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Computer-aided Moorish geometric design and patterns

Abstract: Humans have been striving to decorate their surroundings with various visual elements, such as shapes, textures, and symbols, since ancient times. A lot of times the inspiration for these patterns and textures came from nature, which has always motivated people to create aesthetically pleasing patterns. Geometry assists us to comprehend and reproduce numerous patterns found in nature. Hence, producing geometric patterns has been an integral part of art and ornamental interior design. Exploring a design process for recreating ornamental patterns has led to the development of software for generating Moorish patterns using computer-aided tools. The generated geometric patterns are two-dimensional elements, and could be transformed into three-dimensional objects before they can be used in numerous aspects in interior and architectural design. Thus, combining a two-dimensional pattern with a three-dimensional graphical software, adding extra features and functions to it, provides a powerful tool for artists and designers. The Moorish geometric patterns, renowned for their intricate interlacing and strongly geometric designs, have a long history embedded in multiple cultures. Nevertheless, modern-day computer software has been utilized to incorporate Moorish geometric design into the process of creating interior design- furniture and even in architecture planning and building structures. Computer-aided Moorish geometric design and patterns can influence the manner in which designers and architects create their work. This research traces some of the historical backdrop of Moorish style, the posthumous dynamic of the development of geometric patterns, the advances in PC programming that empower its utilization, and the potential applications of this correlation. The study object was geometric patterns as a form of decoration in architecture and design in the context of geometry and form creating with the purpose of aesthetic search. The study subject was the creation of geometric patterns and the ways possible to make this process faster and more efficient in the work of today's designer and architects. The study purpose was to investigate the source of making geometric design patterns, in terms of employing them in decorating interior spaces and in architecture in general by a brief exploration in historical samples. By inspecting an example of how PC helped Moorish geometric designs can be used in the process of designing interior places or in architecture planning, this exploration will show how innovation can be utilized to produce works of art and design. The last section concludes by summarizing the main aspects of this work and explaining points for further improvements.

Keywords: Moorish architecture, Taprats, software integration, geometric patterns, 3ds MAX modelling, design, object modelling, Adobe Photoshop.

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Мавритански геометричен дизайн и компютърни програми

Абстракт: От древни времена хората се стремят да подобряват заобикалящата ги среда с различни визуални елементи, като форми, текстури и символи. Вдъхновението за тези модели много често идва от природата, която мотивира хората да създават оподобяващи форми и чрез анализа им да извеждат геометричните завизимости и закони, на базата но които са изградени. Геометрията ни помага да разберем и възпроизведем множество модели, открити в природата. Следователно създаването на геометрични дизайни е широко използван похват в изкуството, интериорния дизайн и арихтектурата. Проучването на процеса на проектиране довежда до разработването на софтуер за създаване на геометричен дизайн. Генерираните геометрични модели като двуизмерни елементи могат да бъдат трансформирани и в обемни обекти, преди да бъдат използвани в интериорния дизайн и архитектурата. По този начин комбинирането на софтуер за генериране на двуизмерни геометрични форми и възможността за последващото им развитие чрез триизмерен графичен софтуер чрез добавяне на допълнителни характеристики и функции към тях, осигурява мощен инструмент за дизайнери и архитекти. Мавританските декоративни форми, известни със своите силно геометрични дизайни, имат дълга история, засягаща множество култури в миналото. Въпреки това съвременният компютърен софтуер също може да се използва паралелно с принципите, взаимствани от древните практики, за интегрирането им в днешния процес на проектиране на продуктов дизайн, третирането на интериорните пространства и дори и в архитектурното проектиране. Тази статия разглежда основните насоки в историческото развитие на мавританския дизайн, напредъка в компютърното програмиране, който позволява използването му в съвременния процес на проектиране и потенциалните му приложения в интериорния дизайн и архитектурата. Чрез разглеждане на примери за генерирани с помощта на, разработен специално за целта софтуер- Taprats, геометрични дизайни в Мавритански стил, тази статия разглежда темата как съвременните технологии могат да бъдат използвани за създаване на произведения на изкуството и дизайна на база на добре изследвани практики познати в миналото. Последният раздел завършва с обобщаване на основните аспекти на тази работа и описва посоките за бъдещо развитие по темата.

Ключови думи: мавританска архитектура, Taprats, софтуерна интеграция, геометрични модели, 3ds MAX моделиране, дизайн, обектно моделиране, Adobe Photoshop.

Introduction

Today when we study the history of art and in particular the Moorish architectural style, we are intrigued by the intricate patterns that can be generated with the help of a compass and straight edge, or paper-folding. As in the past the artists and scientists delve deeper into the process, they become more adept at perceiving points and lines, calculating angles visually, and recognizing generative units and proportional relationships. As artists progress, they are exposed to terms such as orthogonal, periodic, algorithmic, group theory, set theory, combinatorics, permutations, tilings, and tessellations (*Necipoglu, 1996*; *Grünbaum & Shephard, 1987*), which are unfamiliar but vital to mathematical art. The mathematical ideas expressed in art are not merely representational, but also expressive. Nowadays modern mathematics, algorithms and technology can be applied to the study of these ornamental styles and used for understanding and further development of new more complex designs and forms. Geometric patterns have been an integral part of art and decorative design for thousands of years. Mathematical concepts of geometric patterns and related works have been reviewed extensively in scholarly research

(*Necipoglu, 1996*; *Grünbaum & Shephard, 1987*). Specialized computer software, such as Taprats by Craig Kaplan (*Kaplan, n.d.*), has been developed to generate Islamic star patterns. These patterns are typically represented in two-dimensional (2D) formats, but for architectural design, three-dimensional (3D) elements are also necessary. To achieve this transformation, a graphical environment like 3ds MAX modeling software can be used. This paper aims to illustrate the implications of architectural design with geometric patterns, and to demonstrate how patterns can be used to generate forms.

The study object is geometric patterns as a form of decoration in architecture and design in the context of geometry and form creating with the purpose of aesthetic search.

The study subject is the creