether several items that propose to measure the same general construct produce similar scores. A commonly-accepted rule of thumb is that a Cronbach's α (alpha) of 0.6-0.7 indicates acceptable reliability, and 0.8 or higher indicates good reliability. The table 5.6 shows that the overall reliability for

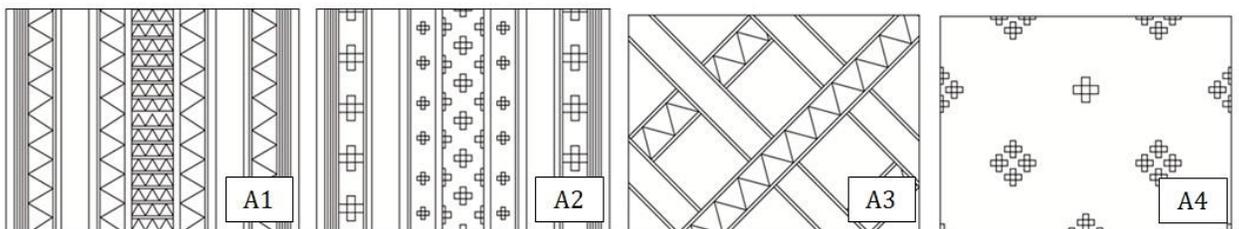
both recognition and likability is high. The measure for each group is also indicative of reliability.

Recognition			Likability		
Groups	Cronbach's Alpha	N of Items	Groups	Cronbach's Alpha	N of Items
A	.689	4	A	.601	4
B	.729	4	B	.676	4
C	.752	4	C	.695	4
D	.614	4	D	.669	4
E	.753	4	E	.638	4
F	.786	4	F	.718	4
G	.720	4	G	.667	4
Overall	.936	28	Overall	.919	28

Table 5.6: Reliability test.

5.4.2 Evaluating the methods: recognition

Group A: Q1, Is this a Kuwaiti Sadu style?



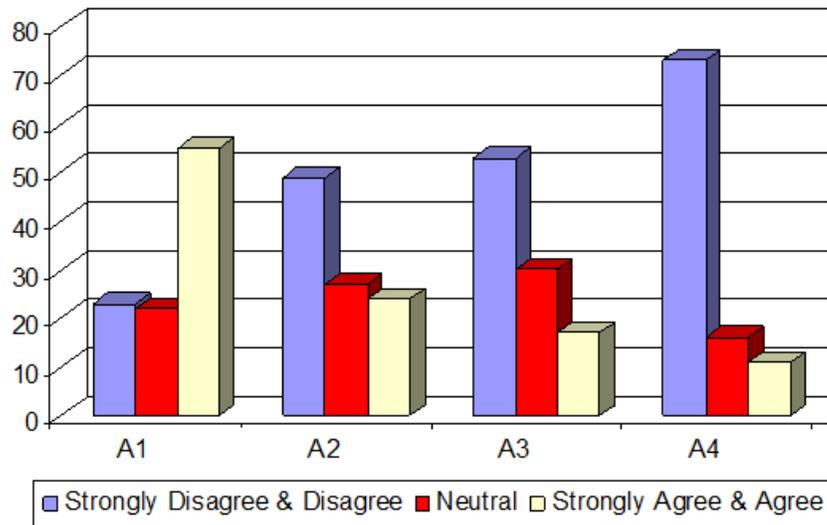


Figure 5.26: Recognition chart of group A.

The result in figure 5.26 shows that:

- A1 is the most recognisable example of Kuwaiti Sadu style among the four examples. A very popular Sadu design which is made of triangles was chosen and repeated it inside the borders using non popular symmetry rules in Sadu style. The result shows that people will recognise popular designs even if it applied using non popular symmetry rules.
- In example A2, non popular Sadu design was used, applied to it a very popular symmetry Sadu rule, and then repeated it inside the borders. The results show that the majority of participants did not recognise the A2 example as a Kuwaiti style, which means that the effect of the designs looks regarding the perception of a style is more significant than how it is arrange inside the borders.
- The participants in example A3 did not recognise it as a Sadu style although it has the same pattern as A1, and this is attributed to the change in border angle.
- A4 also is not recognised as Sadu because there are no borders and the design is not popular Sadu style.

Group B: Q1, Is this a Kuwaiti Sadu style?

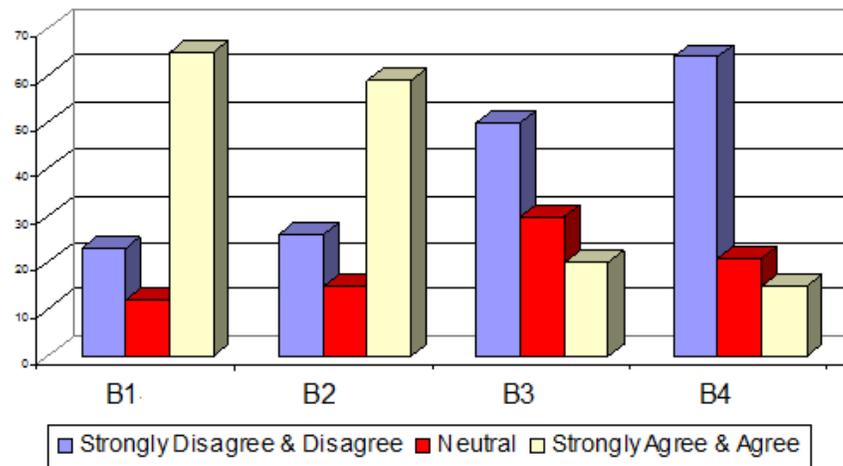
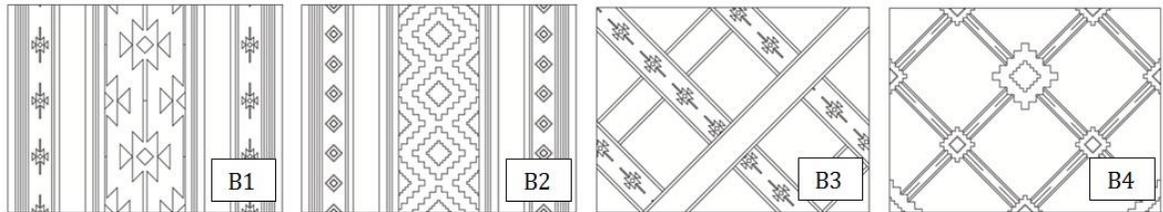


Figure 5.27: Recognition chart of group B.

Figure 5.27 shows that:

- B1 and B2 are both recognised as Kuwaiti Sadu style. They both contain popular Sadu designs and they share the same symmetry rules, but the result shows that A1 is more Kuwaiti. That is probably because Kuwaitis lean towards the original Sadu designs which have a triangle as part of their structure.
- B3 is not recognised as Sadu style although it has the same design as B1; because of the diagonal borders it has lost the original style.

In example B4 the researcher removed the designs from inside the borders of B2 and placed them over diagonal borders, but still this is not recognisable as Kuwaiti Sadu style.

Group C: Q1, Is this a Kuwaiti Sadu style?

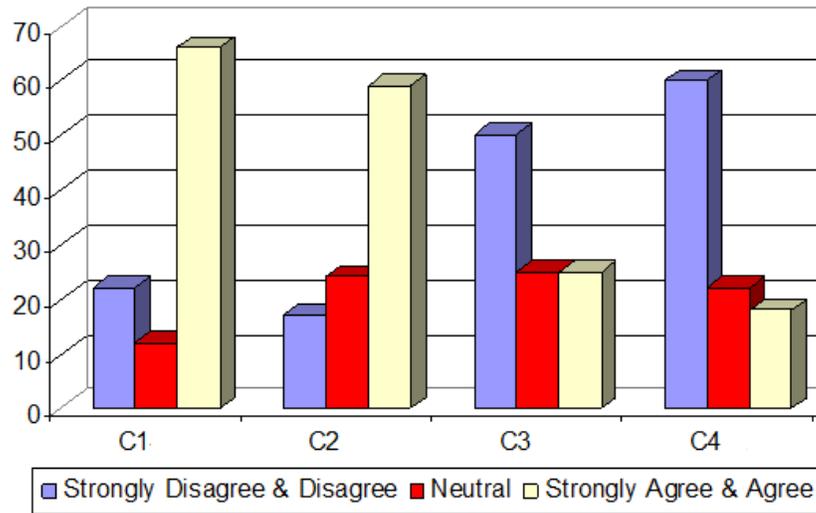
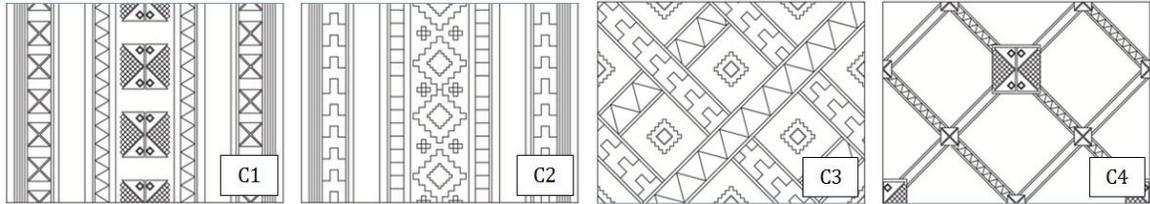


Figure 5.28: Recognition chart of group C.

The result in figure 5.28 shows that:

- C1 and C2 are both recognised by participants as Kuwaiti Sadu style because the method of creating the patterns in this group is similar to the original style which combines groups A and B. The difference between them is that group C has four designs as a maximum in each example whereas in the original style the number of designs in each piece is more than seven in most cases. Also the arrangement of the design inside the borders is different from the original.

C3 and C4 are not recognised as Sadu because of the diagonal borders and the designs arranged without borders, although these are the same designs as in C1 and C2.

Group D: Q1, Is this a Kuwaiti Sadu style?

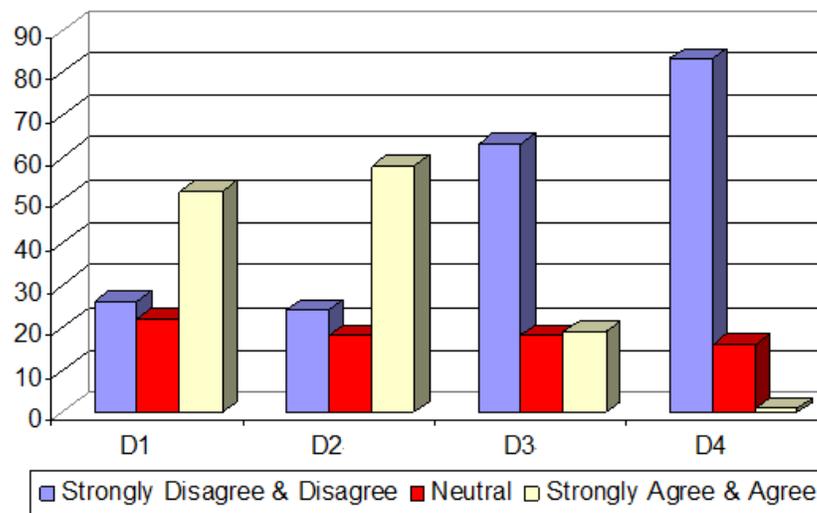
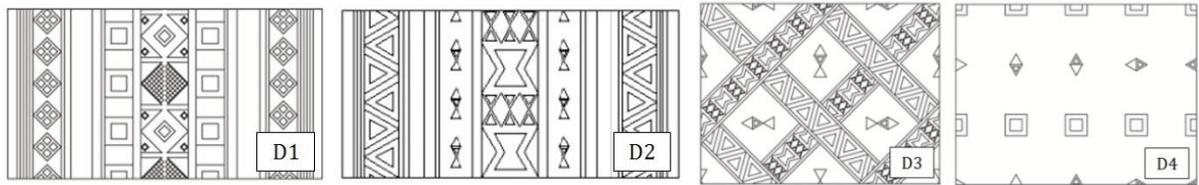


Figure 5.29: Recognition chart of group D.

The result in figure 5.29 shows that:

- D2 is the pattern most recognised as Sadu among the four examples. All the designs are modified and came from the same initial source which is the triangle.
- As the results show, D1 is not far behind D2 and is also recognised as Kuwaiti Sadu style.
- D3 is not recognised as Sadu although the designs used in it are from D2. The borders have changed from 90 degrees to 45 degrees and one of the designs has been placed outside the borders.

The majority did not recognise D4 as Sadu style. This is because the designs are not placed inside borders and they were taken from the early stages of production which meant they had formed none of the character of the Sadu style.

Group E: Q1, Is this a Kuwaiti Sadu style?

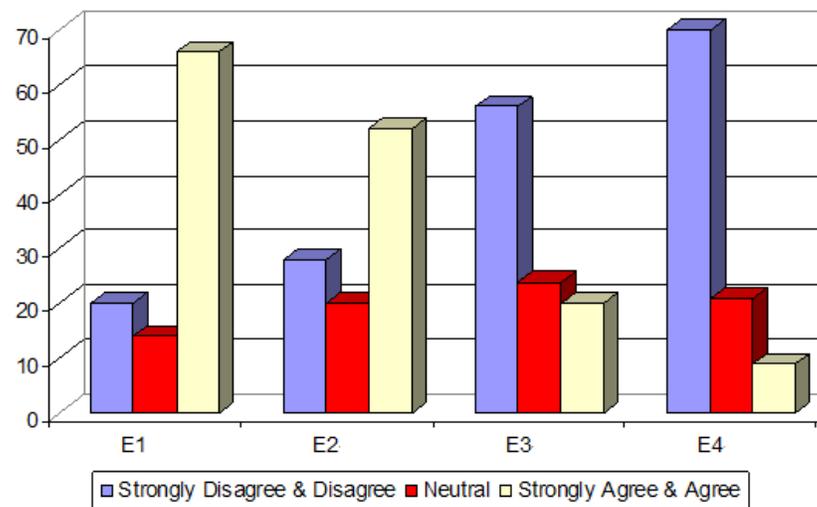
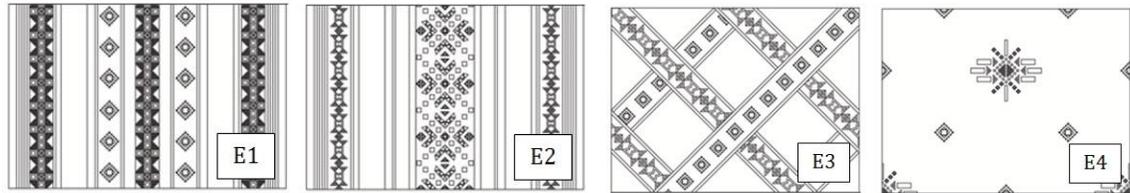


Figure 5.30: Recognition chart of group E.

The result in figure 5.30 shows that:

- E1 is the drawing which is most recognisable as Kuwaiti Sadu style among the four examples. The designs in it are made of two design trees and the symmetry rule used here is the most popular rule in Sadu.
- E2 is also recognised as Sadu and it came in second place but with a big difference in results compared to E1, as shown in the results. More than three design trees were used to create the design in the middle border and that is what made the participants unsure whether this design was Sadu. Also the symmetry rule used here is the same as that in E1.

- E3 is not recognised as Sadu although it has designs created from two design trees and used in the first two examples; the difference here is that the borders are diagonal ones instead of vertical.

E4 is the least recognised example. It has no borders and the large design is drawn from more than three design trees.

Group F: Q1, Is this a Kuwaiti Sadu style?

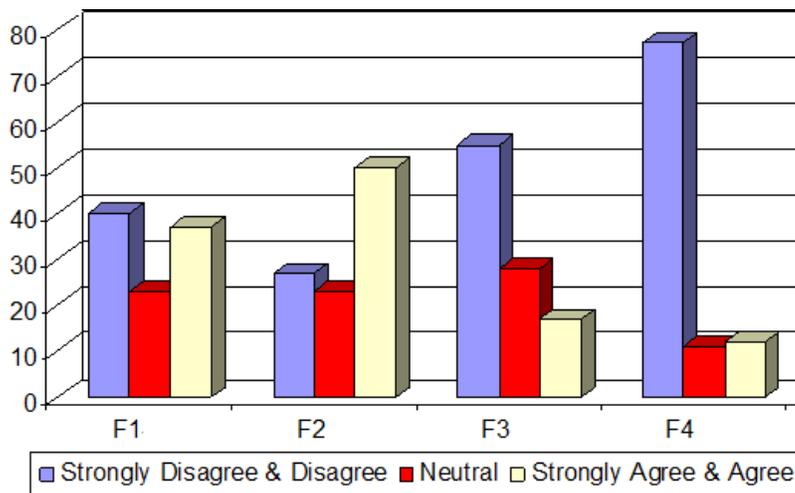
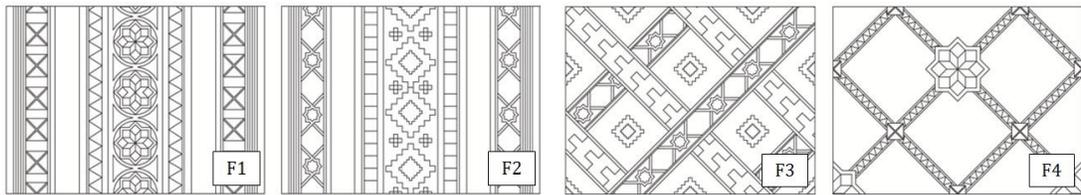


Figure 5.31: Recognition chart of group F.

The result in figure 5.31 shows that:

- Examples F1 & F2 are recognised as Kuwait Sadu style, and the answers that vary between totally disagree and totally agree are approximated.
- For F3, the researcher used the patterns in F2 but changed the borders angles, and the results show that participants did not recognise it as Sadu style.

- F4 is not recognised as Kuwaiti Sadu style.

Group G: Q1, Is this a Kuwaiti Sadu style?

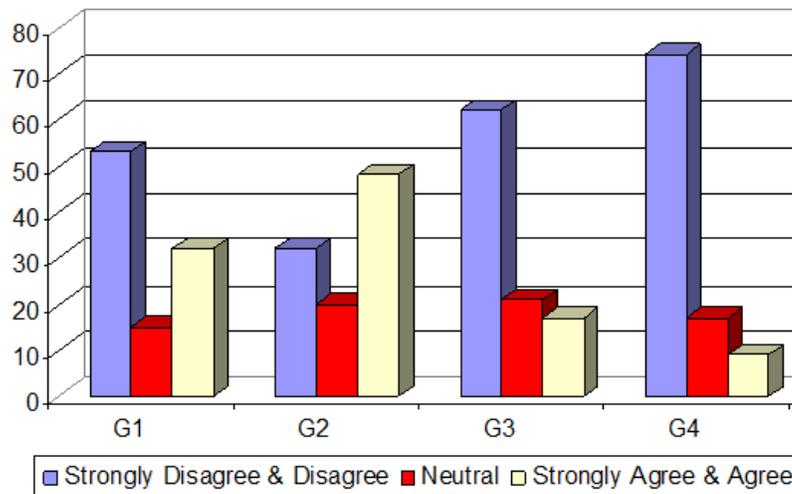
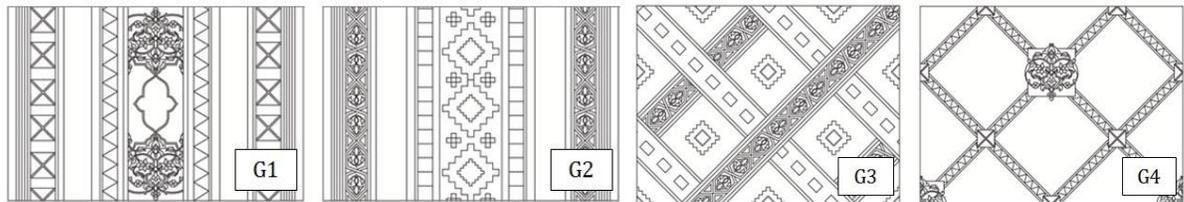


Figure 5.32: Recognition chart of group G.

The result in figure 5.32 shows that:

- Although G1 has original Sadu designs and vertical borders, adding the organic Islamic patterns in large scale made it lose its original identity.
- G2 is recognised as Kuwaiti Sadu style because the organic patterns were applied in a small scale and not as the main design.

G3 & G4 were not recognised as Sadu style because of the diagonal borders and the designs placed without borders.

5.4.3 Recognition Groups Average

By calculating the average of each group, which is the sum divided by the count, and comparing them, we can identify the methods that produced the most recognised patterns as Kuwaiti style. As shown in figure 5.33:

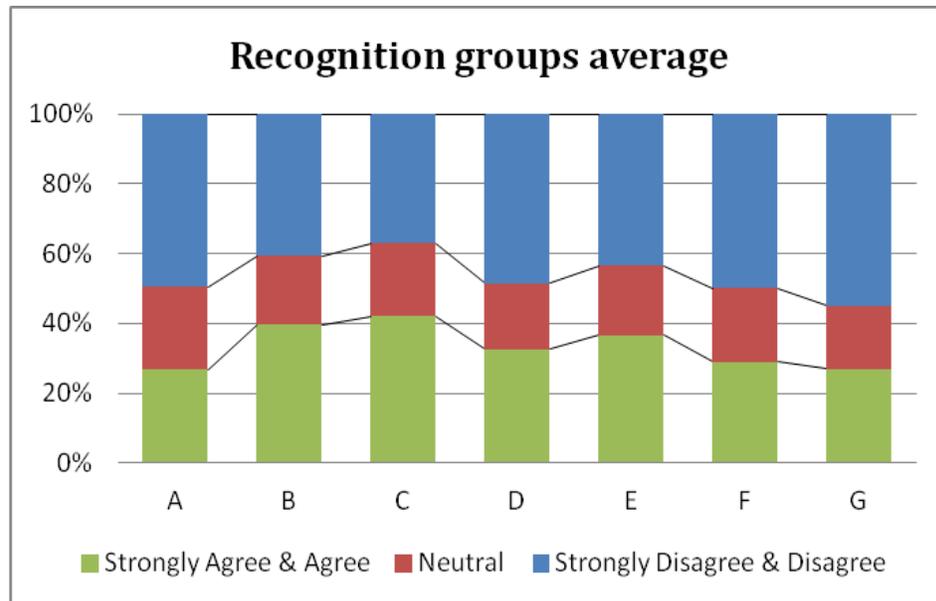


Figure 5.33: Group averages.

- The group A method of developing the patterns using designs created from one initial shape is not sufficient to revive the traditional Kuwaiti style, and that can be seen in the linear trend line for the average.
- The method in group B produced drawings that people managed to relate to the original style.
- Kuwaiti people were more inclined to recognise group C as Sadu style than the first two groups and this can be seen in the linear trend line for the average.
- Many Kuwaitis did not see group D as Sadu style.
- The difference between the averages for group E is not large. The result for Kuwaitis who said they did not recognise the designs as Sadu is slightly higher than for those who did.

- Method F of developing the patterns did not produce designs that were recognised as Sadu style, as can be seen in the linear trend line for the average.
- Most of the participants did not recognise the outcome of group G as Kuwaiti Sadu style.

Table 5.7 shows the top overall ranking for the group averages regarding recognition:

Rank	1	2	3	4	5	6	7
Group	C	B	E	D	F	A	G

Table 5.7: Groups average ranks.

5.4.4 Evaluating the methods: likability

Group A: Q2, Do you like it?

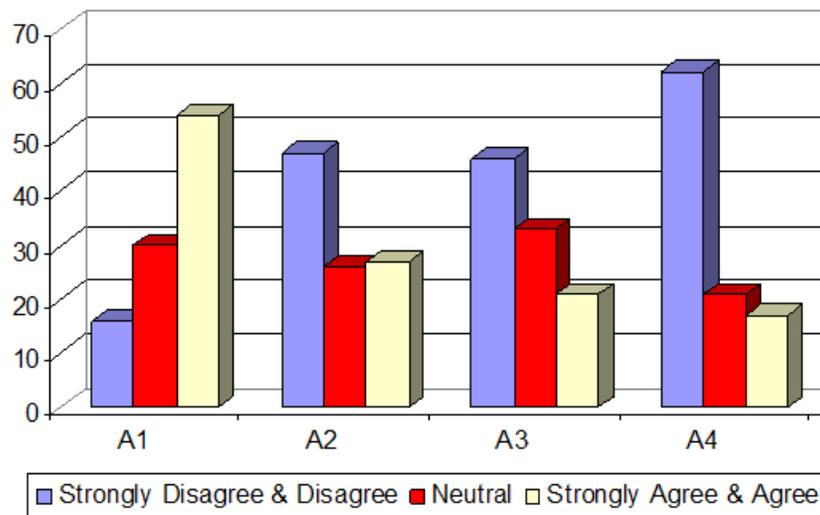


Figure 5.34: Likability chart of group A.

The result in figure 5.34 shows that:

The only example which was liked by most of the participants was A1. The rest of the examples were disliked as an extension to the original style.

Group B: Q2, Do you like it?

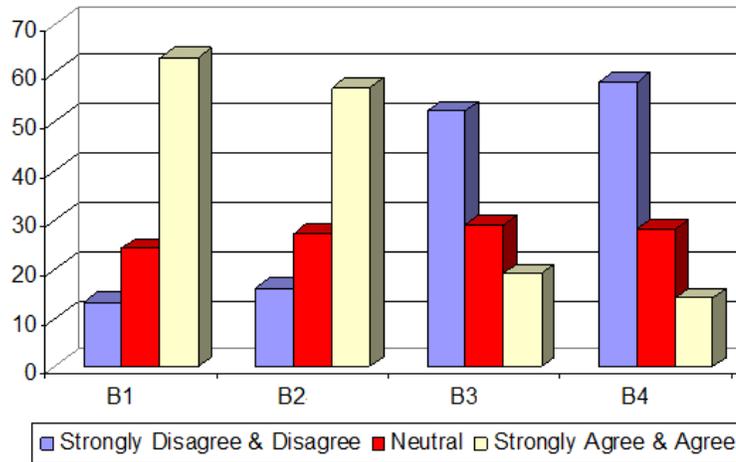


Figure 5.35: Likability chart of group B.

The result in figure 5.35 shows that:

B1 is the most liked drawing, followed by B2. The participants did not like B3 and B4 although they had the same designs as the liked ones but different space fillings.

Group C: Q2, Do you like it?

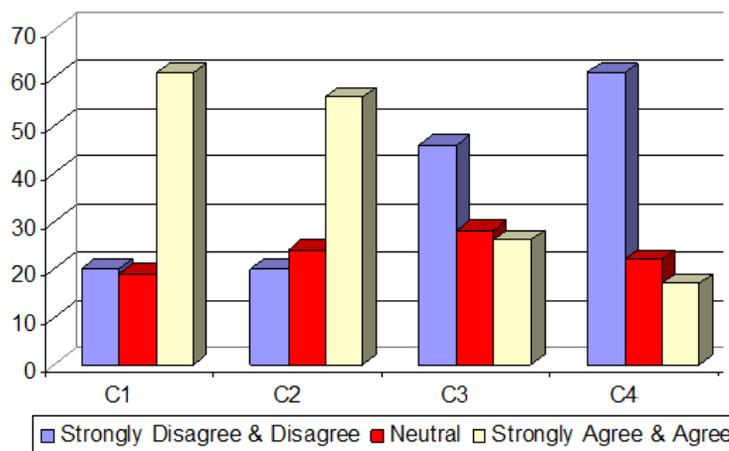


Figure 5.36: Likability chart of group C.

The results in figure 5.36 show that C1 and C2 are the most liked in the group whereas C3 and C4 are not liked by the participants.

Group D: Q2, Do you like it?

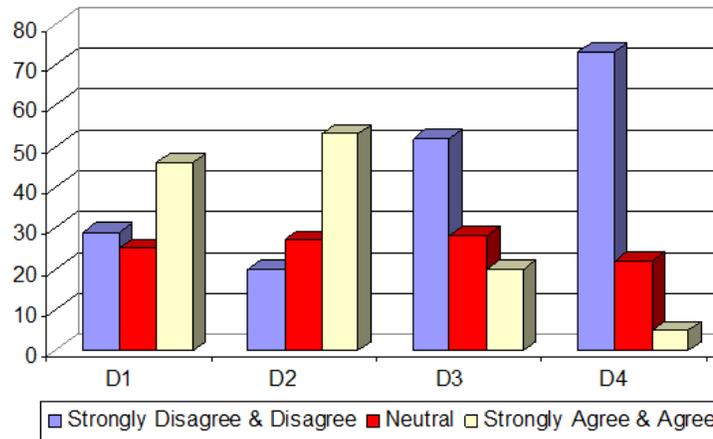


Figure 5.37: Likability chart of group D.

The result in figure 5.37 shows that:

D2 is the most liked example followed by D1, and the majority disliked D4.

Group E: Q2, Do you like it?

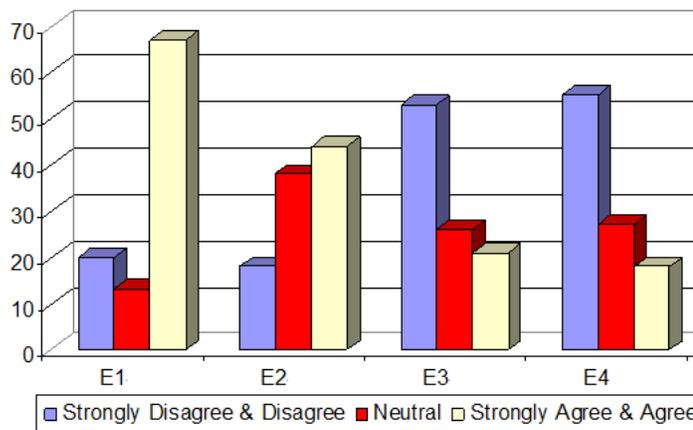


Figure 5.38: Likability chart of group E.

The result in figure 5.38 shows that:

E1 is the most liked example followed by E2 but many participants were not sure whether or not they liked it as can be seen in answer three for E2. The results for E3 and E4 show that people did not like these examples.

Group F: Q2, Do you like it?

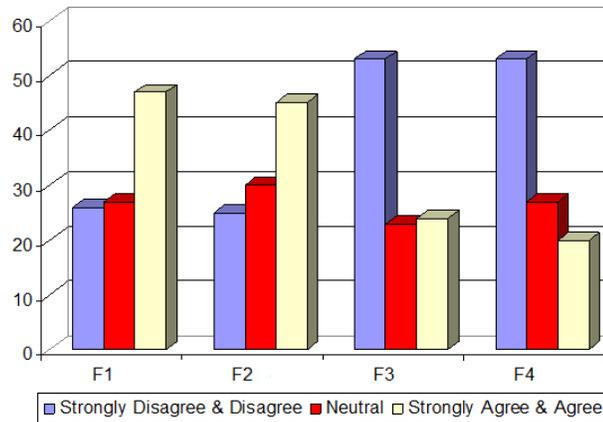


Figure 5.39: Likability chart of group F.

Figure 5.39 shows that:

The first two examples were liked by the participants although the scores were approximated. The last two examples were not liked.

Group G: Q2, Do you like it?

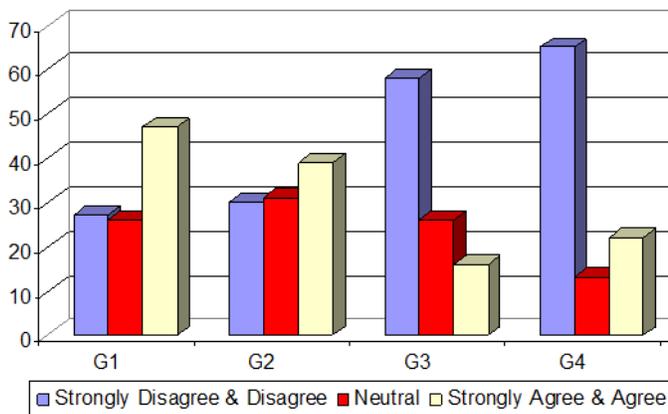


Figure 5.40: Likability chart of group G.

The result in figure 5.40 shows that:

As in group F, the results were approximated for the first two examples. G1 was liked the most followed by G2 which was slightly liked. G3 and G4 were not liked by Kuwaitis.

5.4.5 Likability Groups Average

As in the recognition analysis step, the average for each group was calculated and compared the answers with each other. The result shows that (see figure 5.41):

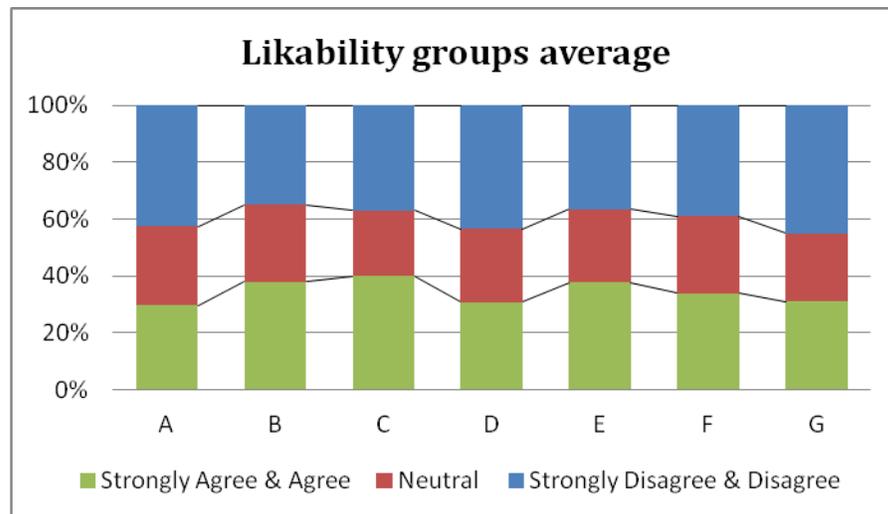


figure 5.41: Likability group averages.

- In general, Kuwaitis did not like the examples created by method A, and this can be seen in the linear trend line for the answers average which has higher numbers in the dislike section.
- Kuwaitis did like the examples created by method B, and that can be seen in the linear trend line for the answers average which has higher numbers in the like section. Although there is not a big difference between the averages of the answers in this group, the variation will make a difference when we compare it with the other groups to choose the methods that best present the Kuwaiti style.
- Chart 5.41 shows that the participants liked group C in general.
- Group D is not well liked by Kuwaitis in general as a replacement for their cultural style.
- From the linear trend line for the answers average, Kuwaitis did like the outcome of method E.
- Half of the participants did not like the outcome of method F whereas the other half did like it.

- Many participants did not like the examples in group G.

The overall likability ranking for the seven groups was as shown in table 5.8:

Rank	1	2	3	4	5	6	7
Group	C	B	E	F	D	G	A

Table 5.8: Group average ranks.

5.4.6 Additional Findings

Also it was noticed from the crosstabs between two variables (age- gender) for the top ranked designs in each group that (see appendix D):

- Participants aged over forty recognised and liked the developed Sadu style better than those under forty.
- Females recognised and liked the developed style better than the men.

The findings were used to create a tool that produces Kuwaiti patterns and these were tested to see whether there was consistency between them.

5.5 Rules about the Developed Sadu Style

In order to make the tool that will help designers to maintain the cultural identity of the Kuwaiti Sadu style more efficient, the designer needs to follow a number of recommendations to produce developed and consistent patterns, as follows:

- All the patterns need to be inside borders.
- The borders have to be vertical ones.
- If patterns are placed outside borders or in diagonal borders, the design will not be recognised as Sadu in style.

- Using well known designs is more important than the method of placement inside borders.
- Original designs that have the triangle as the initial shape in their shape grammar process are more readily recognised as Sadu than are other designs.
- Designs which are created from four or more design trees lose their original identity.
- Combining two styles with different characteristics will lead to loss of the original style and Kuwaitis will not accept it as an extension to their cultural style.
- To ensure that the original style is captured, it is advisable to modify designs that have a triangle in their formation.
- Combining original and modified designs will produce a pattern that captures the Sadu style.
- Shapes produced in the early stages of the design trees were not recognised as Sadu style because they did not contain the required style characters, but they can still be used if an original design is added to support recognition.
- The most popular symmetry rules in Sadu which will be used in the new patterns are: Pmm2, Pm11, P1m1 and Pma2.

5.6 Summary

The seven groups of the developed Sadu style were demonstrated along with an explanation of how they were constructed. Then a test was conducted on these groups to measure the recognition and likability among the Kuwaitis. The results were reliable based on Cronbach's alpha statistics. The designs were analysed individually to identify the top ranked design in each group, then the common rules that constructed the developed Sadu style were concluded by comparing the top ranked designs with each other.

Based on the comparison of the groups, the researcher decided to incorporate the methods of groups C and E to generate the Sadu patterns, because group C produced patterns that are recognised as Kuwaiti Sadu style, whereas group E were liked by Kuwaitis because the design language of the original style has been changed.

6 Design tool

6.1 Introduction

Creating a design tool with features inspired from the data and evidence gathered throughout the study is the third step in this research. The purpose of this tool is to enable both Kuwaitis and non-Kuwaitis to produce consistent Sadu patterns. A test will be conducted to measure the consistency of the tool's output. Also, written suggestions will be made by the users for developing the tool in the future. The features of the prototype software will be demonstrated in this chapter, the test will be described, and the results reported. Also a case study of building and designing a hotel inspired by the outcome of the tools, that captures the cultural identity of the Kuwaiti style, will be demonstrated.

6.2 Flash software

Flash software was selected for building a design tool because it is an application tool that has come to represent new media in general. Lev Manovich (2002) uses the term “Flash generation” to refer more broadly to the cultural sensibility of a new generation of software artists, designers, and developers who may be using Flash or who may be using other tools, such as Director, Quicktime, or DHTML. Manovich (2002) and Anna Munster (2003) have offered definitions of a Flash aesthetic referring to “a range of applications being used to create new media and software art”. This shorthand terminology that places Flash at the centre of new media production suggests the important place of Flash in developing trends of media, technology, and writing.

Flash began in the early 1990s as FutureSplash Animator, an animation application tool designed for the pen computer. Purchased by Macromedia in 1996, Flash evolved through several versions into a sophisticated application tool with its own scripting language (ActionScript). Flash is currently in the midst of a significant transition, from being an

animation application tool tied primarily to Internet advertising, entertainment, and art to being a multimedia-development environment designed primarily to facilitate Internet-based commercial enterprises. With Adobe's acquisition of Macromedia in 2005, additional changes are in store as Adobe melds and merges Flash with its other products.

Anthony Ellertson (2003) has described Flash as a "simulacra machine" in which "any digitized object (text, images, sound, video, animation) can be separated from its subject and repurposed for the needs and desires of the designer/writer. The simulacra machines can take these objects, and collide/collage them into interface environments that are dynamic, cinematic, and immersive". And these are the key feature areas in Flash:

- Flash features a complete set of drawing tools to handle intricate illustration and typography.
- Flash is a native vector drawing application where the user can create rich, detailed, and scalable digital illustrations.
- Flash supports programmes typically used in design such as Illustrator and Photoshop files in their native file formats.
- Flash creates lightweight animation that incorporates images, sound, and video, and can be quickly downloaded through the web.

6.2.1 Code writing in actionscript

Unlike writing as text and as image, which both appear on the screen, code writing occurs behind the scenes, but it is nevertheless crucial in powering Flash projects. It rarely happens that one would create a Flash project without any code; without the 'stop()' command, for example, an object in Flash would loop infinitely. More sophisticated and interactive projects require more code. When ActionScript was first introduced and as it has evolved, programmers at Macromedia focused on making it accessible and inviting to people who have no prior experience of writing code. Peter Santangeli, vice president for Flash Engineering at

Macromedia, wrote in Reinhardt and Lott's (2002) Macromedia Flash MX ActionScript Bible that "ActionScript was designed to provide an easy way for artists, animators, and other creative types to write scripts. Unlike traditional scripting languages, the original ActionScript was edited or displayed by means of artist-friendly dialog boxes specific to each action".

6.3 The design tool

In order to make a tool that produces developed and consistent patterns, the tool needs to adhere to a number of rules concerning the Kuwaiti Sadu style based on the results of the previous test. Also the production and analysis rules for Sadu play an important role in the making of the software. There are two versions of the design tool; one is called Sadu Pattern, and the second is called Sadu Designs. The first was mainly created for use by those with no knowledge of design and by designers, whereas the second is more complex and should be used by designers and developers only because it requires an understanding of design rules. Both are prototypes and they were tested to measure whether or not they can accomplish what they were created to do.

6.3.1 Sadu patterns software (SP1)

The main purpose of the SP1 software is to produce a variety of Sadu pattern designs that can be used by interior designers as inspiration for wall coverings, textiles and floorings. Even if the user is not Kuwaiti and has no knowledge of how Sadu looks, the software should allow them to utilise certain functions which will ultimately produce a pattern which is of Kuwaiti style. The patterns in SP1 are taken from the top three methods used to modify the Sadu in the previous test which are also the same methods most liked by the Kuwaitis in the sample. The tool was tested by showing the patterns it produced to the Kuwaitis to measure the consistency of the Sadu style. Here is an explanation of the application tool's contents as shown in figure 6.1:

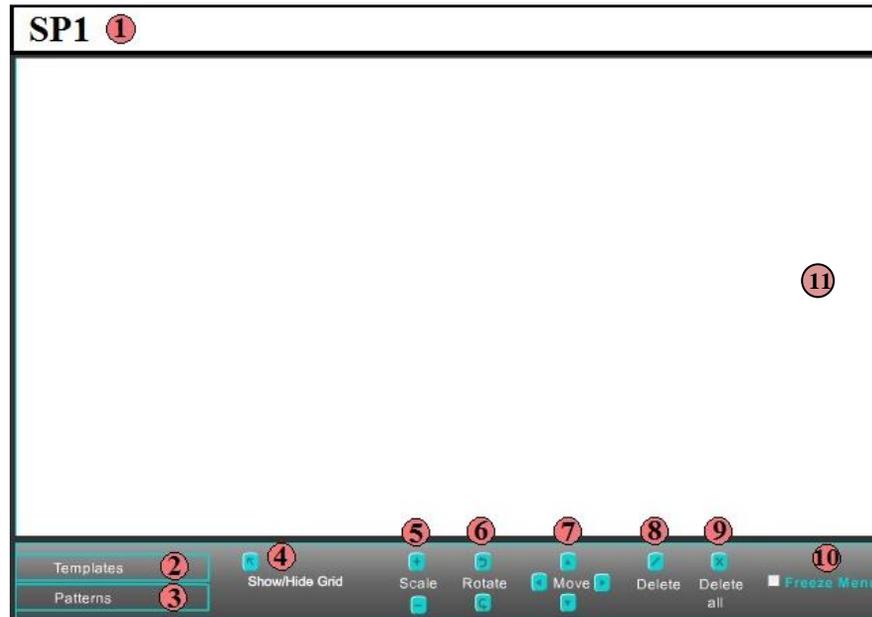


Figure 6.1: The Sadu Patterns tool.

- 1- The title (Sadu Patterns).
- 2- Templates: there are six different Sadu templates that the user can choose from. These templates represent the borders that the user fill it with patterns, or he/she may leave some of them blank. Pressing this button will make a table of templates appear, then when choosing the preferred template the drawing area will be filled with empty borders.
- 3- When pressing the patterns button a table of Sadu patterns will appear containing different groups from which to choose. There are the original patterns from methods B and C in chapter five, developed designs taken from group E, and independent borders so the user can create his own template. After choosing the template the user drags the patterns from the table and sets them between the borders in the drawing area.
- 4- The grid function is used to create accurate designs. It can be shown or hidden by pressing the button.
- 5- Scale: this function helps the user to scale the patterns up or down.

- 6- Rotate: the user can rotate the designs by forty five degree angles only, because it has been discovered that designs with rotation values of more or less than forty five degrees are not common in the Sadu style.
- 7- Move: this function is to move the patterns in a vertical or horizontal direction after they have been placed in the drawing area.
- 8- Delete: to delete the chosen item.
- 9- Delete all: to delete everything in the drawing area.
- 10-Freeze menu: this function is used to freeze the template and patterns table, instead of allowing it to disappear every time the user picks a pattern.
- 11- Drawing area.

The researcher adopted simple modify commands, as they are called in AutoCAD, such as add, move, proportion, rotate and delete, so that the untrained user can use the software to produce creative patterns. Adding more commands is related to the user's responses to the tool as we will see in the test results section.

6.3.2 Sadu designs software (SD1)

The previous application tool was built to be user friendly so that designers and non designers can still use it produce innovative patterns, whereas SD1 is a tool for designers and developers to use to create a single design unit and then measure it to find out whether or not their design is of Kuwaiti Sadu style. This software requires some knowledge of design rules. An explanation follows for each of the numbers in figure 6.2:

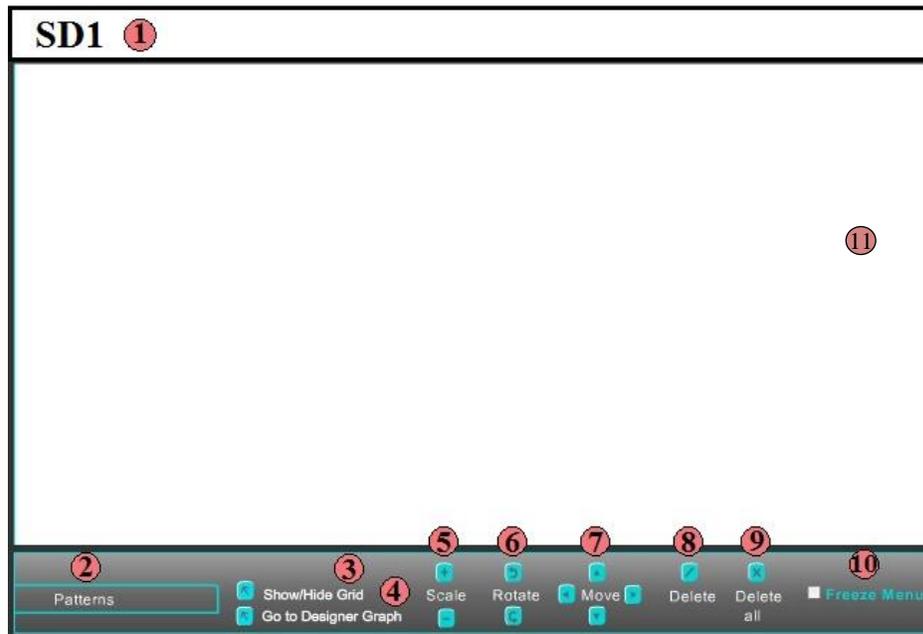


Figure 6.2: The Sadu Designs tool.

- 1- The title (SD1).
- 2- A table will appear when pressing the patterns button that contains shapes which adhere to strong Sadu production rules in the design trees. The designer can build any sort of design by placing and arranging the shapes in the drawing area. All the modified patterns in SP1 were created from this tool.
- 3- The grid function is used to create accurate designs.
- 4- Designer graph: this function is the core of this tool where designers can measure their work and find out whether or not the outcome is close to the Sadu style. When pressing the button a graph will appear containing a set of analysis rules and a meter that indicates how close the design is to Sadu (see figure 6.3). As mentioned in chapter four, there were two groups of analysis rules, the first for designs based on one initial shape, and the second for those based on multiple initial shapes. Each group has its own strong production and analysis rules, but having learnt from the test in chapter five that designs with multiple initial shapes are more recognised and liked by Kuwaitis, the researcher used the analysis rules for that group in this graph. Each rule has a measured weight

which was identified by investigating the original Sadu. So the more rules the new design has the more Kuwaiti it is.

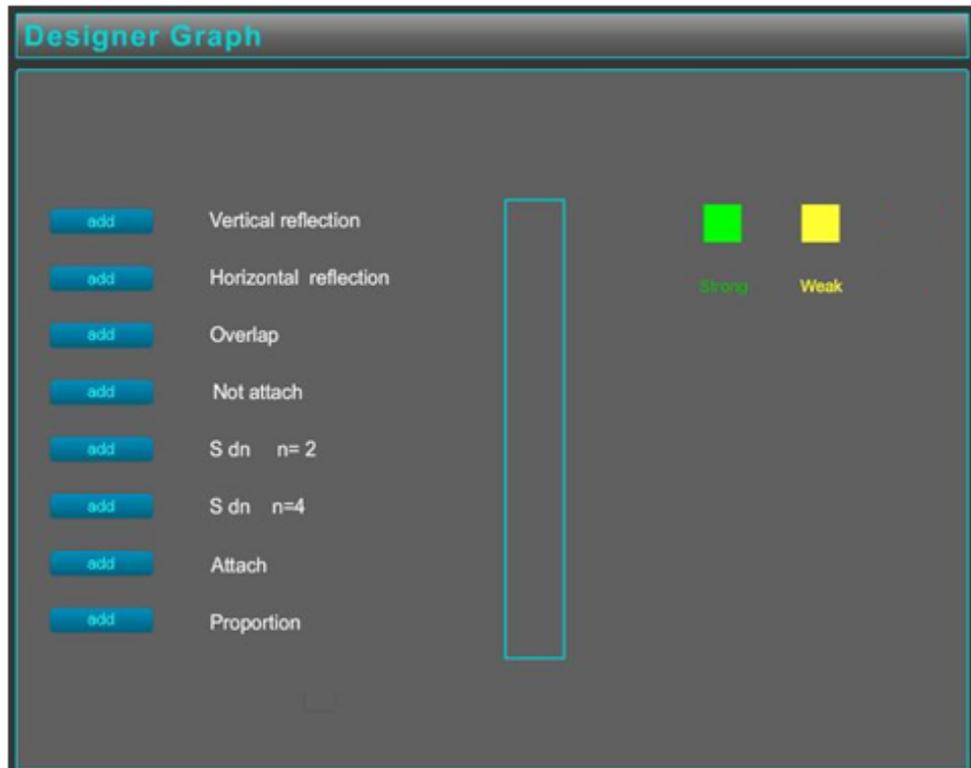


Figure 6.3: Designer graph.

- 5- Scale: this function helps the user to scale the patterns up or down.
- 6- Rotate: the user can rotate the designs by forty five degree angles.
- 7- Move: this function is to move the patterns in a vertical or horizontal direction after they have been placed in the drawing area.
- 8- Delete: to delete the chosen item.
- 9- Delete all: to delete everything in the drawing area.
- 10-Freeze menu: this function is used to freeze the template and patterns table, instead of disappearing every time the user picks a pattern.
- 11-Drawing area.

In the design graph there are eight rules to choose from, each with measured weight as shown in table 14:

Rule names and references	1	2	3	4	5	6	7	8
	Vertical reflection	Horizontal reflection	Overlapped shapes	Not attached shapes	Rotation S dn, n=2	Rotation S dn, n=4	Attached shapes	Proportion
Weight	9	9	8	6	5	3	3	3

Table 6.1: The common analysis rules in Sadu design and their weights.

The meter in the graph is scaled from zero to forty three and it indicates how close the design is to Sadu style. The total summation of all the weights is forty six, but because the rotation rules n=2 and n=4 cannot occur at the same time in one design, the researcher has to discard the lowest weight value in order to arrive at the top weight summation rank of forty three, which will be the target for designers to reach. The meter readings were divided into two categories, weak and strong. The weak weightings are scaled from zero to fifteen and are coloured yellow, whereas the strong weightings are scaled from sixteen to forty three, for which the meter turns green. The categorization is based on these facts:

- In the ten analysed Sadu designs, the rule which is common to them all is symmetry; either vertical or horizontal reflection or both together. In order for a design to qualify as part of the Sadu design language, there must be at least one symmetry rule with a weighting of nine.
- Also it was noticed that the minimum number of analysis rules in the ten designs was three. From the previous bullet point we know that symmetry has to be one of these three rules, and the other two are going to be the lowest weighted values; that is three. This step gave us the value of the highest reading in the weak scale, which consequently ranged from zero to fifteen.

6.4 Combination of the analysis rules

A combination is one of the different arrangements of a group of items or symbols where order does not matter, and when order does not matter $AB = BA$. The formula of the combination is written: ${}_n C_r = n! / (n-r)! * (r)!$

where,

n , r are non negative integers and $r \leq n$.

r is the size of each combination.

n is the size of the set from which elements are combined.

! is the factorial operator.

For example, if we want to find the number of combinations: $n=6$; $r=4$. Then

Step 1: we find the factorial of 6.

$$6! = 6*5*4*3*2*1 = 720$$

Step 2: we find the factorial of 4.

$$4! = 4*3*2*1 = 24$$

Step 3: we find the factorial of 6-4.

$$(6-4)! = 2! = 2$$

Step 4: then multiply $(n-r)! * (r)!$

$$2*24 = 48$$

Step 5: divide 720 by 48.

So the combination for this example is $= 720/48 = 15$.

Now, to apply this method to the analysis rules to find the number of possibilities that the design tool (SD1) can provide, we used MATLAB software to complete the calculations (see appendix F). Here, the total number of rules is referred to as n and the number of each set combination is r . Knowing that we have eight analysis rules, the results were as follows:

- Combinations without repetition (n=8, r=1)

{1} {2} {3} {4} {5} {6} {7} {8}

- Combinations without repetition (n=8, r=2)

{1,2} {1,3} {1,4} {1,5} {1,6} {1,7} {1,8} {2,3} {2,4} {2,5} {2,6} {2,7} {2,8} {3,4} {3,5}
 {3,6} {3,7} {3,8} {4,5} {4,6} {4,7} {4,8} {5,6} {5,7} {5,8} {6,7} {6,8} {7,8}

- Combinations without repetition (n=8, r=3)

{1,2,3} {1,2,4} {1,2,5} {1,2,6} {1,2,7} {1,2,8} {1,3,4} {1,3,5} {1,3,6} {1,3,7} {1,3,8}
 {1,4,5} {1,4,6} {1,4,7} {1,4,8} {1,5,6} {1,5,7} {1,5,8} {1,6,7} {1,6,8} {1,7,8} {2,3,4}
 {2,3,5} {2,3,6} {2,3,7} {2,3,8} {2,4,5} {2,4,6} {2,4,7} {2,4,8} {2,5,6} {2,5,7} {2,5,8}
 {2,6,7} {2,6,8} {2,7,8} {3,4,5} {3,4,6} {3,4,7} {3,4,8} {3,5,6} {3,5,7} {3,5,8} {3,6,7}
 {3,6,8} {3,7,8} {4,5,6} {4,5,7} {4,5,8} {4,6,7} {4,6,8} {4,7,8} {5,6,7} {5,6,8} {5,7,8}
 {6,7,8}

- Combinations without repetition (n=8, r=4)

{1,2,3,4} {1,2,3,5} {1,2,3,6} {1,2,3,7} {1,2,3,8} {1,2,4,5} {1,2,4,6} {1,2,4,7} {1,2,4,8}
 {1,2,5,6} {1,2,5,7} {1,2,5,8} {1,2,6,7} {1,2,6,8} {1,2,7,8} {1,3,4,5} {1,3,4,6} {1,3,4,7}
 {1,3,4,8} {1,3,5,6} {1,3,5,7} {1,3,5,8} {1,3,6,7} {1,3,6,8} {1,3,7,8} {1,4,5,6} {1,4,5,7}
 {1,4,5,8} {1,4,6,7} {1,4,6,8} {1,4,7,8} {1,5,6,7} {1,5,6,8} {1,5,7,8} {1,6,7,8} {2,3,4,5}
 {2,3,4,6} {2,3,4,7} {2,3,4,8} {2,3,5,6} {2,3,5,7} {2,3,5,8} {2,3,6,7} {2,3,6,8} {2,3,7,8}
 {2,4,5,6} {2,4,5,7} {2,4,5,8} {2,4,6,7} {2,4,6,8} {2,4,7,8} {2,5,6,7} {2,5,6,8} {2,5,7,8}
 {2,6,7,8} {3,4,5,6} {3,4,5,7} {3,4,5,8} {3,4,6,7} {3,4,6,8} {3,4,7,8} {3,5,6,7} {3,5,6,8}
 {3,5,7,8} {3,6,7,8} {4,5,6,7} {4,5,6,8} {4,5,7,8} {4,6,7,8} {5,6,7,8}

- Combinations without repetition (n=8, r=5)

{1,2,3,4,5} {1,2,3,4,6} {1,2,3,4,7} {1,2,3,4,8} {1,2,3,5,6} {1,2,3,5,7} {1,2,3,5,8}
 {1,2,3,6,7} {1,2,3,6,8} {1,2,3,7,8} {1,2,4,5,6} {1,2,4,5,7} {1,2,4,5,8} {1,2,4,6,7}
 {1,2,4,6,8} {1,2,4,7,8} {1,2,5,6,7} {1,2,5,6,8} {1,2,5,7,8} {1,2,6,7,8} {1,3,4,5,6}
 {1,3,4,5,7} {1,3,4,5,8} {1,3,4,6,7} {1,3,4,6,8} {1,3,4,7,8} {1,3,5,6,7} {1,3,5,6,8}

{1,3,5,7,8} {1,3,6,7,8} {1,4,5,6,7} {1,4,5,6,8} {1,4,5,7,8} {1,4,6,7,8} {1,5,6,7,8}
 {2,3,4,5,6} {2,3,4,5,7} {2,3,4,5,8} {2,3,4,6,7} {2,3,4,6,8} {2,3,4,7,8} {2,3,5,6,7}
 {2,3,5,6,8} {2,3,5,7,8} {2,3,6,7,8} {2,4,5,6,7} {2,4,5,6,8} {2,4,5,7,8} {2,4,6,7,8}
 {2,5,6,7,8} {3,4,5,6,7} {3,4,5,6,8} {3,4,5,7,8} {3,4,6,7,8} {3,5,6,7,8} {4,5,6,7,8}

- Combinations without repetition (n=8, r=7)

{1,2,3,4,5,6,7} {1,2,3,4,5,6,8} {1,2,3,4,5,7,8} {1,2,3,4,6,7,8} {1,2,3,5,6,7,8}
 {1,2,4,5,6,7,8} {1,3,4,5,6,7,8} {2,3,4,5,6,7,8}

- Combinations without repetition (n=8, r=8)

{1,2,3,4,5,6,7,8}

The results show that there are 255 combinations of the analysis rules, varying between weak and strong, which will achieve the Sadu style. However, knowing that the two rotation rules (n=2 and n=4) cannot occur in the same design, then fifty sets of different combination rules which had these two rules together were discarded, leaving a total of 205 possibilities.

Also, the weight of each combination was identified using Microsoft Excel (see appendix G) and it showed that the strength of the designs was not related to the number of rules, but rather to the type of rule. For example, design A has two rules whereas B has four rules, but which design is more Kuwaiti? The answer is obtained by measuring the rules' weight:

Design A has: vertical reflection and horizontal reflection.

So the weight of A is: $9+9= 18$

Design B has: not attached shapes, attached shapes, rotation n=4 and proportion.

The weight of B is: $6+3+3+3= 15$

Since $18>15$, then design A is more Sadu style because it is closer to the top weight rank of forty three than design B.

6.5 Testing the tool

The aim of testing the tool is to evaluate the method that the author has used in developing a traditional style and to find out whether the tool produces consistent Kuwaiti style patterns.

The two software applications were given to nine designers of different nationalities and they were asked to explore them and to find out what each button did. The researcher did not show the participants the Sadu style to ensure that they did not imitate it. For SP1, each designer had to create his preferred pattern design regardless of whether they were familiar with the Sadu style. The purpose of this step was to measure the consistency of the designs produced by the tool. The software was then evaluated by showing these nine designs to the Kuwaiti public and asking them for their opinion about the displayed style (see figure 6.4). After using the tool, the designers were asked to give their written opinions of it, identifying points of strength and weakness for future development.

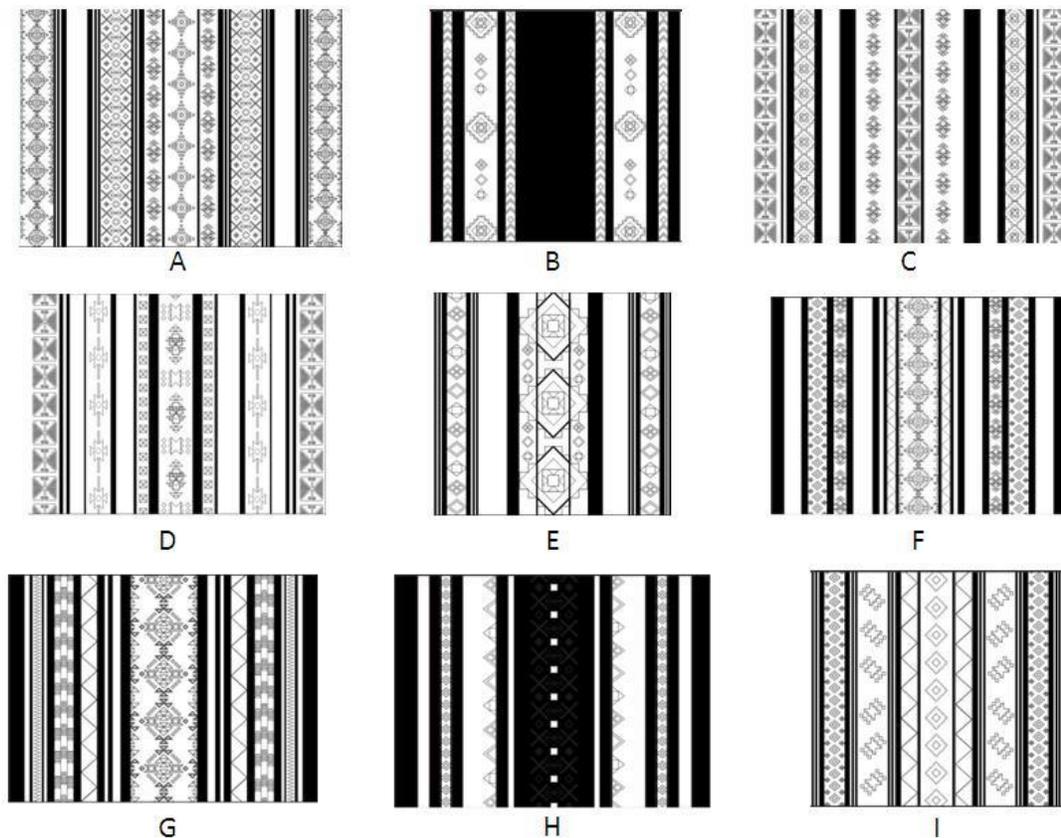


Figure 6.4: The tested patterns.

Then the participants used the SD1 tool. They explored it and each one of them created a single design unit as shown in figure 6.5. The designer graph were explained and how it works, then the participants were asked to measure their designs and find out how close they were to Sadu style. Each designer was then asked to write down their comments about the tool.

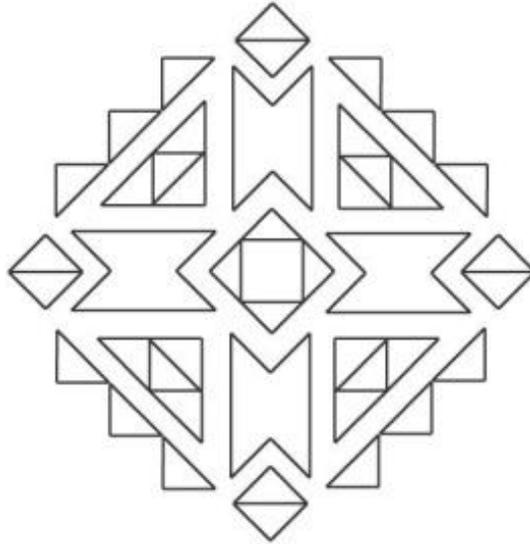


Figure 6.5: An example of a single design unit.

6.6 Test result

A questionnaire was conducted among Kuwaitis to identify whether the tool can produce a Kuwaiti Sadu style even if the user is not Kuwaiti and has no knowledge of that style. There were thirty participants and each was given nine drawings; each drawing was made by a designer from amongst the nine multi-national designers. The participants were then asked one question:

- Is this Kuwaiti Sadu style?

The answers were written on a Likert scale and varied between 1, which was strongly disagree, and 5, strongly agree.

6.6.1 Reliability statistics

A commonly-accepted method is that a Cronbach's α (alpha) of 0.6-0.7 indicates 'acceptable reliability', and 0.8 or higher indicates 'good reliability'. From table 6.2 below, the overall reliability for the nine items is 'reliable'.

Cronbach's Alpha	N of Items
.711	9

Table 6.2: Reliability test.

6.6.2 Data correlation

Does the relationship between the nine drawings really indicate that they are all of the same style? This question can be answered by finding the significance of the relationship statistically.

The significance of the relationship is expressed in probability levels: **p**, were a common alpha level for educational research is .05. Therefore, if $p < .05$ then that means the correlation coefficient exceeds the critical value found in the table and we are 95% confident that a relationship exists, and the smaller the p-level, the more significant the relationship. Whereas if $p > .05$ this means that the correlation coefficient is less than the critical value in the table and we cannot be 95% confident that a relationship exists.

	Correlations	Average
A	Sig. (2-tailed)	.000
N		30
B	Sig. (2-tailed)	.005
N		30

C	Sig. (2-tailed)	.000
N		30
D	Sig. (2-tailed)	.001
N		30
E	Sig. (2-tailed)	.001
N		30
F	Sig. (2-tailed)	.001
N		30
G	Sig. (2-tailed)	.001
N		30
H	Sig. (2-tailed)	.019
N		30
I	Sig. (2-tailed)	.036
N		30

Table 6.3: Data correlation.

The table 6.3 above shows that there is a statistically significant relationship between the drawings. This proves that the tool can produce a consistent Kuwaiti Sadu style even if it has been used by a non-Kuwaiti person.

6.6.3 Designers' comments

The designers made certain comments in common when it came to identifying the points of strength for the two tools. As for SP1, they said that it is a user friendly tool, and they liked having a template and traditional patterns menu. With regard to SD1, the designers mentioned that the tool produces inspirational designs that can be used for architecture or product design that has a theme of cultural identity, such as furniture, illumination, flooring and plan layout (see figure 98).

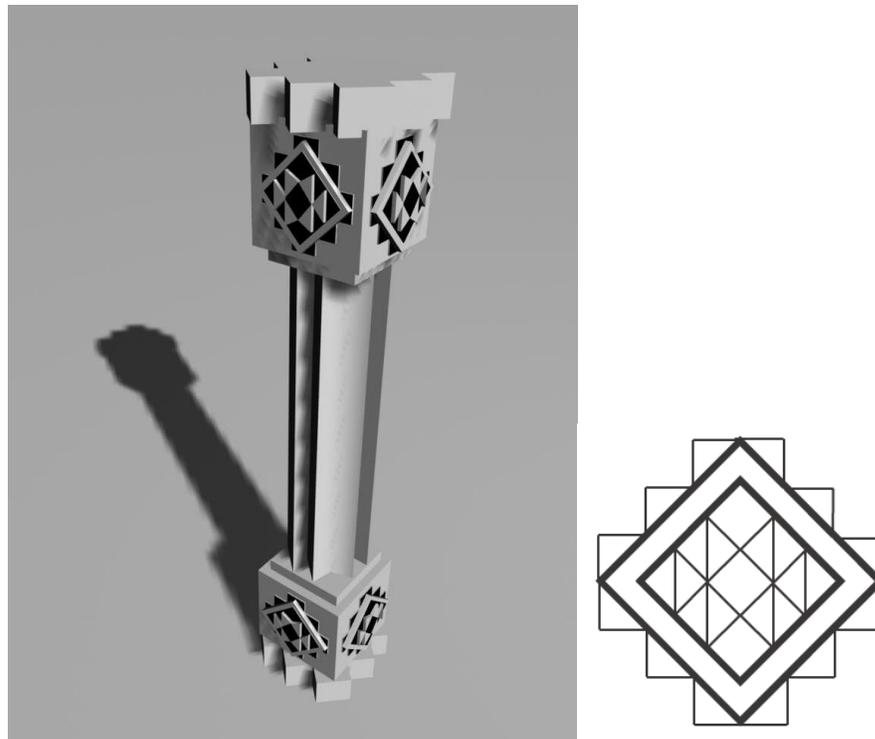


Figure 6.6: Column inspired by a design created from SD1 tool.

Also they said that the idea of measuring the designs is very innovative and they were impressed by this.

Comments regarding the tools' short falls and things that need consideration to varied from one designer to another. Below are the comments for the SP1 tool bearing in mind that repeated comments are written only once in this list to avoid repetition:

- Lack of copy and paste command.

- Need to add mirror effect.
- Text should be clickable.
- Template and patterns menus should disappear when the cursor is clicked on the screen.
- Move function needs to be a little smaller for more precision.
- More patterns are required.
- The tool needs a colouring function.
- Absence of save option.
- Needs a fade command.
- The tool needs to have a more attractive interface.
- Manual rotate by the cursor when clicking on the design.
- The buttons are too small.
- When the patterns are scaled down they do not fit into the length of the drawing area.

The comments that need attention for the SD1 tool were as follows:

- The design graph needs to be movable because it is blocking the drawing area.
- There are no initial basic shapes.
- Save option is required.
- The measuring function needs to be automatic.
- Some of the rules are confusing and difficult to understand.
- Need to increase the font size in the designer graph.

- The ratio of the scaling is not the same for all shapes.
- Need to add explanation text when the user points the cursor at the rules.
- Shapes alignment option is required.
- Add a mirror command.

6.7 Putting words into action

To demonstrate how the knowledge gathered in this research can help to create a design that captures cultural identity and at the same time produces creative designs, images of a hotel lobby and counter were created using 3D MAX software (see Appendix H). All the furniture and decorative items were inspired by the tools developed in this research. The overall theme represents the Kuwaiti culture, and in particular the Sadu style, the design rules of which were used to capture its identity and provide a consistent style (see figure 7.2a and b).



Figure 6.7a: The hotel lobby and counter.



Figure 6.7b: The hotel lobby and counter.

Different designs and ideas were used to build the interior of this hotel. They can be divided into the following four groups:

- In the first group the SP1 tool was used to provide Sadu patterns that were used for textiles and decoration.
- The second group of designs were inspired by the shapes that the PD1 tool produces.
- The third group of designs were not produced by the design tools. Instead they were created by applying the Sadu style rules that were explored throughout this research.
- The designer's touch and vision also played a role in creating this hotel.

6.7.1 Designs created with the SP1 tool

The patterns that have been used for texturing and decorating the hotel are not taken directly from the original Sadu and placed on the products as the retailers in Kuwait do. Instead they

were taken from the SP1 tool that provides a developed Kuwaiti Sadu style but gives more variety to that style. The examples in figure 6.8 demonstrate where the patterns were applied bearing in mind that the colours of the textiles are the same as the original Sadu colours because this research is focused on developing one element of design which is shapes. Also to guarantee maintaining the cultural style in the designs, the mm2 band pattern which is the most common symmetry rule in the Sadu style has been applied intensively.



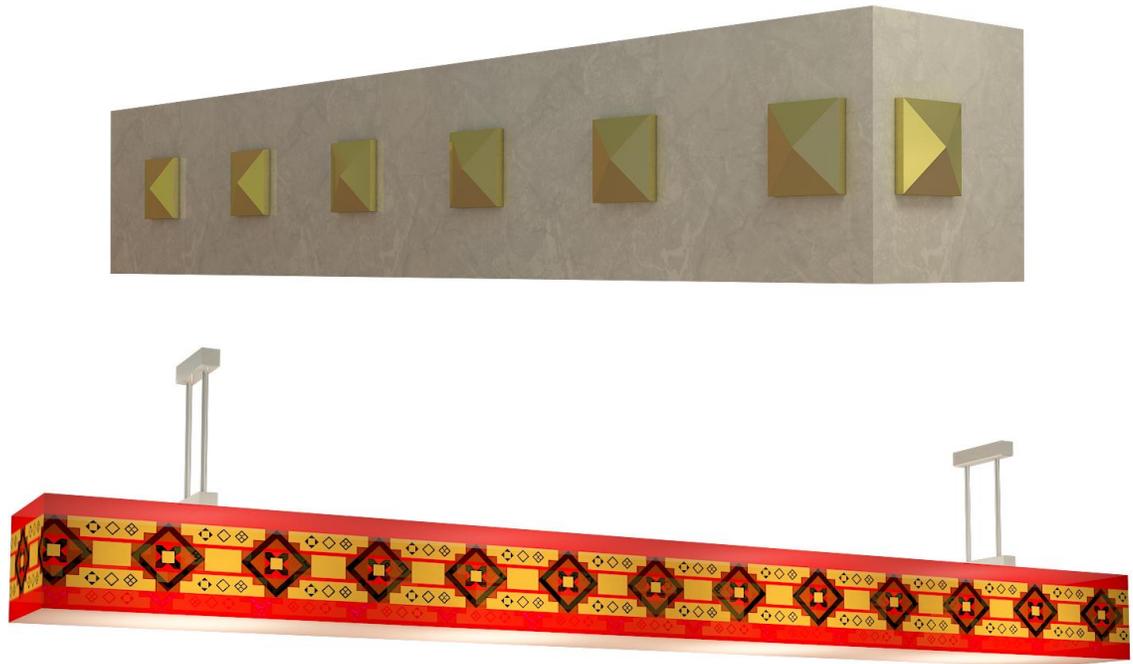


Figure 6.8: Patterns created with the SP1 tool.

The light unit in figure 6.9 is made of porcelain. The purpose of this unit is not only to provide illumination but decoration as well. The engraved patterns allow the light rays to pass through it and to illustrate the shapes of the Sadu style when seen directly or reflected on a wall.

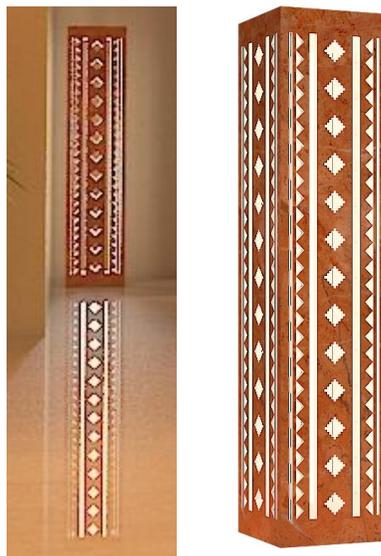
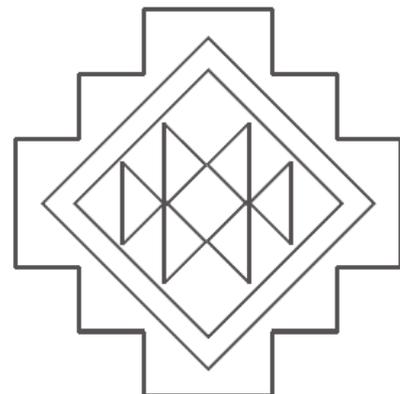
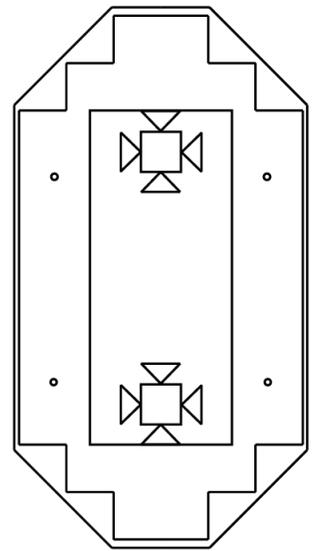


Figure 6.9: Floor light unit.

6.7.2 Designs created with the SD1 tool

SD1 is a tool that provides designers with inspiration for creating patterns, decoration units and products based on the Kuwaiti cultural style. Thanks to technology the designs can be built in any material, be it wood, glass, fabric, steel or gibes. Figure 6.10 gives examples of some applications, transforming the 2D designs into products and decorations.



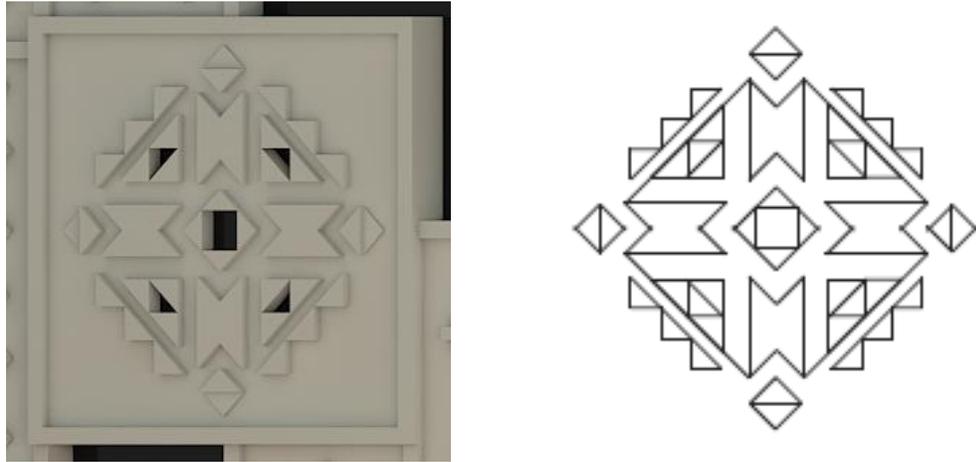


Figure 6.10: Examples of transforming the 2D designs into 3D products and decorations.

The designs produced by this tool cannot be found in the original traditional Sadu style, but they all have vertical reflection and horizontal reflection which by themselves as rules qualify the designs for the weak end of the scale on the designer's graph in the previous chapter, and imply a strong level of Sadu style. Other rules, such as rotation, overlapped shapes, and not attached shapes, are making the designs even closer to the Sadu style (see figure 6.11).

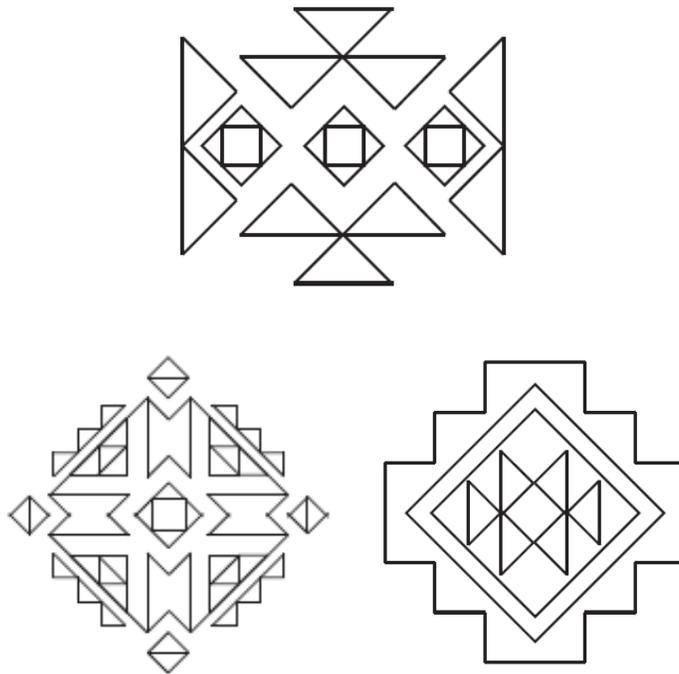


Figure 6.11: Developed Sadu style designs.

The designs produced by the SD1 tool can be applied to small spaces such as lamps or used in large spaces such as floor decorations. Figure 6.12 is an example of a design used at two different scales.



Figure 6.12: Two different scales for one pattern.

6.7.3 Using Sadu rules for design

Exploration of the Kuwaiti cultural style showed that there are rules, and that without them the style is lost, as shown in chapter five. Thus, designers should bear these rules in mind as references when designing anything based on cultural style. For example, knowing that the triangle is one of the most popular shapes in Sadu, part of the ceiling of the first and second floor, and the lobby's walls were decorated with triangles. There is a hidden light behind the triangles which gives them more depth and makes them stand out more clearly. Also there is a rule in the Sadu style that has been applied to each of these locations; this rule insists that all patterns must be in between borders. So on the ceiling, the borders were engraved behind and in front of the patterns, whereas for the lobby wall the wooden borders constrained the patterns within them (see figure 6.13).



Figure 6.13: Using a common geometric shape in the Kuwaiti cultural style for decoration.

Figure 6.14 shows the wall behind the reception counter which is made of black marble with light units installed in the middle. The light units were arranged in such a way that when the light rays intersect they create a diamond pattern, which is a common Sadu shape. Then two borders were put above and below the light units for two reasons; the first was that Sadu style rules insist that the patterns should always be inside borders. The second reason was to make the shapes made by the light rays look sharper.

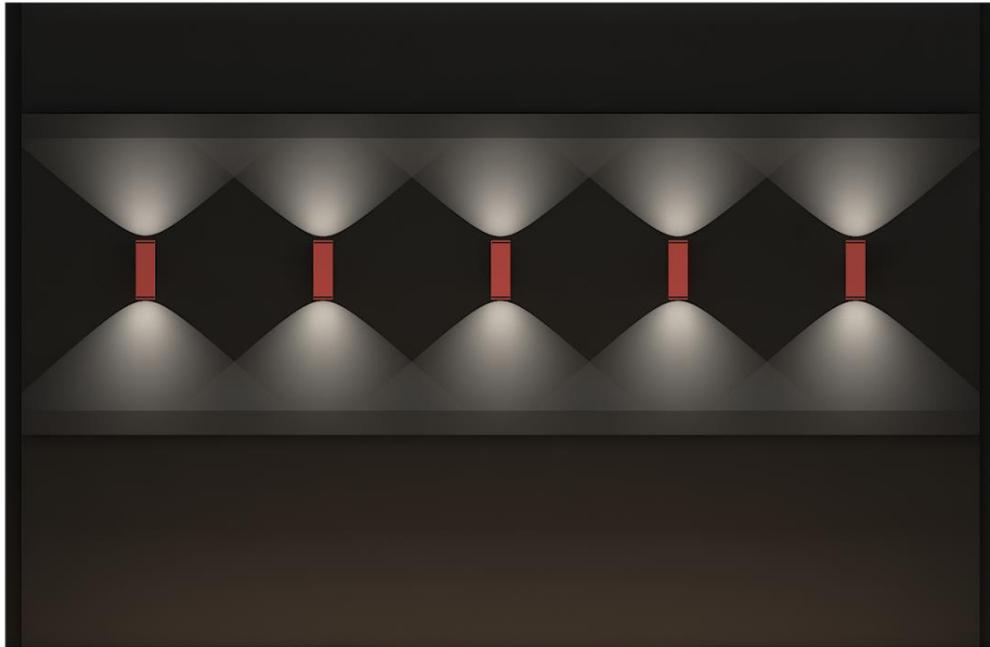


Figure 6.14: The wall behind the counter.

6.7.4 Designer's Touch

The counter in figure 6.15 is designed to reflect the desert environment of Kuwait. The materials used in the scene are dark and light wood. The dark wood is the shade and the light wood is the sand under the sun. The top and down edges are made from marble.



Figure 6.15: Hotel counter.

Decorative palm trees and desert plants were used to link between the hotel atmosphere and the Kuwaiti desert environment, creating a more realistic experience for the guests. Also paintings of old Kuwait drawn by Kuwaiti artists were hung on the walls of the hotel to fill the empty spaces and at the same time work as documents of how Kuwaitis used to live before the discovery of oil (see figure 6.16).



Figure 6.16: Desert plants and a painting of old Kuwait.

6.8 Summary

This chapter has shown how the researcher managed to maintain the traditional Sadu style whilst also developing the design identity. The reasons behind choosing Flash software for creating the tool were explained, as was the method used for gathering together the research knowledge and using it in a practical application. The testing of the tool to measure how well the outcome was characterised by consistency was also described. Finally, the tool users' written comments and suggestions for future development of the software were obtained.

7 Conclusion

7.1 Introduction

As can be seen throughout the study, the researcher has managed to develop a 2D traditional style and to maintain its cultural identity. This chapter will demonstrate the highlights of the research as well as the findings of the tests, and will suggest future plans for development and improvement.

The inspiration for this work came from the need to find a solution to the fact that there is a lack of cultural identity in the field of design, in particular in the state of Kuwait. To tackle this, the researcher developed an innovative system based on successful studies which have analysed and developed different types of style.

This framework was devised for use with any style, as were the global elements and design rules used in the research. The process of maintaining and developing the cultural identity was divided into three related steps: identifying the style, modifying the style and creating a design tool. In each step there was a test which was designed to validate the suggested methods as well as to answer the research questions, which were:

- What is the Kuwaiti style and how can it be measured?
 - What is the most recognisable feature?
 - What are the common features of Kuwaiti style?
- How is it possible to develop the traditional designs without losing their identity, and at the same time not turn them into cliché designs?
- Is there a consistency in the proposed design tool?

7.1.1 Identifying the style

In order to set the boundaries that tell us how much the style can be stretched and modified without losing its original identity (see figure 7.1), we had to measure the style by locating its common features. In this research the common features that needed to be investigated were one element of design, which was geometric shapes, and one rule of design, which was symmetry. This was achieved through a focus group test. There were three groups in this test; first year design students, final year design students, and the researcher. Besides exploring the common features in the tested style the researcher identified a degree of similarity in the visual analyses made by the three groups. This was undertaken to ensure that the researcher did not analyse the style based purely on personal preference, failing to appreciate what locals and designers saw in it.

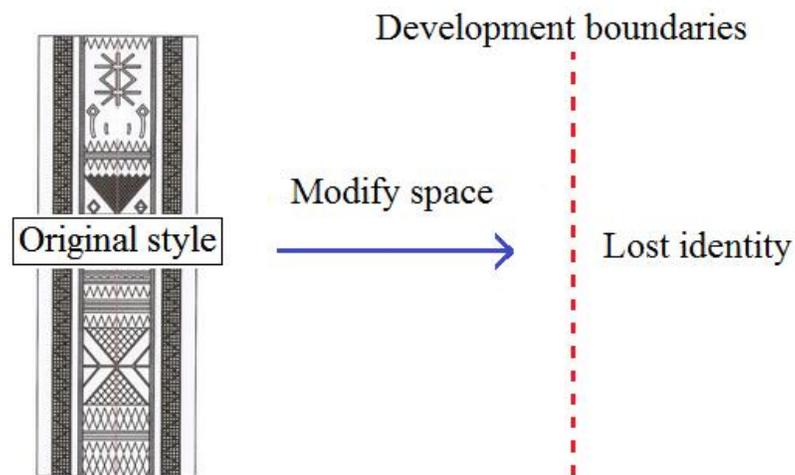


Figure 7.1: Style stretching.

The next stage in measuring a style is to explore its design language or its DNA by investigating the shape grammar. Knowing the shape grammar of a style will help to identify the rules that shaped that style, and will also play a big part in modifying it. Shape grammar consists of rules that are applied to initial shapes to create the language of design, and by locating the strong rules which are the most common among the designs or products, a model was proposed that could guide us in developing the style.

7.1.2 Modifying the style

The next step in maintaining the cultural identity in a design was to modify it based on the knowledge gained from the previous step. But knowing the elements and rules of design as well as the shape grammar was not enough to allow us to set the new boundaries because we still did not know which method of modification was most acceptable to Kuwaitis as an extension to their original style. For that, the researcher created seven design groups, each with a unique approach to producing new Sadu patterns. Testing the groups helped the researcher to identify which method produces the most recognisable Kuwaiti Sadu style patterns, and what were the common rules in the seven groups that successfully generated this style. Also, the test measured the likability of the design group amongst Kuwaitis, because there was no point in investing in a method that produces Kuwaiti patterns which people do not like, or choosing a method where people liked the patterns but where the original style was lost.

7.1.3 The design tool

Creating a tool with features inspired by the data and evidence gathered throughout the study was the final step in this research. The purpose of this software tool is to produce developed and consistent Sadu patterns so that Kuwaitis and non-Kuwaitis can achieve the same result. A test was conducted to measure the consistency of the tool's outcomes as well as to prove that the framework the researcher had used in developing the traditional style was successful.

7.2 Findings of the research

There were three tests in the course of the study, each with a specific role in either identifying, modifying or measuring traditional Kuwaiti Sadu style. The findings of the first test showed that:

- Strong common geometric shapes were identified amongst the designs and they were: triangle, square, rectangle and diamond - these were the most repeated shapes.

- The results show that there are some symmetry rules which have been repeated in almost all the products, and there is similarity between the focus groups' answers. The most popular symmetry rules in Sadu are: Pmm2, Pm11, P1m1 and Pma2.
- There is similarity in the visual analysis of Sadu between the three groups; first year design students, final year design students and the researcher. When applying a similarity model based on the theory of feature matching, the results also showed that the researcher's answers had more in common with those of the designers (final year students) than with those of the customers (first year students).

The shape grammar for the Kuwaiti Sadu style showed that:

- The designs with one initial shape mostly use the production rules Add, Move, Attach, Not attach, Cut and Rotation, whereas the most frequently found analysis rules are Vertical reflection, Horizontal reflection, Attach, Not attach and Sdn.
- The designs with multiple initial shapes are related to the production rules Add, Move, Cut, Proportion, Attach, overlap, Vertical reflection and Horizontal reflection, whereas the most frequently found analysis rules are: Vertical reflection, Horizontal reflection, Attach, Not attach, Overlap, Proportion and Sdn (n= 2 and 4).

The results of the second test showed that:

- Participants aged over forty recognised and liked the developed Sadu style better than those under forty.
- Females recognised and liked the developed style better than the men.
- The test helped the researcher to explore which method produces the most recognisable and liked modified patterns of the Kuwaiti Sadu style.

- The common rules in the seven groups that successfully generate this Kuwaiti style have been identified.

The results of testing the design tool showed that:

- There is a statistically significant relationship between the designers' drawings. This proves that the tool can produce a consistent Kuwaiti Sadu style even if it has been used by a non-Kuwaiti person.
- The designers made certain comments in common when it came to identifying the points of strength for the tool such as it produces inspirational designs that can be used for architecture that has a theme of cultural identity , whereas comments regarding the tool's shortfalls and things that need consideration varied from one designer to another.

As far as the researcher could ascertain, this is the first time that the development and maintenance of the design language of Kuwaiti traditional style has been investigated in this manner. Hence, it is hoped that the findings of this field study will provide a baseline for any subsequent explorations, and the guidelines generated from it may contribute to the debate about the shape of future designs in Kuwait.

7.3 Recommendations for further research

The focus of this research is on maintaining cultural identity in a design field that embraces the need for improvement. A range of issues have emerged in relation to the proposed approach and the implementation of that approach, which require further investigation. This research has demonstrated the feasibility of the proposed approach through a case study of the traditional Kuwaiti product called Sadu. More applications to varieties of different artifact categories are needed to identify whether the framework of the proposed approach is capable of developing the Kuwaiti style irrespective of the artifact.

Test one defined the Kuwaiti Sadu style by exploring the common features. The geometric shapes and symmetry rules were the key features for measuring that style. There are other elements, such as colour, lines, texture and motion, that are considered important features for identifying a style, besides the rules of design, such as rhythm, unity and contrast. It will be important to perform further research to find out whether the model applied in this study could be used with the other elements and rules to identify a style.

A well defined shape grammar provides a rule based system for generating and modifying a cultural design style. Although the shape grammars were considered to be sufficient for the purpose of this work, further research is needed to propose a formal definition for production and analysis rules for other cultural styles and artifacts than the Kuwaiti Sadu. This could enable identification of styles by setting rule parameter values, and conducting a comparison between styles based upon the similarity and/or difference between separate cultural styles and their artifacts.

As seen in test three, the suggested tool has achieved the purpose for which it was intended which was to produce developed and consistent Sadu patterns in such a way that Kuwaitis and non-Kuwaitis could achieve the same result. However, it falls short in areas that require professional programming skills. Other investigators from a programming background (such as artificial intelligence) would have a more sophisticated basis from which to start regarding computational tools and methods.

7.4 Concluding comments

This research, which is concerned with maintaining cultural identity in the design field, has involved the measurement, exploration of the design language, and the development of the Kuwaiti style. Finding the common geometric shapes and symmetry rules was the first step in identifying the Kuwaiti Sadu style, that contributed in choosing the distinguished features that were to encode it into a language of shapes and rules via shape grammars. A table was created which was used as a model for producing and analysing the spatial relationships between the designs in this research. The production rules for the Kuwaiti Sadu style were generated by

repeatedly using certain rules and by applying rules in a consistent manner throughout the production process. Whereas the analysis rules came from analysing the final design and finding out what rules it had. They are one of the key aspects of modifying the style and comparing between the designs.

In the second step, the Kuwaiti Sadu style was developed then its recognisability and likability were tested on a group of Kuwaitis. The knowledge gathered from the first step was the basis for creating different design groups, each with a unique approach to making patterns. The results showed the rules which produced the most recognisable and the most likable patterns of the developed Sadu style, and the common rules among the groups that successfully generated this Kuwaiti style.

A software tool was then created so that both Kuwaitis and non-Kuwaitis could produce consistent 2D Sadu designs that could be used for architecture or interior design. Additionally, the 2D developed style designs were translated into 3D models, to prove that the tool could produce inspirational ideas in line with the theme of cultural identity.

This work has discussed a crucially important issue because it would be an incalculable loss if the cultural design style of a country were lost forever. It is the hope of the researcher that, through the publication of this thesis and by bringing the research to the attention of the various interior designers and researchers who are interested in the design field, cultural identity in the built environment may regain a little of its former status. The case study offered in this research is only a sample of possible ideas intended to raise awareness of the decline of traditional style in the design field and to demonstrate how inspiration can be taken from culture and applied within contemporary design, while still maintaining its original identity.

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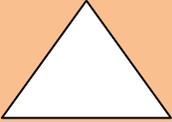
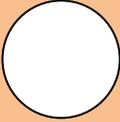
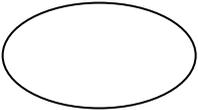
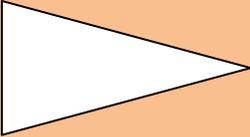
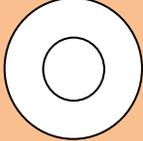
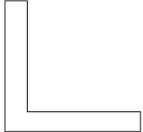
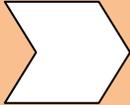
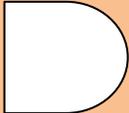
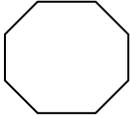
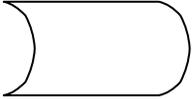
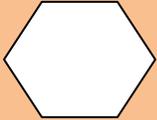
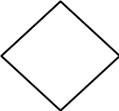
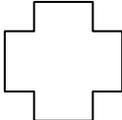
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Appendix A

Test one- part one

Basic shapes chart

		
1	9	17
		
2	10	18
		
3	11	19
		
4	12	20
		
5	13	21
		
6	14	22
		
7	15	23
		
8	16	24

Gender:

Age:

Nationality:

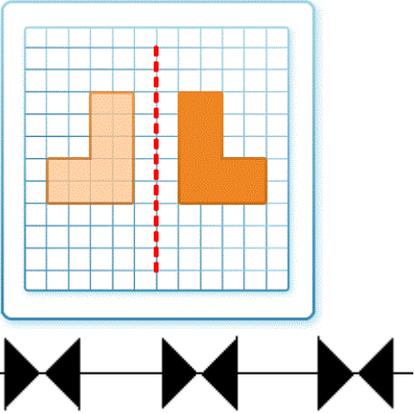
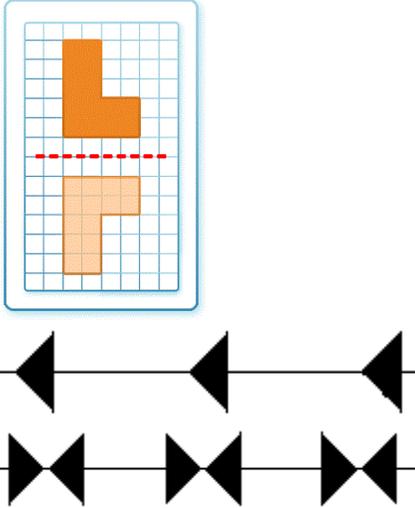
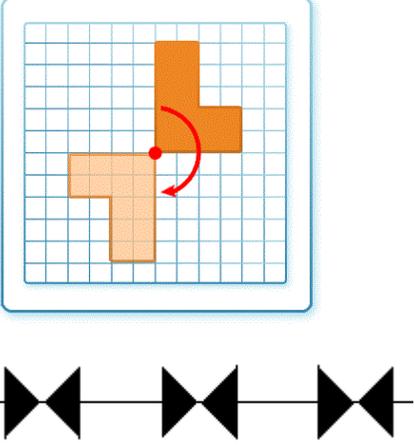
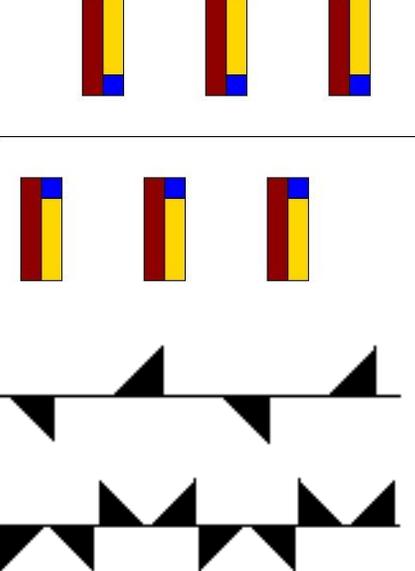
- Write down the basic shape codes of each product as you see it.

Product A												
Product B												
Product C												
Product D												
Product E												
Product F												
Product G												
Product H												

Product I												
Product J												

Test one- part two

Rules of symmetry

Vertical mirror	Horizontal mirror
	
Rotation	Glide reflection
	

- Please concentrate on the following products' borders and select the appropriate symmetry rules by ticking the boxes.

Vm= Vertical mirror, Hm= Horizontal mirror, Gr= Glide reflection, R= Rotation

Note: If Horizontal mirror is found in a border, then the Glide reflection must be skipped. The opposite is also true.

Product A							
Border 1		Vm		Hm		Gr	R
Border 2		Vm		Hm		Gr	R
Border 3	3.1	Vm		Hm		Gr	R
	3.2	Vm		Hm		Gr	R
	3.3	Vm		Hm		Gr	R
	3.4	Vm		Hm		Gr	R
	3.5	Vm		Hm		Gr	R
Border 4		Vm		Hm		Gr	R
Border 5		Vm		Hm		Gr	R
Product B							
Border 1		Vm		Hm		Gr	R
Border 2		Vm		Hm		Gr	R
Border 3		Vm		Hm		Gr	R
Border 4		Vm		Hm		Gr	R
Border 5		Vm		Hm		Gr	R
Border 6		Vm		Hm		Gr	R
Border 7		Vm		Hm		Gr	R
Border 8		Vm		Hm		Gr	R

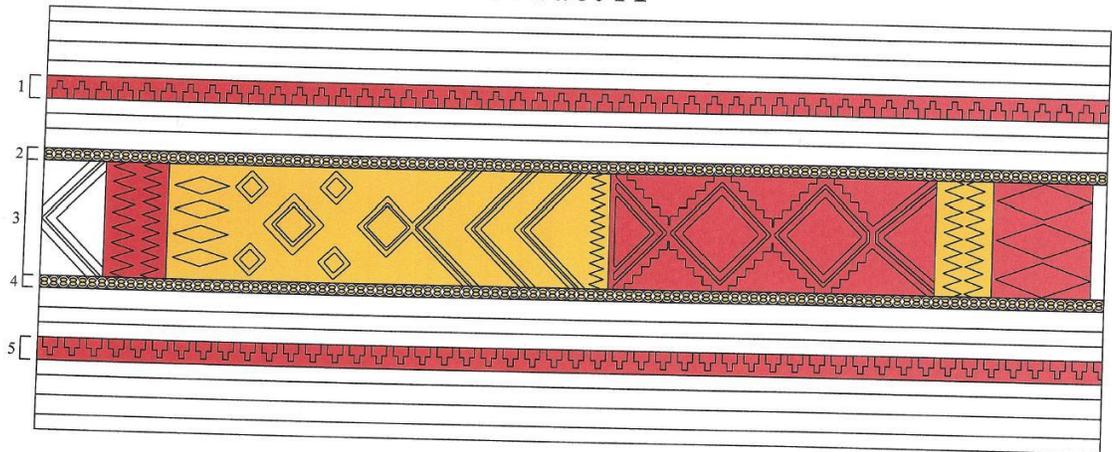
Border 9	Vm		Hm		Gr		R	
Border 10	Vm		Hm		Gr		R	
Border 11	Vm		Hm		Gr		R	
Product C								
Border 1	Vm		Hm		Gr		R	
Border 2	Vm		Hm		Gr		R	
Border 3	Vm		Hm		Gr		R	
Border 4	Vm		Hm		Gr		R	
Border 5	Vm		Hm		Gr		R	
Product D								
Border 1	Vm		Hm		Gr		R	
Border 2	Vm		Hm		Gr		R	
Border 3	Vm		Hm		Gr		R	
Product E								
Border 1	Vm		Hm		Gr		R	
Border 2	Vm		Hm		Gr		R	
Border 3	Vm		Hm		Gr		R	
Border 4	Vm		Hm		Gr		R	
Border 5	Vm		Hm		Gr		R	
Product F								
Border 1	Vm		Hm		Gr		R	
Border 2	Vm		Hm		Gr		R	
Border 3	Vm		Hm		Gr		R	
Product G								
Border 1	Vm		Hm		Gr		R	

Border 2		Vm		Hm		Gr		R	
Border 3		Vm		Hm		Gr		R	
Border 4		Vm		Hm		Gr		R	
Border 5		Vm		Hm		Gr		R	
Product H									
Border 1		Vm		Hm		Gr		R	
Border 2		Vm		Hm		Gr		R	
Border 3		Vm		Hm		Gr		R	
Border 4		Vm		Hm		Gr		R	
Border 5		Vm		Hm		Gr		R	
Border 6		Vm		Hm		Gr		R	
Border 7		Vm		Hm		Gr		R	
Product I									
Border 1		Vm		Hm		Gr		R	
Product J									
Border 1		Vm		Hm		Gr		R	
Border 2		Vm		Hm		Gr		R	
Border 3		Vm		Hm		Gr		R	
Border 4		Vm		Hm		Gr		R	
Border 5		Vm		Hm		Gr		R	
Border 6		Vm		Hm		Gr		R	
Border 7	7.1	Vm		Hm		Gr		R	
	7.2	Vm		Hm		Gr		R	
	7.3	Vm		Hm		Gr		R	
	7.4	Vm		Hm		Gr		R	

	7.5	Vm		Hm		Gr		R	
	7.6	Vm		Hm		Gr		R	
	7.7	Vm		Hm		Gr		R	
Border 8		Vm		Hm		Gr		R	
Border 9		Vm		Hm		Gr		R	
Border 10		Vm		Hm		Gr		R	
Border 11		Vm		Hm		Gr		R	
Border 12	12.1	Vm		Hm		Gr		R	
	12.2	Vm		Hm		Gr		R	
	12.3	Vm		Hm		Gr		R	
	12.4	Vm		Hm		Gr		R	
Border 13		Vm		Hm		Gr		R	
Border 14		Vm		Hm		Gr		R	

Sadu designs

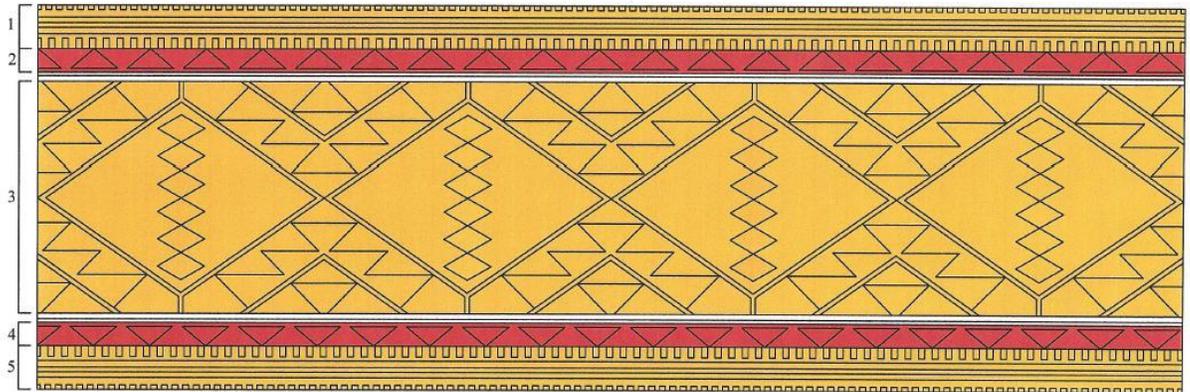
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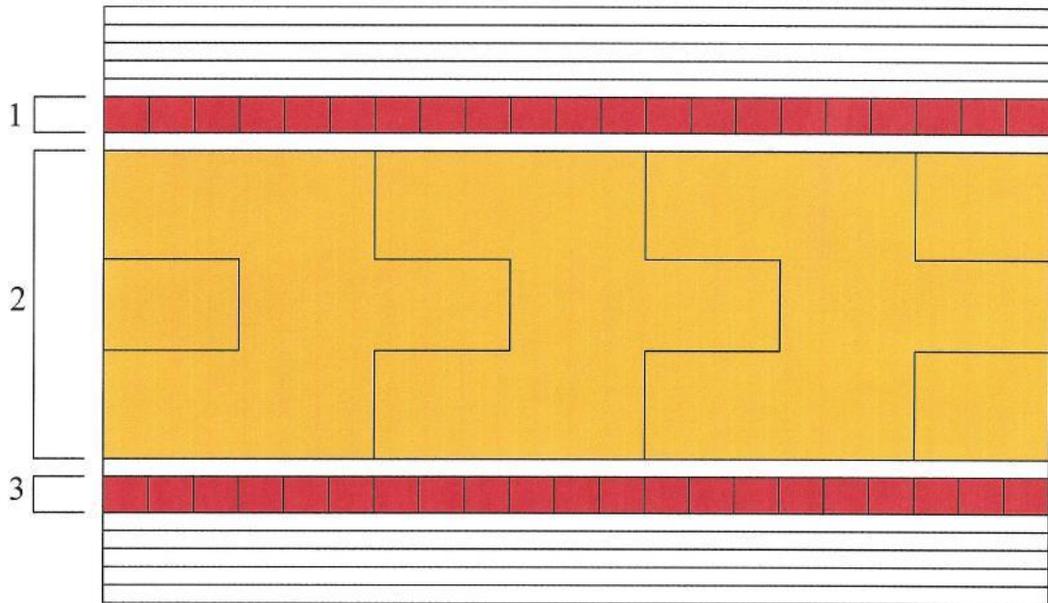
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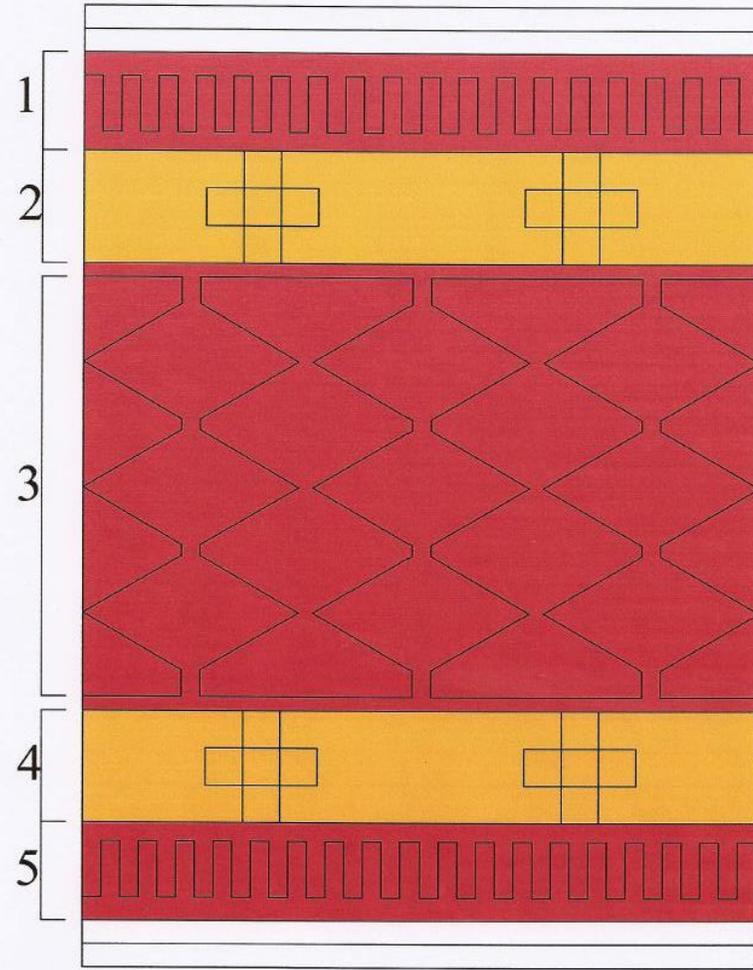
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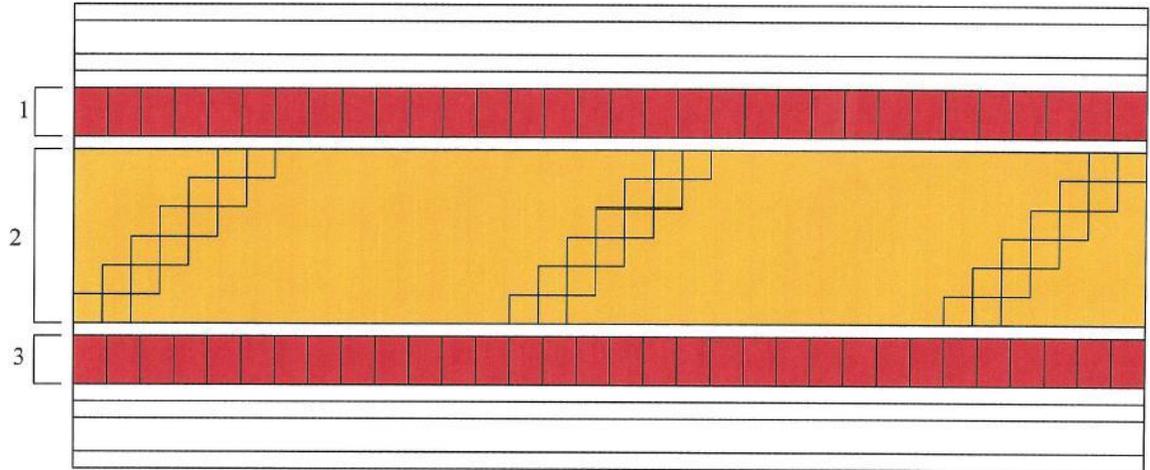
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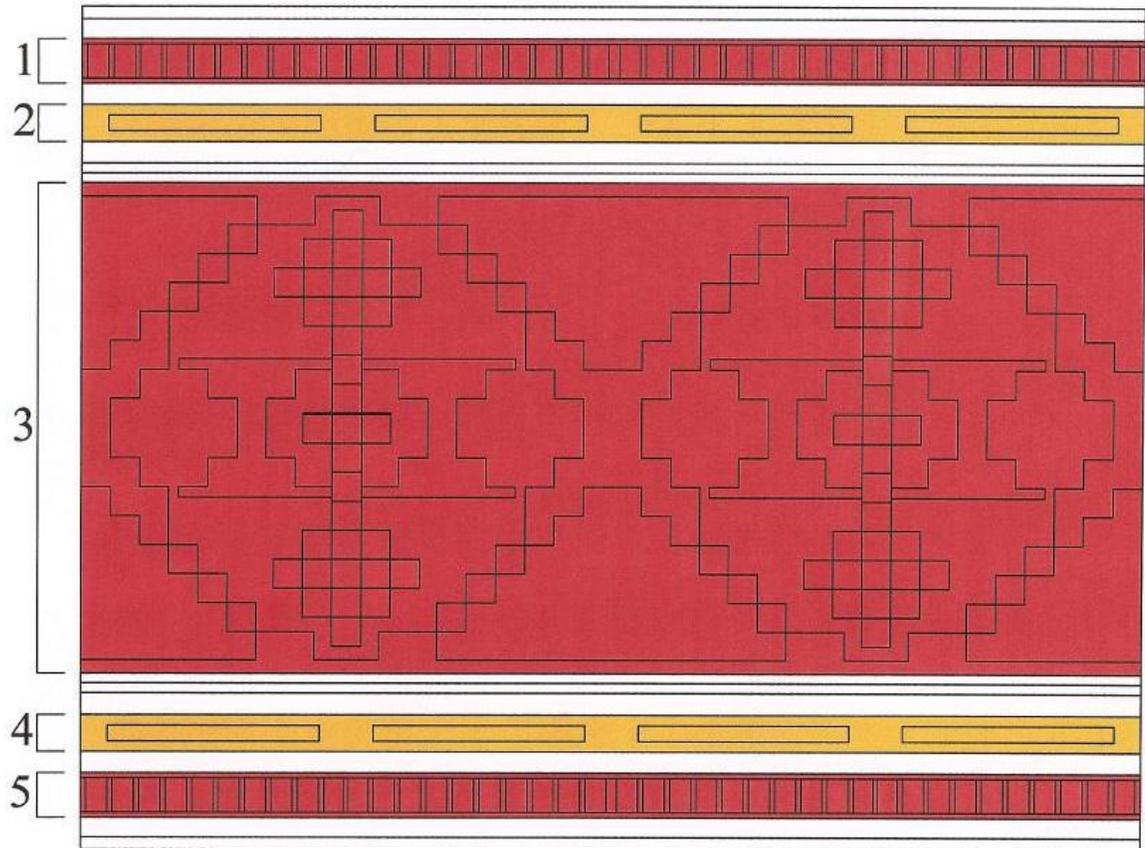
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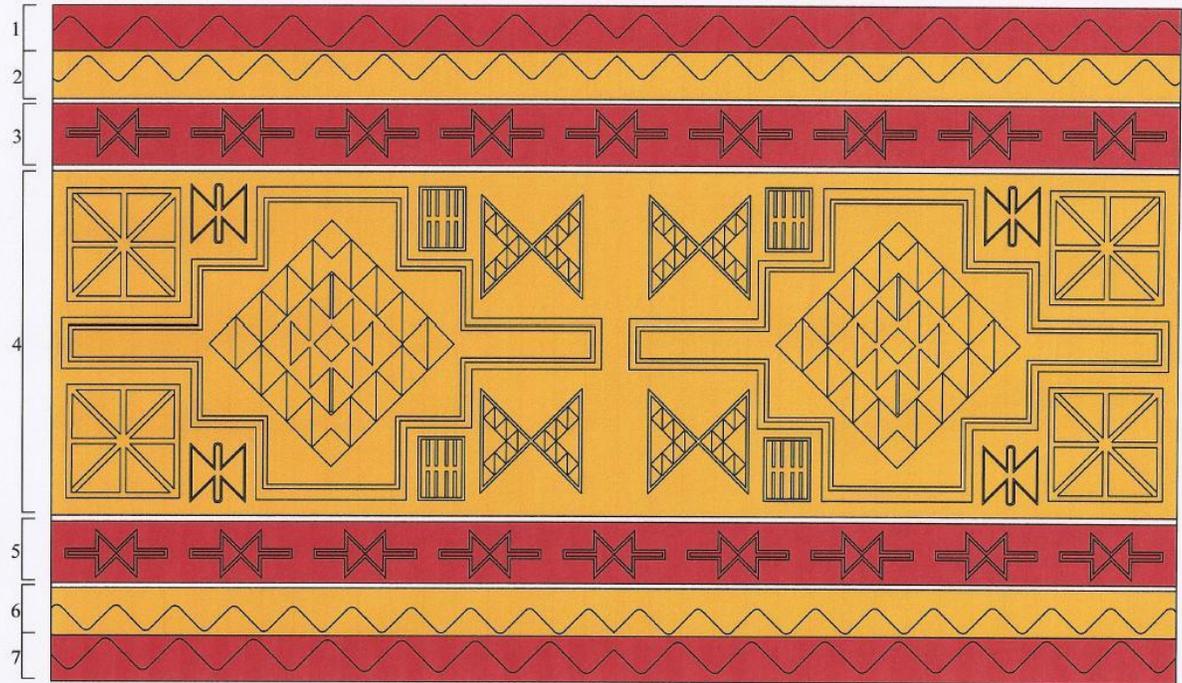
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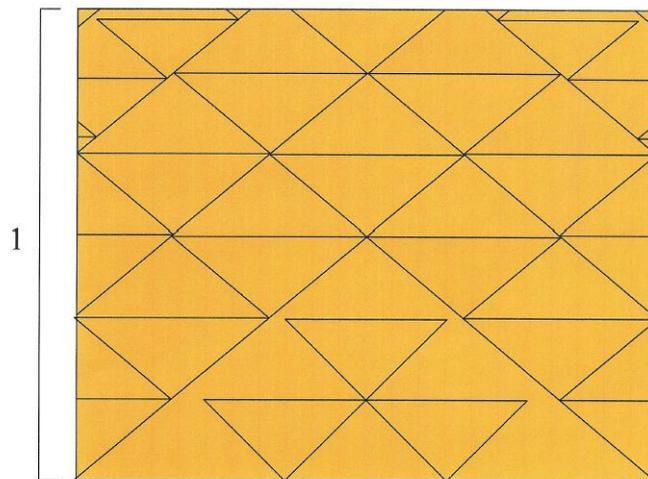
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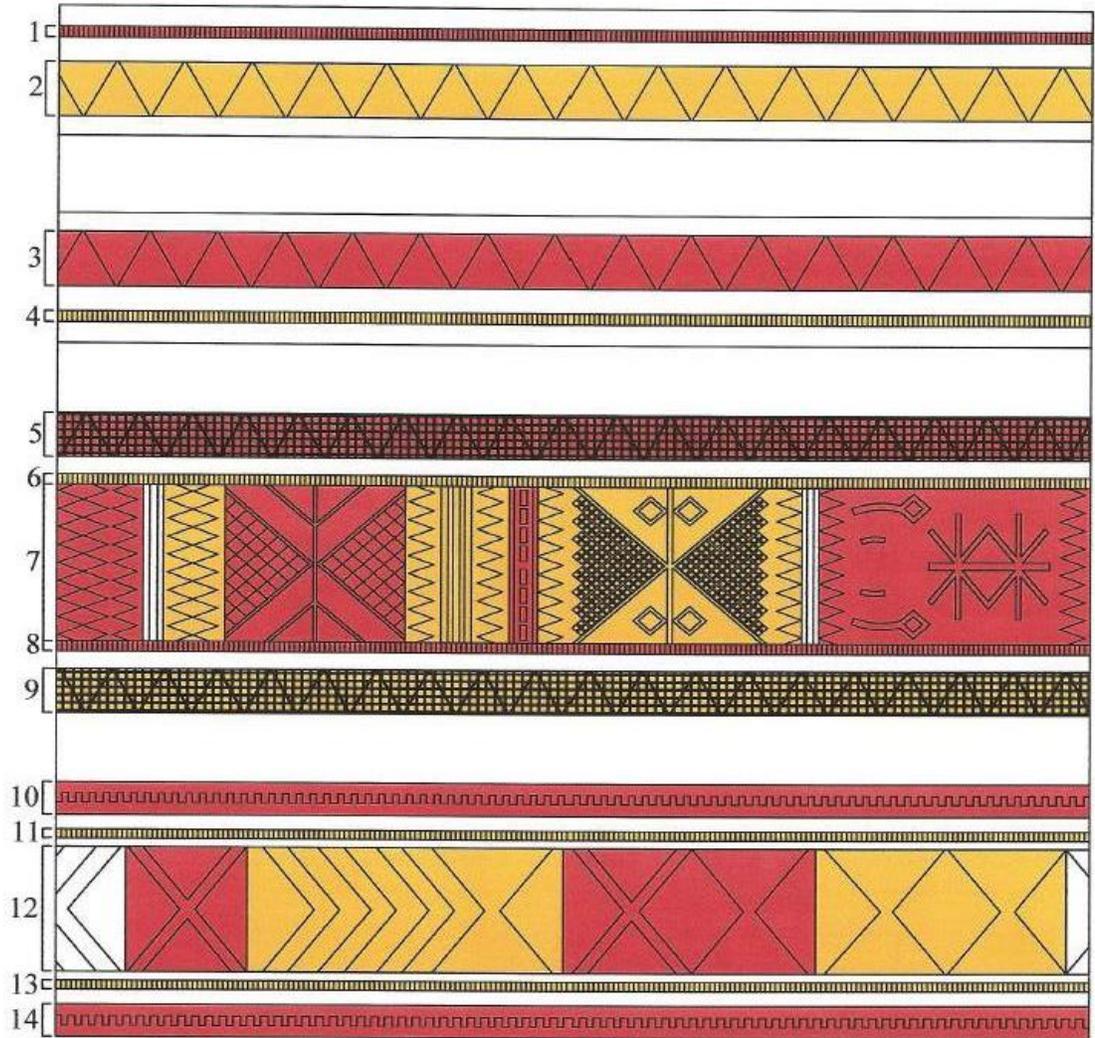
Product H



Product I

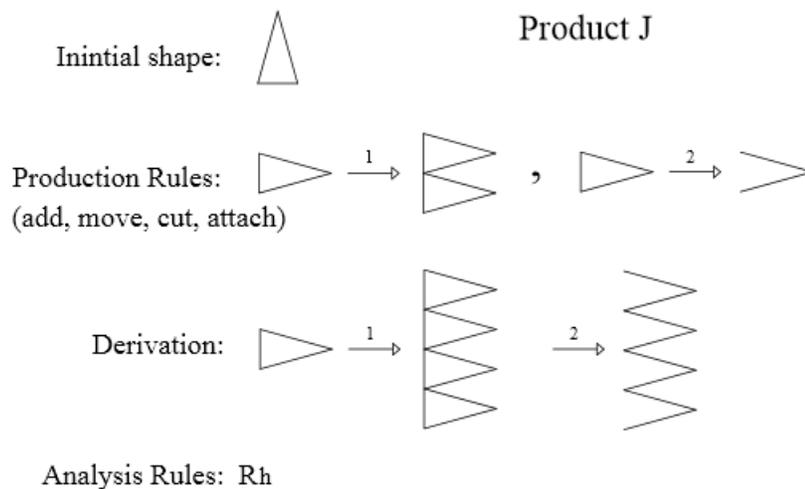
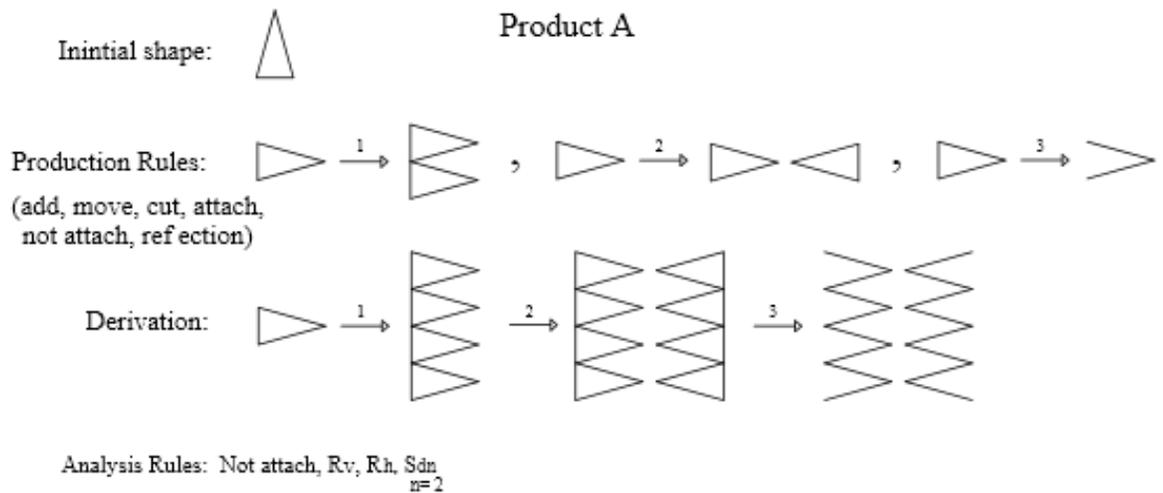


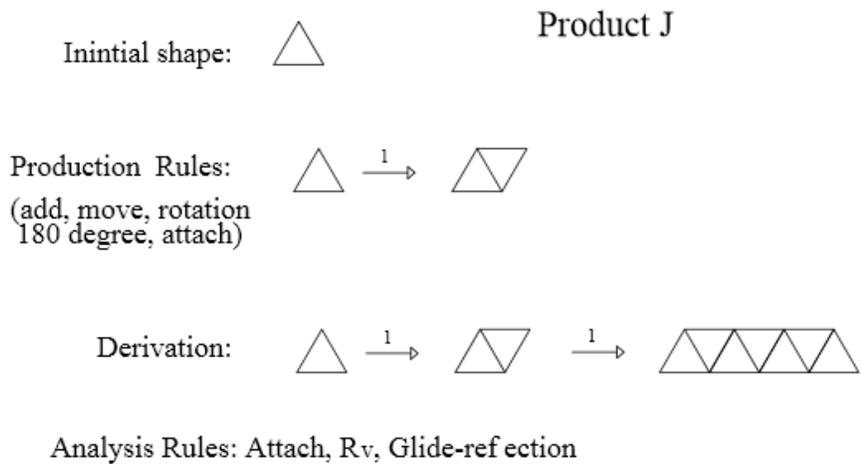
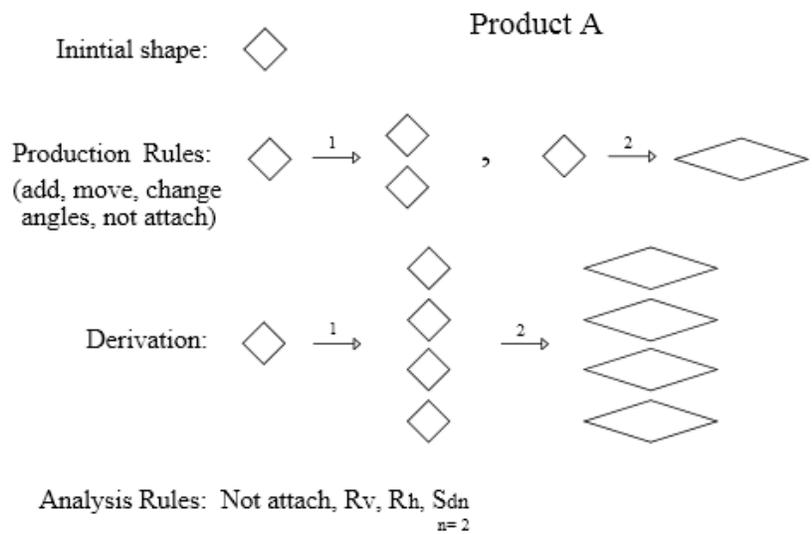
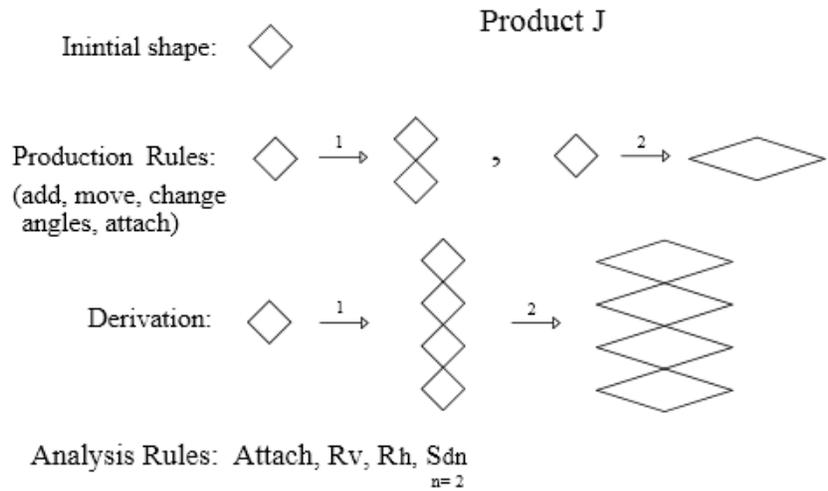
Product J



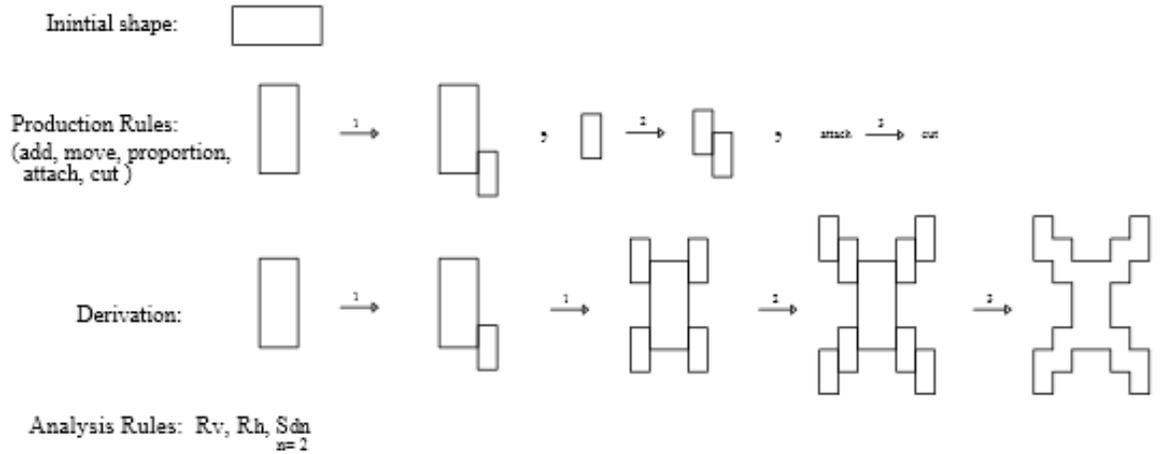
Appendix B

Shape grammars- designs created from one initial shape

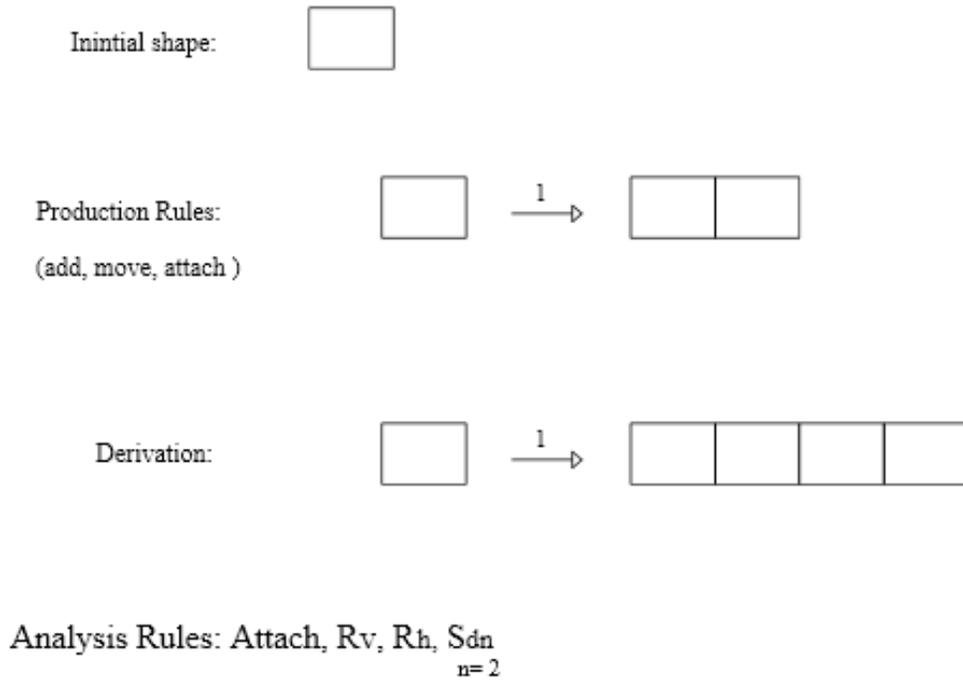




Product G

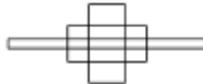


Product D

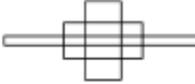


Product H

Initial shape: 

Production Rules:  $\xrightarrow{1}$  ,  $\xrightarrow{2}$  , overlape $\xrightarrow{3}$ cut

(add, rotation 90 degree, change outline, cut, overlape)

Derivation:  $\xrightarrow{1}$  $\xrightarrow{2}$  $\xrightarrow{3}$ 

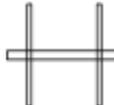
Analysis Rules: Rv, Rh, Sdn
n=2

Product J

Initial shape: 

Production Rules:  $\xrightarrow{1}$  ,  $\xrightarrow{2}$  , overlape $\xrightarrow{3}$ cut

(add, move, rotation 90 and 45 degree, change outline, cut, overlape)

Derivation:  $\xrightarrow{1}$  $\xrightarrow{1}$  $\xrightarrow{2}$  $\xrightarrow{3}$ 

Analysis Rules: Rv, Rh, Sdn
n=2

Product G

Initial shape: 

Production Rules:  $\xrightarrow{1}$  

(add, move, not attach)

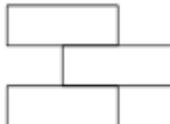
Derivation:  $\xrightarrow{1}$    

Analysis Rules: Not attach, Rv, Rh, Sdn
n=2

Product D

Initial shape: 

Production Rules:  $\xrightarrow{1}$  , attach $\xrightarrow{2}$ cut
 (add, move, attach, cut)

Derivation:  $\xrightarrow{1}$  $\xrightarrow{1}$  $\xrightarrow{2}$ 

Analysis Rules: Rh

Product H

Initial shape: 

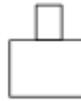
Production Rules:  $\xrightarrow{1}$  ,  $\xrightarrow{2}$  , | $\xrightarrow{2}$ ||
 (add, move, proportion, change outline, not attach, overlap)

Derivation:  $\xrightarrow{1}$  $\xrightarrow{2}$  $\xrightarrow{3}$ 

Analysis Rules: Overlap, Rv, Rh, Sdn_{n=2}

Product A

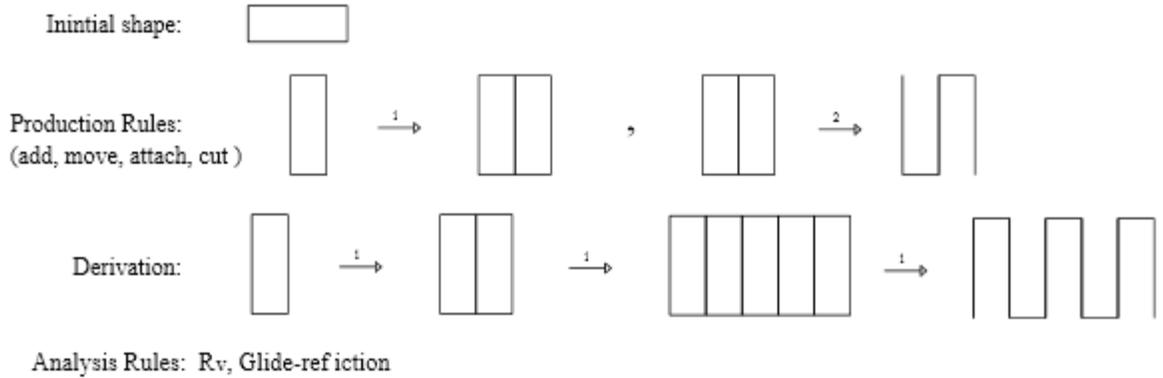
Initial shape: 

Production Rules:  $\xrightarrow{1}$  , attach $\xrightarrow{2}$ cut
 (add, move, proportion, rotation 90 degree, attach, cut)

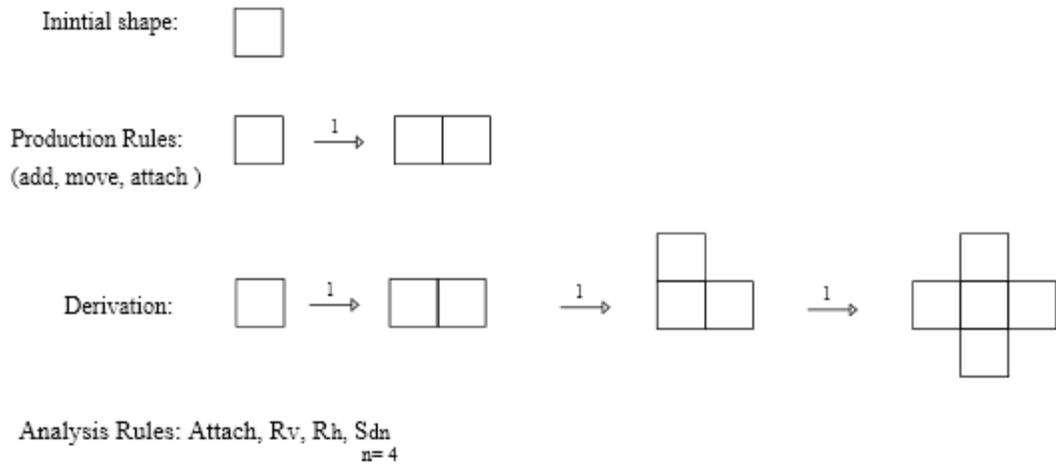
Derivation:  $\xrightarrow{1}$  $\xrightarrow{2}$ 

Analysis Rules: Rv

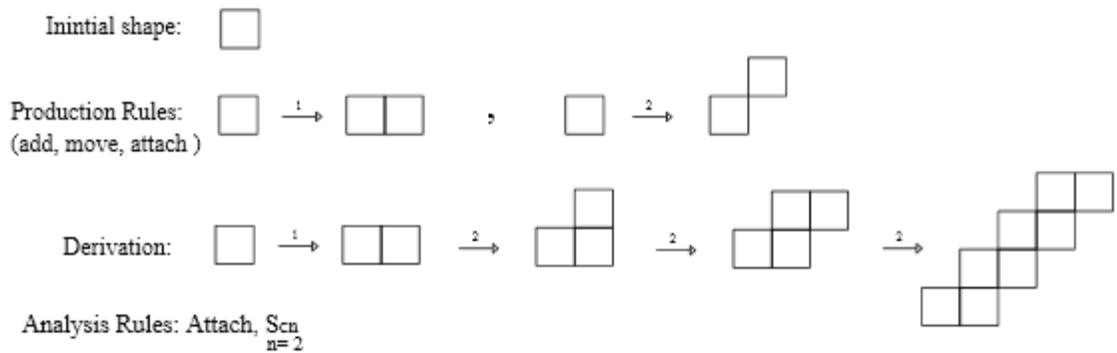
Product E

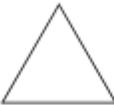
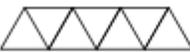
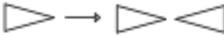


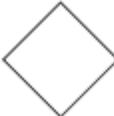
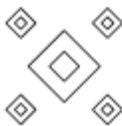
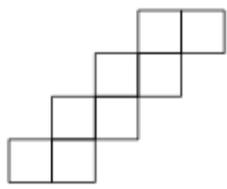
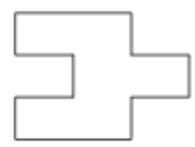
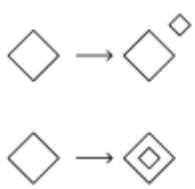
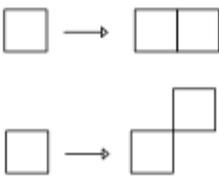
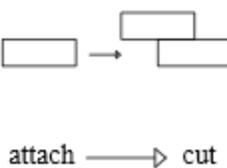
Product E

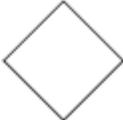
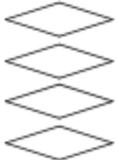
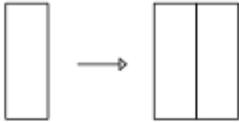
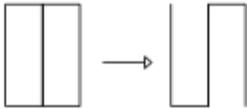


Product F



Shape grammar of designs based on one initial shape				
	1	2	3	4
Initial shapes				
Designs				
Production rules	Add, Move, Attach	Add, Move, Rotation 180 degree, Attach.	Add, Move, Proportion, Rotation 90 degree, Attach, Cut.	Add, Move, Cut, Attach, Not attach, Reflection.
Shape rules			 attach → cut	  
Analysis rules	Attach, Reflection v, Reflection h, Sdn _{n=4}	Attach, Reflection v, Glide-reflection	Reflection v	Not attach, Reflection v, Reflection h, Sdn _{n=2}

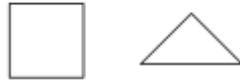
Shape grammar of designs based on one initial shape			
	5	6	7
Initial shapes			
Designs			
Production rules	Add, Slide, Not attach, Overlape, Proportion.	Add, Slide, Attach.	Add, Slide, Attach, Cut.
Shape rules			
Analysis rules	Not attach, Overlape, Proportion, Reflection v, Reflection h and S dn n= 4	Attach, Scn n= 2	Ref ection h

Shape grammar of designs based on one initial shape			
	8	9	10
Initial shapes			
Designs			
Production rules	Add, Slide, Attach.	Add, Slide, Attach, Cut .	Add, Slide, Change angles, Not attach.
Shape rules		 	 
Analysis rules	Attach, Reflection v, Reflection h, $Sdn_{n=2}$	Reflection v, Glide-ref iction	Not attach, Reflection v, Reflection h, $Sdn_{n=2}$

Shape grammars- designs created from multiple initial shapes

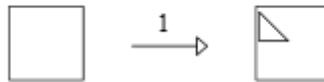
Product H

Initial shape:



Production Rules:

(add, move, overlape)



Derivation:



Analysis Rules: Overlape, Not attach, Rv, Rh, Sdn
n=4

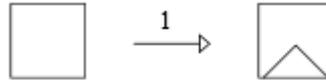
Product J

Initial shape:



Production Rules:

(add, move, overlape)



Derivation:

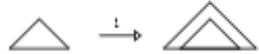
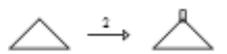


Analysis Rules: Overlape, Attach, Rv, Rh, Sdn
n=4

Product B

Initial shape: 

Production Rules:
(add, move, proportion,
overlape, cut)

 ,  , overlape $\xrightarrow{3}$ cut

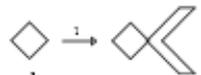
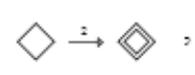
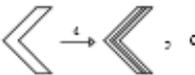
Derivation: 

Analysis Rules: Overlape, Not attach, Rv, Proportion

Product A

Initial shape: 

Production Rules:
(add, move, proportion, change
outline, overlape, attach)

 ,  ,  ,  , overlape $\xrightarrow{5}$ cut

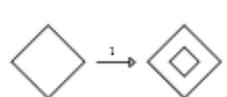
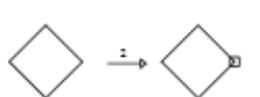
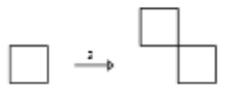
Derivation: 

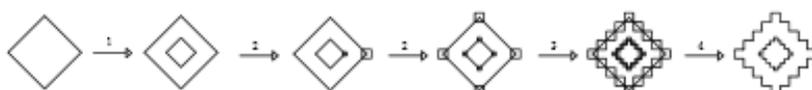
Analysis Rules: Not attach, Overlape, Rh, Proportion, Change outline.

Product B

Initial shape: 

Production Rules:
(add, move, proportion,
attach, cut, overlape)

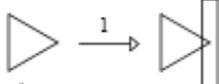
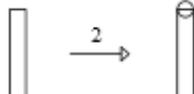
 ,  ,  , overlape $\xrightarrow{4}$ cut

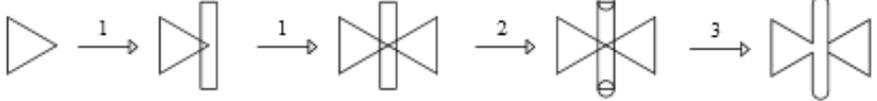
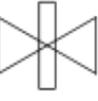
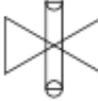
Derivation: 

Analysis Rules: Overlape, Not attach, Rv, Rh, Scm
n=4

Product H

Initial shape: 

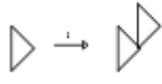
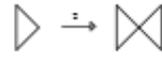
Production Rules:  ,  , overlape $\xrightarrow{3}$ cut
(add, move, overlape, cut)

Derivation:  $\xrightarrow{1}$  $\xrightarrow{1}$  $\xrightarrow{2}$  $\xrightarrow{3}$ 

Analysis Rules: Rv, Rh, Sdn_{n=2}

Product H

Initial shape: 

Production Rules:  ,  , 
(add, move, refecton, proportion, cut, overlape)
  , overlape $\xrightarrow{6}$ cut

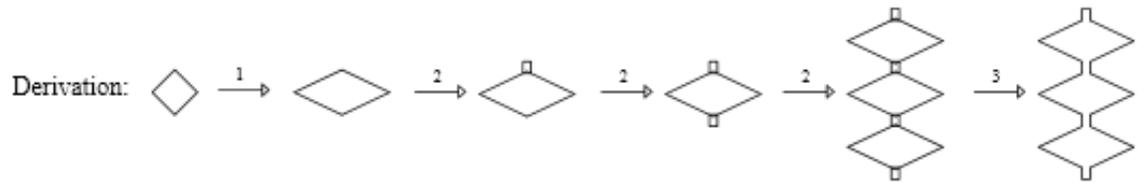
Derivation:  $\xrightarrow{1}$  $\xrightarrow{2}$  $\xrightarrow{3}$  $\xrightarrow{4}$  $\xrightarrow{5}$  $\xrightarrow{6}$ 

Analysis Rules: Overlape, Not attach, Rv, Rh, Sdn_{n=2}

Product E

Initial shape: 

Production Rules:  $\xrightarrow{1}$  ,  $\xrightarrow{2}$  , overlape $\xrightarrow{3}$ cut
(add, move, change angle, overlape, cut)

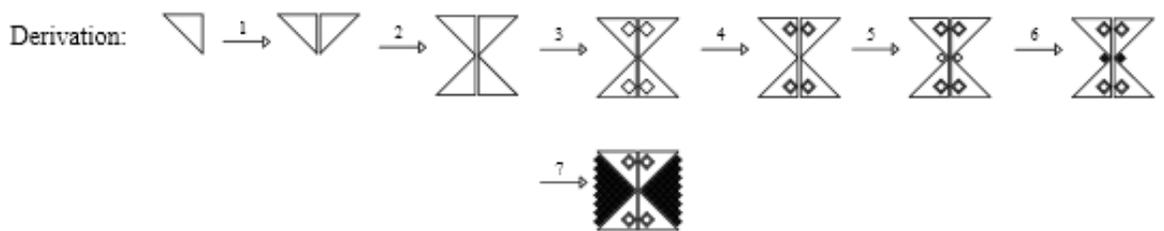
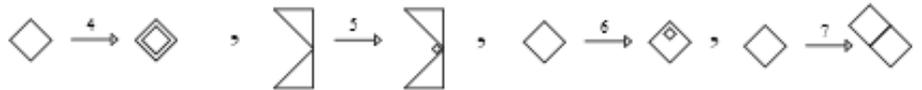


Analysis Rules: Rv, Rh, Sdn_{n=2}

Product J

Initial shape: 

Production Rules:  $\xrightarrow{1}$  ,  $\xrightarrow{2}$  ,  $\xrightarrow{3}$ 
(add, move, proportion, reflection, attach, overlape)

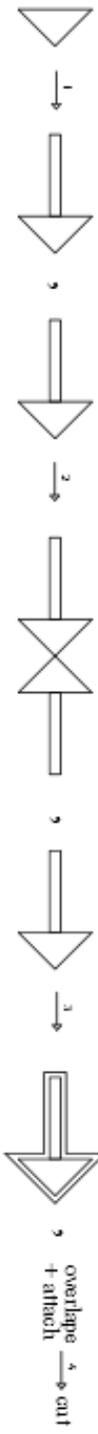


Analysis Rules: Attach, Not attach, Overlape, Rv, Rh, Proportion, Sdn_{n=2}

Product E

Initial shape: 

Production Rules:
 (add, move, reflection, proportion, overlap, attach, cut)

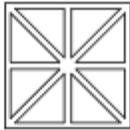


overlape + attach $\xrightarrow{4}$ cut

Derivation:



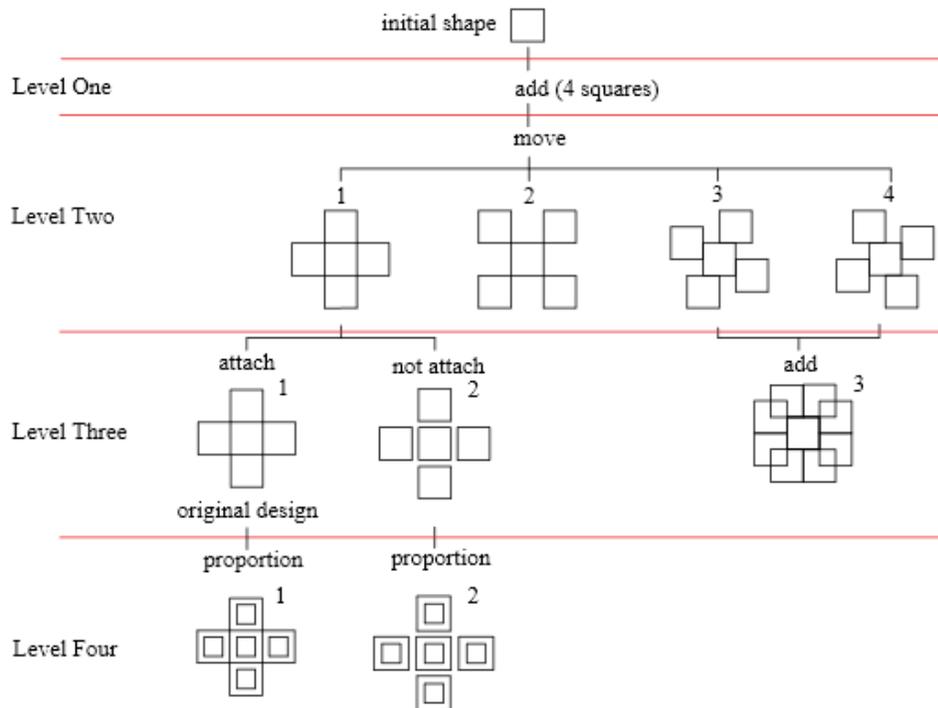
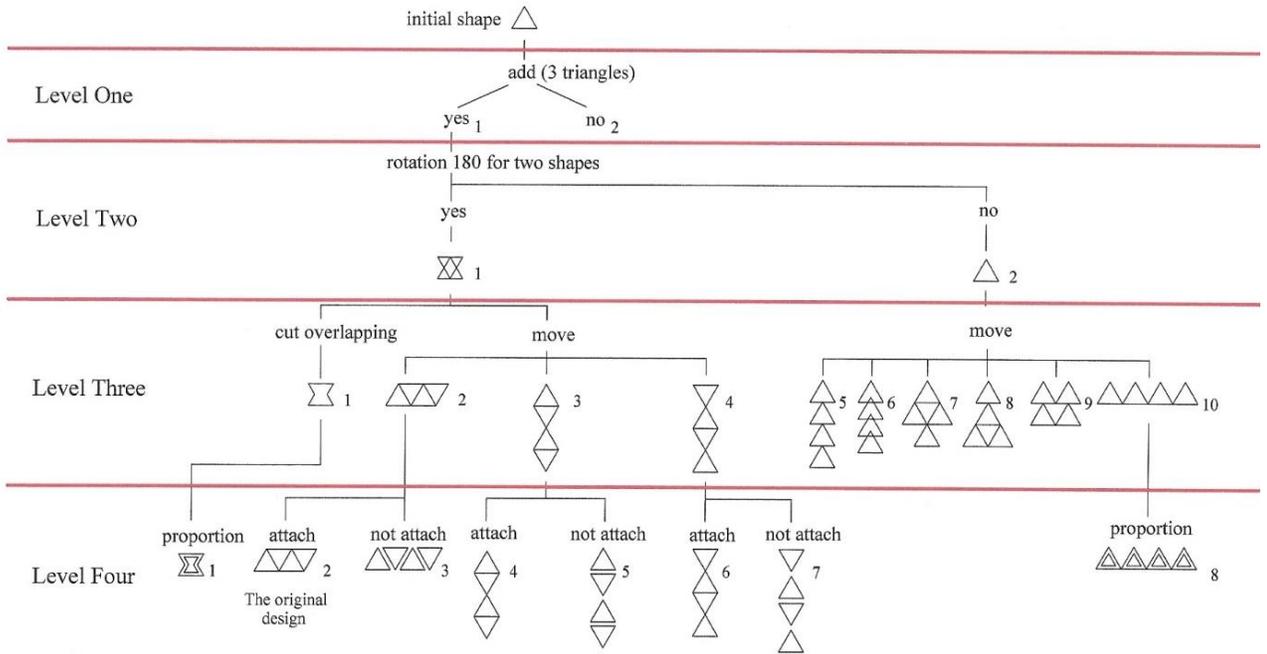
Analysis Rules: Attach, Proportion, R_v, R_h, S_{dn}
 $n=2$

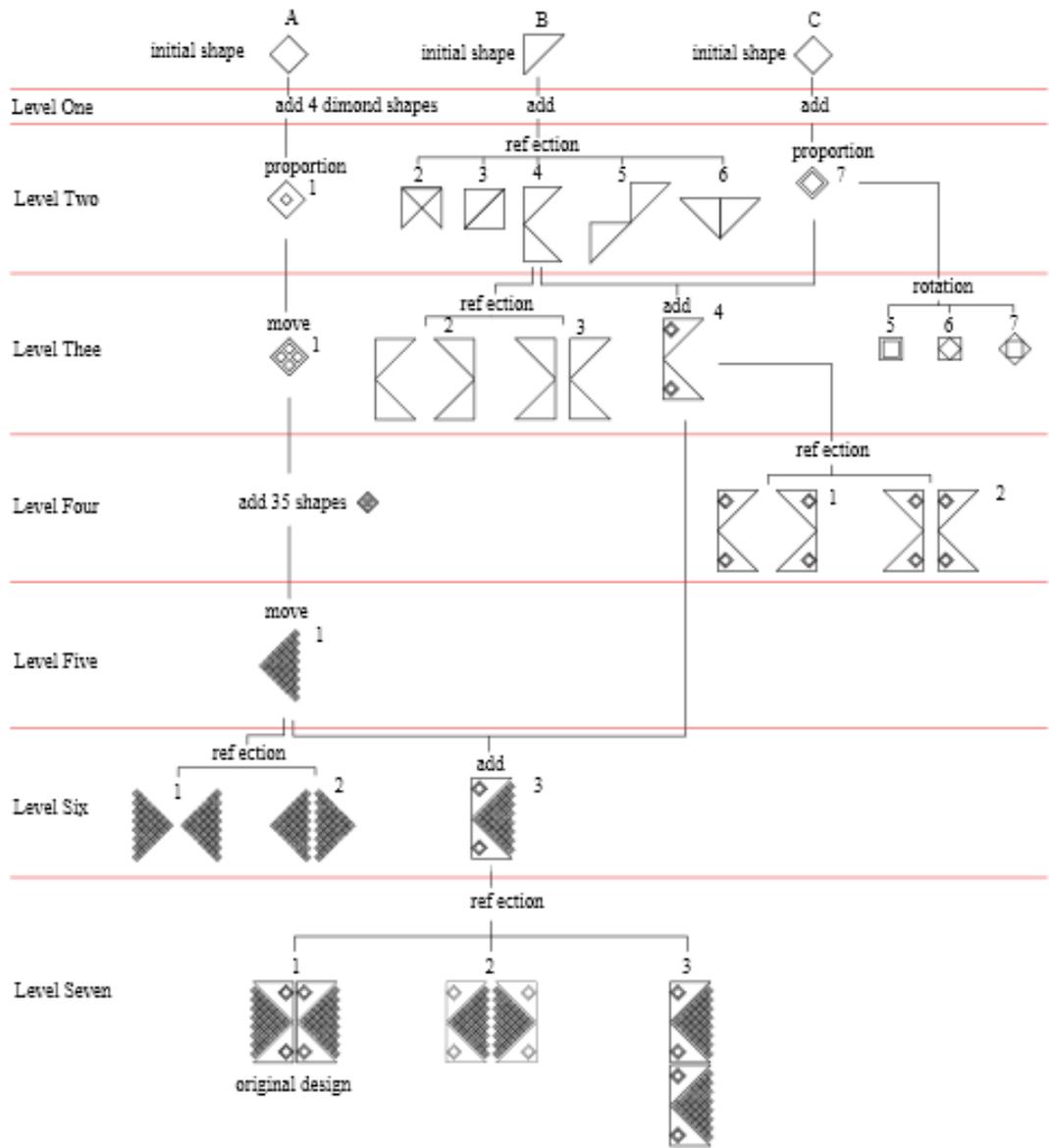
Shape grammar of designs based on multiple initial shapes			
	1	2	3
Initial shapes			
Designs			
Production rules	Add, Move, Overlape.	Add, Move, Overlape.	Add, Move, Change angle, Overlape, Cut.
Shape rules			  overlape → cut
Analysis rules	Overlape, Attach, Ref ection v, Ref ection h, Sdn _{n=4}	Overlape, Not attach, Ref ection v, Ref ection h, Sdn _{n=4}	Ref ection v, Ref ection h, Sdn _{n=2}

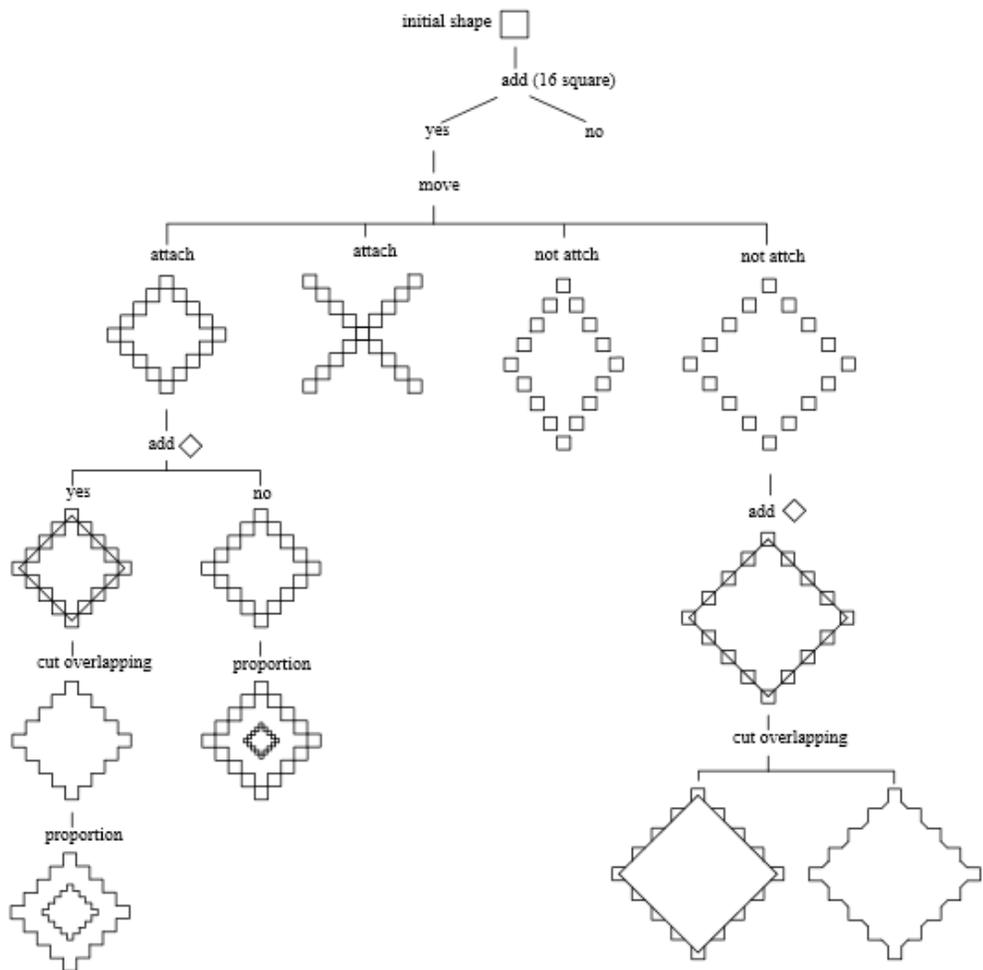
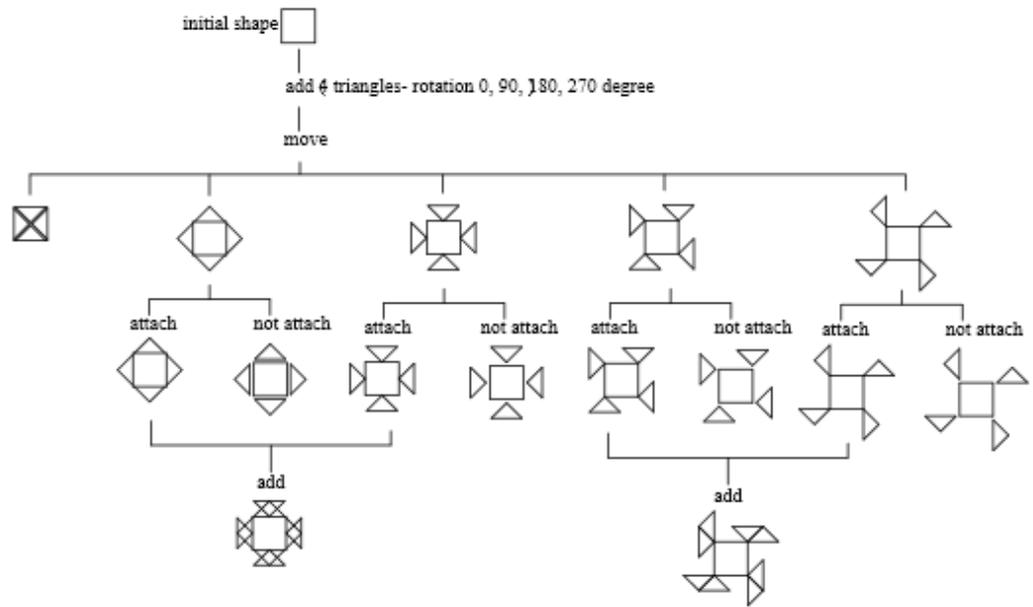
Shape grammar of designs based on multiple initial shapes				
	4	5	6	7
Initial shapes				
Designs				
Production rules	Add, Move, Overlape, Cut.	Add, Slide, Proportion, Change outline, Overlape, Attach.	Add, Slide, Proportion, Attach, Cut, Overlape.	Add, Slide, Proportion, Overlape, Cut.
Shape rules	 	 overlape → cut	 overlape → cut	 overlape → cut
Analysis rules	Ref ection v, Ref ection h, Sdn _{n=2}	Overlape, Not attach, Ref ection h, Proportion, Change outline.	Overlape, Not attach, Ref ection v, Ref ection h, Sdn _{n=4}	Overlape, Not attach, Ref ection v, Proportion

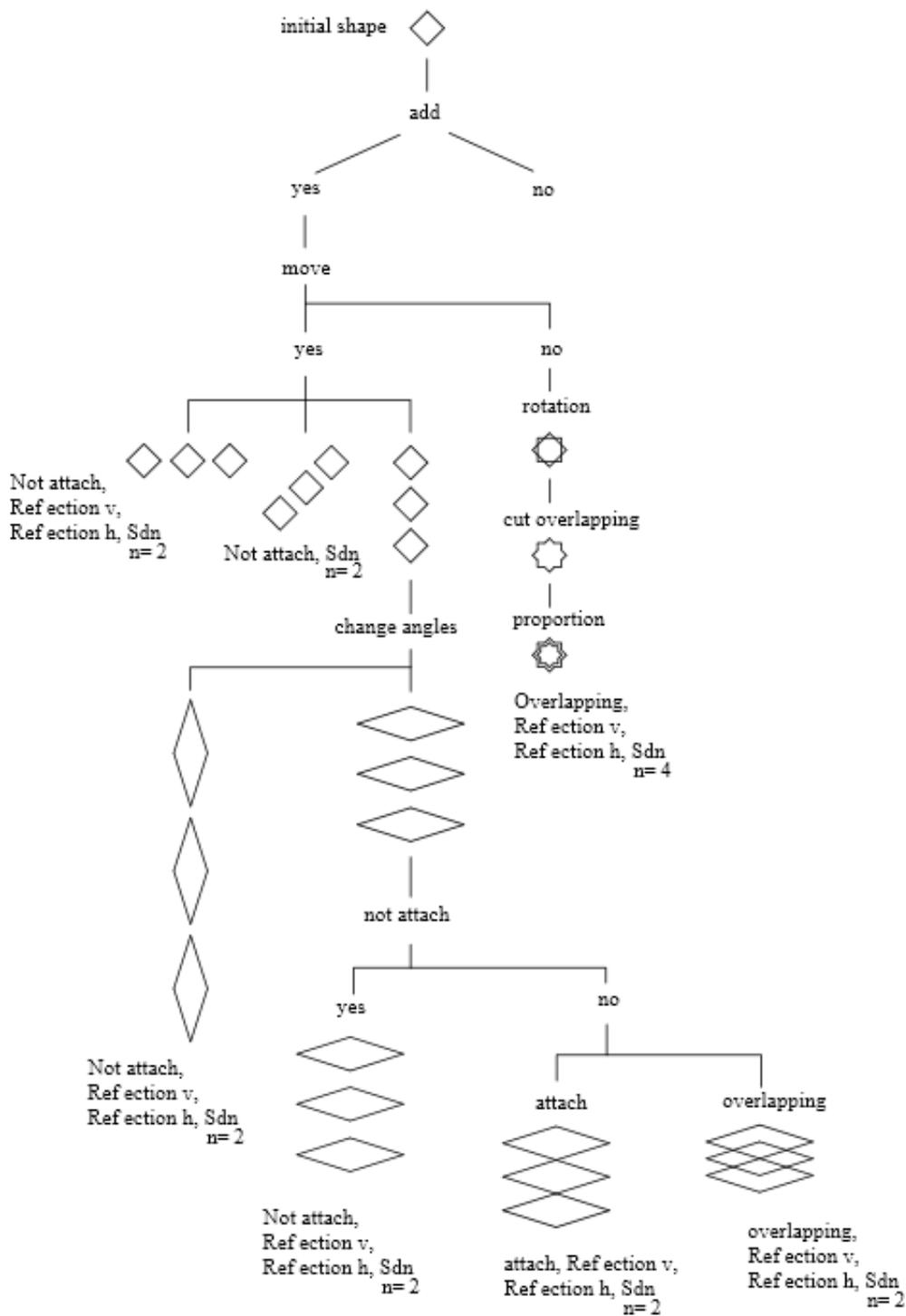
Shape grammar of designs based on multiple initial shapes			
	8	9	10
Initial shapes			
Designs			
Production rules	Add, Slide, Ref ection, Proportion, Cut, Overlape	Add, Slide, Proportion, Ref ection, Attach, Overlape.	Add, Slide, Ref ection, Proportion, Overlape, Attach, Cut.
Shape rules	<p>overlape → cut</p>		<p>overlape + attach → cut</p>
Analysis rules	Overlape, Not attach, Ref ection v, Ref ection h, Sdn n=2	Attach, Not attach, Overlape, Ref ection v, Ref ection h, Proportion, Sdn n=2	Attach, Proportion, Ref ection v, Ref ection h, Sdn n=2

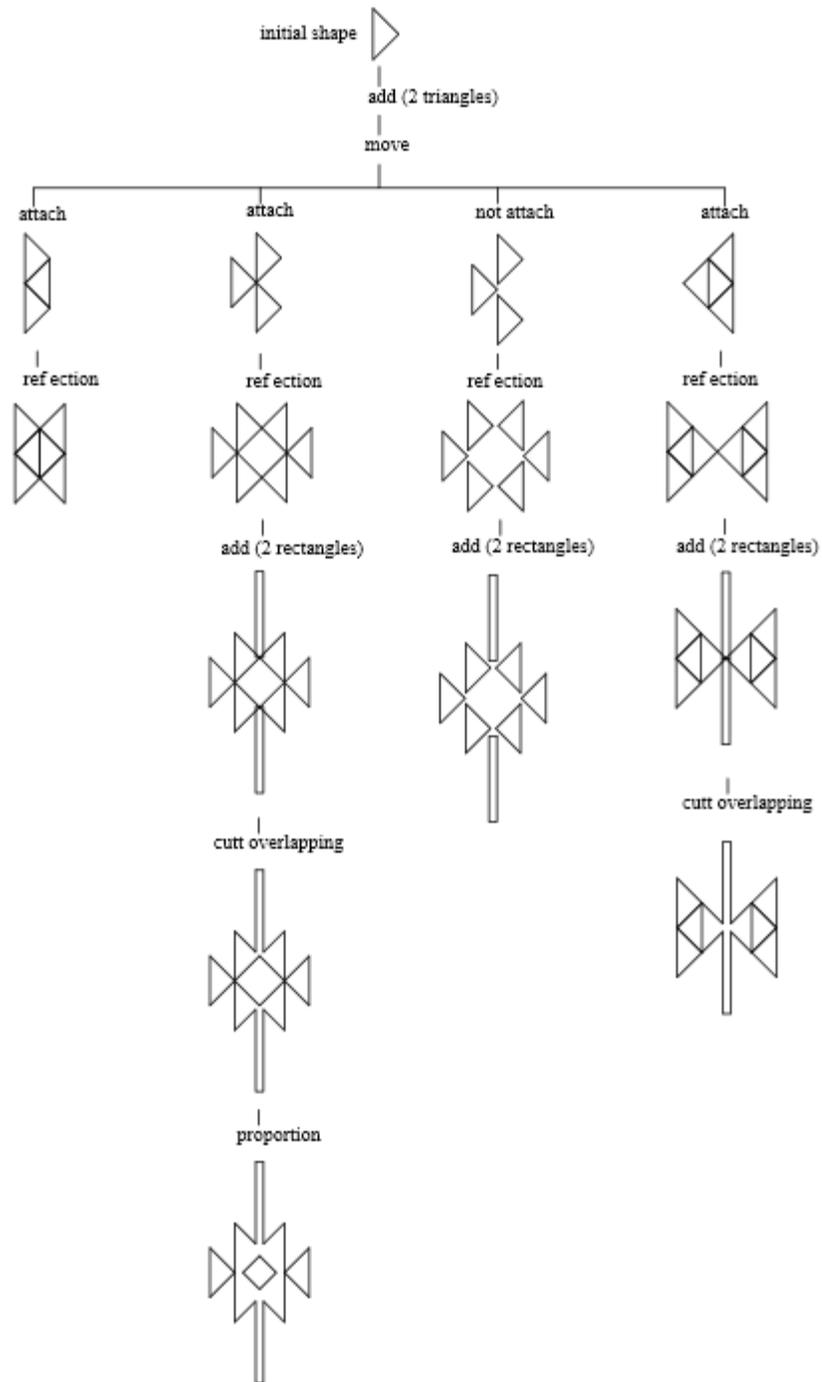
Shape grammars- design trees

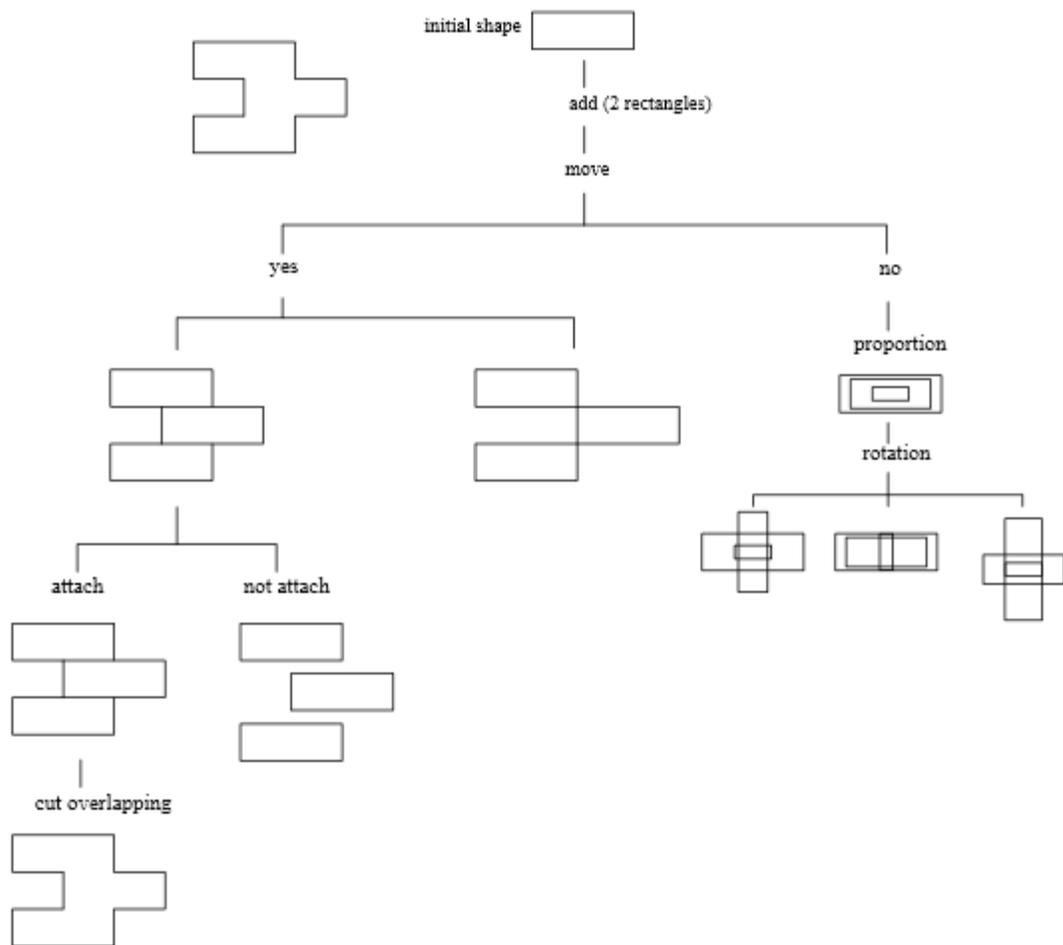








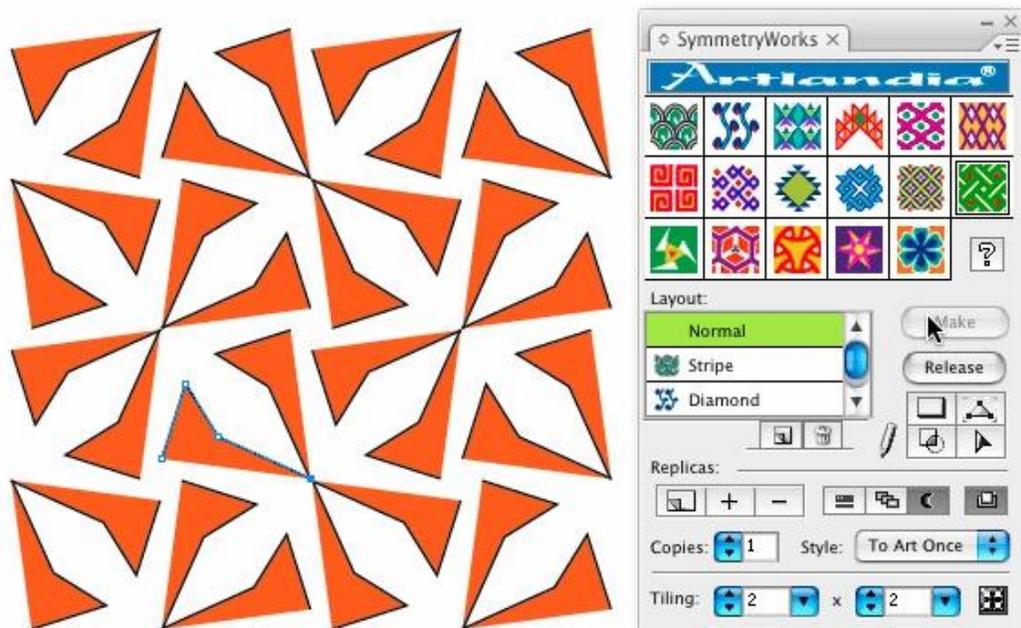




Appendix C

Symmetry works

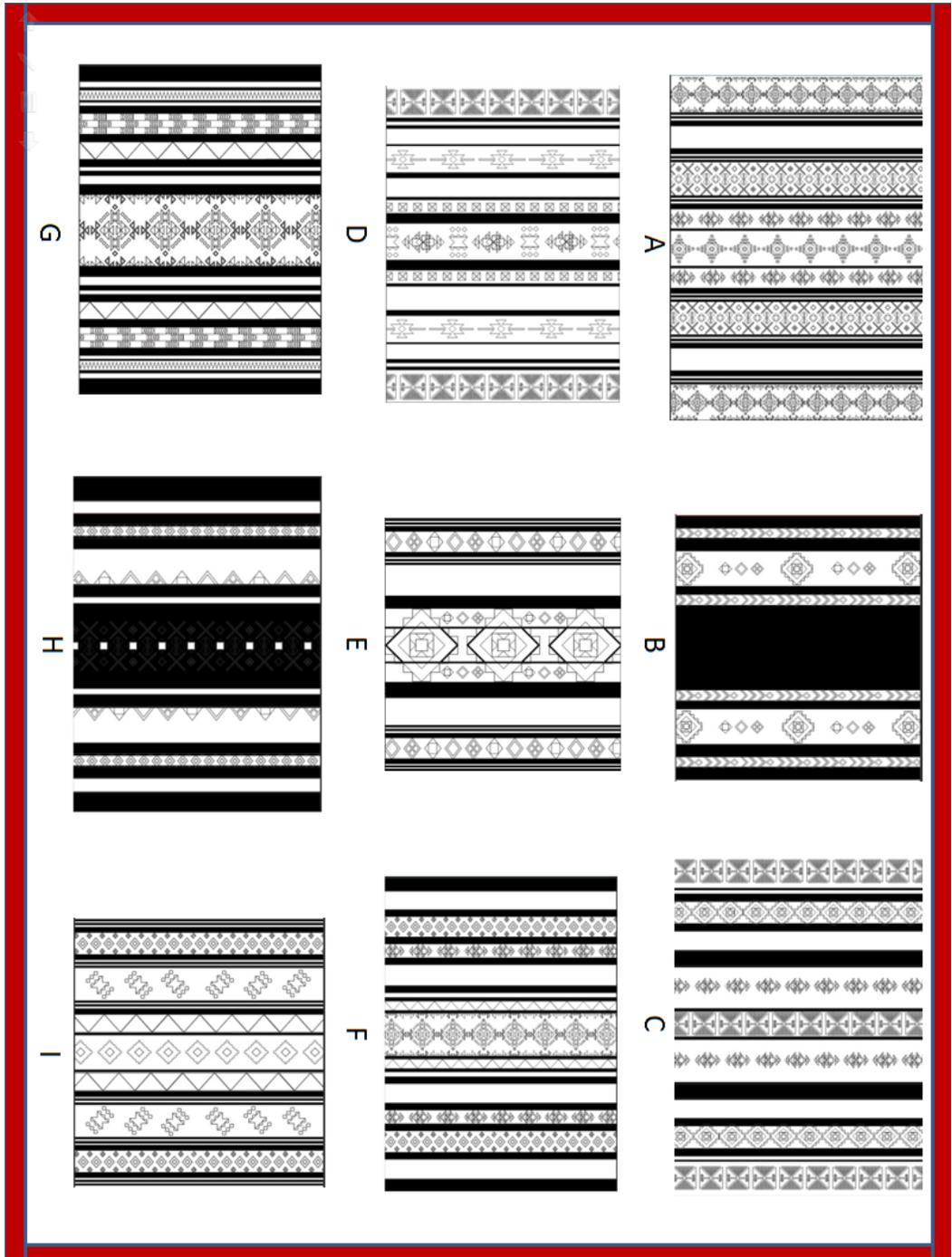
For designers who are not experienced in using symmetry rules, there is Symmetry Works software available which they can use to apply the rules to their designs. It is a plug-in for making repeat patterns in Adobe Illustrator.



Appendix D

Test three

Developed Kuwaiti patterns using SP1



Age	18 – 30	
	31 – 40	
	41 – 50	
	Over 60	

Gender	Male	
	Female	

Nationality	Kuwaiti	
	other	

For each question, circle the number that best describes your opinion

Strongly disagree Strongly agree

A	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

B	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

C	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

D	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

E	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

F	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

G	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

H	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

I	- Is this design a Kuwaiti Sadu style?	1	2	3	4	5
---	--	---	---	---	---	---

Thank you for taking the time to complete this questionnaire

Age:

Nationality:

Please give your opinion and explain the point of strength and weakness in the tested software.

Good

Bad







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Appendix E

Combination_sum (MATLAB)

```
function test
p=[1,0,0,0,0,0,0,0;2,0,0,0,0,0,0,0;3,0,0,0,0,0,0,0;4,0,0,0,0,0,0,0;5,0,0,0,0,0,0,0
,0;6,0,0,0,0,0,0,0;7,0,0,0,0,0,0,0;8,0,0,0,0,0,0,0;1,2,0,0,0,0,0,0;1,3,0,0,0,0,0,0
,0;1,4,0,0,0,0,0,0;1,5,0,0,0,0,0,0;1,6,0,0,0,0,0,0;1,7,0,0,0,0,0,0;1,8,0,0,0,0,0,0
,0;2,3,0,0,0,0,0,0;2,4,0,0,0,0,0,0;2,5,0,0,0,0,0,0;2,6,0,0,0,0,0,0;2,7,0,0,0,0,0,0
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,0;3,5,7,8,0,0,0,0;3,6,7,8,0,0,0,0;4,5,6,7,0,0,0,0;4,5,6,8,0,0,0,0;4,5,7,8,0,0,0,0
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,0;1,2,3,5,6,7,8,0;1,2,4,5,6,7,8,0;1,3,4,5,6,7,8,0;2,3,4,5,6,7,8,0;1,2,3,4,5,6,7
,8;]
for i=1:255
    a1=0;
    a2=0;
    a3=0;
    a4=0;
    a5=0;
    a6=0;
    a7=0;
    a8=0;
    for j=1:8
        if p(i,j)==1
            a1=9;
        end
        if p(i,j)==2
```

```

a2=9;
end
if p(i,j)==3
a3=8;
end
if p(i,j)==4
a4=6;
end
if p(i,j)==5
a5=5;
end
if p(i,j)==6
a6=3;
end
if p(i,j)==7
a7=3;
end
if p(i,j)==8
a8=3;
end
end
sum(i)=a1+a2+a3+a4+a5+a6+a7+a8
end
save sumationtest sum
end

```

Appendix F

The weight of rules combination using Microsoft Excel

Rule names and references	1-Vertical reflection	2-Horizontal reflection	3-Overlapped shapes	4- Not attached shapes	5- Rotation S dn, n=2	6- Rotation S dn, n=4	7- Attached shapes	8- Proportion
Weight	9	9	8	6	5	3	3	3

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
combination reference	rules reference								rules weight summation			combination reference	rules weight from low to high	number of rules
1	1								9			6	3	1
2	2								9			7	3	1
3	3								8			8	3	1
4	4								6			5	5	1
5	5								5			4	6	1
6	6								3			34	6	2
7	7								3			35	6	2
8	8								3			36	6	2
9	1	2							18			3	8	1
10	1	3							17			31	8	2
11	1	4							15			32	8	2
12	1	5							14			33	8	2
13	1	6							12			1	9	1
14	1	7							12			2	9	1
15	1	8							12			28	9	2
16	2	3							17			29	9	2
17	2	4							15			30	9	2
18	2	5							14			92	9	3
19	2	6							12			24	11	2
20	2	7							12			25	11	2
21	2	8							12			26	11	2
22	3	4							14			27	11	2
23	3	5							13			89	11	3
24	3	6							11			90	11	3

25	3	7								11			91	11	3
26	3	8								11			13	12	2
27	4	5								11			14	12	2
28	4	6								9			15	12	2
29	4	7								9			19	12	2
30	4	8								9			20	12	2
31	5	6								8			21	12	2
32	5	7								8			86	12	3
33	5	8								8			87	12	3
34	6	7								6			88	12	3
35	6	8								6			23	13	2
36	7	8								6			12	14	2
37	1	2	3							26			18	14	2
38	1	2	4							24			22	14	2
39	1	2	5							23			80	14	3
40	1	2	6							21			81	14	3
41	1	2	7							21			82	14	3
42	1	2	8							21			83	14	3
43	1	3	4							23			84	14	3
44	1	3	5							22			85	14	3
45	1	3	6							20			162	14	4
46	1	3	7							20			11	15	2
47	1	3	8							20			17	15	2
48	1	4	5							20			55	15	3
49	1	4	6							18			56	15	3
50	1	4	7							18			57	15	3
51	1	4	8							18			70	15	3
52	1	5	6							17			71	15	3
53	1	5	7							17			72	15	3
54	1	5	8							17			161	15	4
55	1	6	7							15			77	16	3
56	1	6	8							15			78	16	3
57	1	7	8							15			79	16	3
58	2	3	4							23			10	17	2
59	2	3	5							22			16	17	2

60	2	3	6							20			52	17	3
61	2	3	7							20			53	17	3
62	2	3	8							20			54	17	3
63	2	4	5							20			67	17	3
64	2	4	6							18			68	17	3
65	2	4	7							18			69	17	3
66	2	4	8							18			74	17	3
67	2	5	6							17			75	17	3
68	2	5	7							17			76	17	3
69	2	5	8							17			157	17	4
70	2	6	7							15			158	17	4
71	2	6	8							15			159	17	4
72	2	7	8							15			160	17	4
73	3	4	5							19			9	18	2
74	3	4	6							17			49	18	3
75	3	4	7							17			50	18	3
76	3	4	8							17			51	18	3
77	3	5	6							16			64	18	3
78	3	5	7							16			65	18	3
79	3	5	8							16			66	18	3
80	3	6	7							14			127	18	4
81	3	6	8							14			147	18	4
82	3	7	8							14			73	19	3
83	4	5	6							14			154	19	4
84	4	5	7							14			155	19	4
85	4	5	8							14			156	19	4
86	4	6	7							12			45	20	3
87	4	6	8							12			46	20	3
88	4	7	8							12			47	20	3
89	5	6	7							11			48	20	3
90	5	6	8							11			60	20	3
91	5	7	8							11			61	20	3
92	6	7	8							9			62	20	3
93	1	2	3	4						32			63	20	3
94	1	2	3	5						31			124	20	4

95	1	2	3	6					29			125	20	4
96	1	2	3	7					29			126	20	4
97	1	2	3	8					29			144	20	4
98	1	2	4	5					29			145	20	4
99	1	2	4	6					27			146	20	4
100	1	2	4	7					27			151	20	4
101	1	2	4	8					27			152	20	4
102	1	2	5	6					26			153	20	4
103	1	2	5	7					26			218	20	5
104	1	2	5	8					26			40	21	3
105	1	2	6	7					24			41	21	3
106	1	2	6	8					24			42	21	3
107	1	2	7	8					24			121	21	4
108	1	3	4	5					28			122	21	4
109	1	3	4	6					26			123	21	4
110	1	3	4	7					26			141	21	4
111	1	3	4	8					26			142	21	4
112	1	3	5	6					25			143	21	4
113	1	3	5	7					25			44	22	3
114	1	3	5	8					25			59	22	3
115	1	3	6	7					23			148	22	4
116	1	3	6	8					23			149	22	4
117	1	3	7	8					23			150	22	4
118	1	4	5	6					23			217	22	5
119	1	4	5	7					23			39	23	3
120	1	4	5	8					23			43	23	3
121	1	4	6	7					21			58	23	3
122	1	4	6	8					21			115	23	4
123	1	4	7	8					21			116	23	4
124	1	5	6	7					20			117	23	4
125	1	5	6	8					20			118	23	4
126	1	5	7	8					20			119	23	4
127	1	6	7	8					18			120	23	4
128	2	3	4	5					28			135	23	4
129	2	3	4	6					26			136	23	4

130	2	3	4	7					26			137	23	4
131	2	3	4	8					26			138	23	4
132	2	3	5	6					25			139	23	4
133	2	3	5	7					25			140	23	4
134	2	3	5	8					25			197	23	5
135	2	3	6	7					23			212	23	5
136	2	3	6	8					23			216	23	5
137	2	3	7	8					23			38	24	3
138	2	4	5	6					23			105	24	4
139	2	4	5	7					23			106	24	4
140	2	4	5	8					23			107	24	4
141	2	4	6	7					21			196	24	5
142	2	4	6	8					21			211	24	5
143	2	4	7	8					21			112	25	4
144	2	5	6	7					20			113	25	4
145	2	5	6	8					20			114	25	4
146	2	5	7	8					20			132	25	4
147	2	6	7	8					18			133	25	4
148	3	4	5	6					22			134	25	4
149	3	4	5	7					22			213	25	5
150	3	4	5	8					22			214	25	5
151	3	4	6	7					20			215	25	5
152	3	4	6	8					20			37	26	3
153	3	4	7	8					20			102	26	4
154	3	5	6	7					19			103	26	4
155	3	5	6	8					19			104	26	4
156	3	5	7	8					19			109	26	4
157	3	6	7	8					17			110	26	4
158	4	5	6	7					17			111	26	4
159	4	5	6	8					17			129	26	4
160	4	5	7	8					17			130	26	4
161	4	6	7	8					15			131	26	4
162	5	6	7	8					14			192	26	5
163	1	2	3	4	5				37			193	26	5
164	1	2	3	4	6				35			194	26	5

165	1	2	3	4	7				35			195	26	5
166	1	2	3	4	8				35			207	26	5
167	1	2	3	5	6				34			208	26	5
168	1	2	3	5	7				34			209	26	5
169	1	2	3	5	8				34			210	26	5
170	1	2	3	6	7				32			99	27	4
171	1	2	3	6	8				32			100	27	4
172	1	2	3	7	8				32			101	27	4
173	1	2	4	5	6				32			182	27	5
174	1	2	4	5	7				32			108	28	4
175	1	2	4	5	8				32			128	28	4
176	1	2	4	6	7				30			189	28	5
177	1	2	4	6	8				30			190	28	5
178	1	2	4	7	8				30			191	28	5
179	1	2	5	6	7				29			204	28	5
180	1	2	5	6	8				29			205	28	5
181	1	2	5	7	8				29			206	28	5
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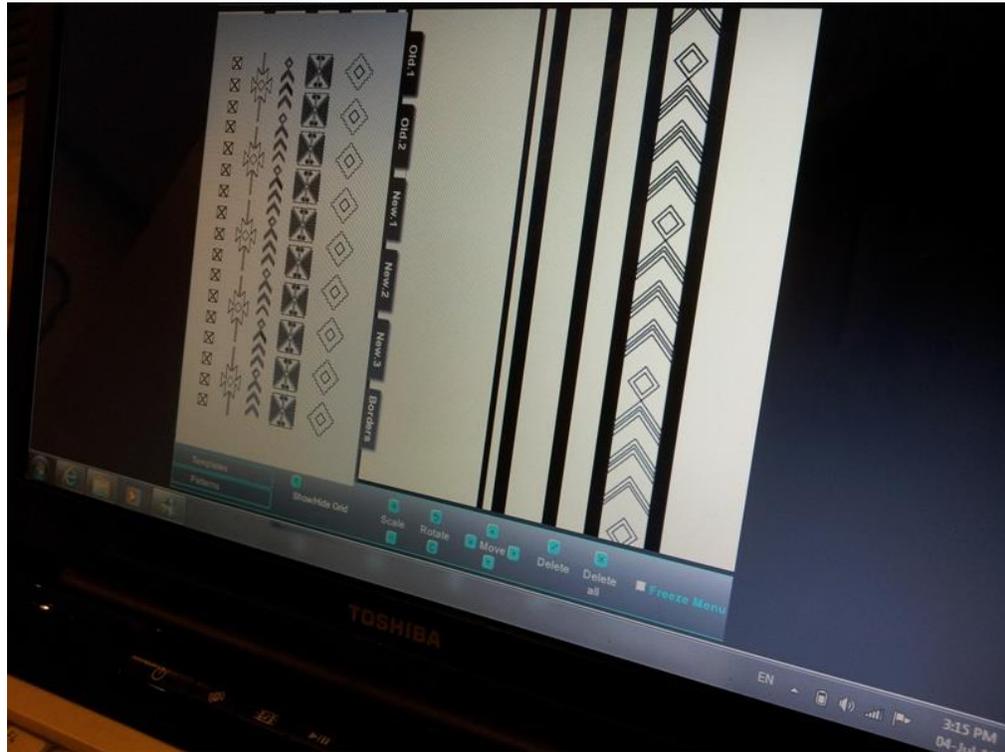
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Appendix G

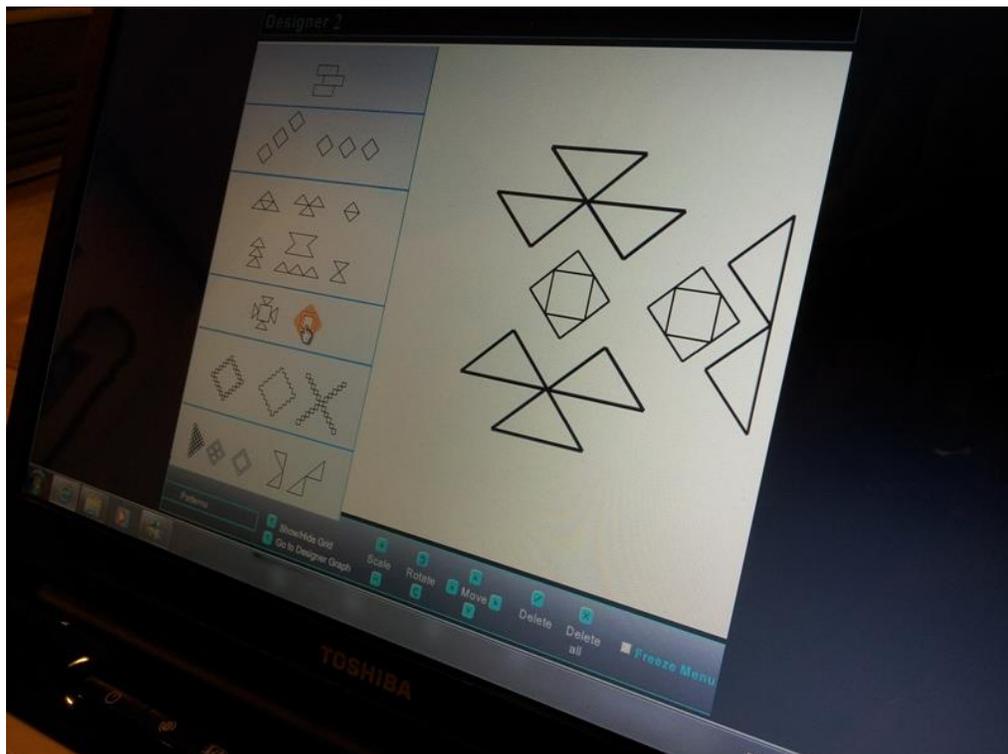
Applications on the proposed method







SP1 tool



SD1 tool

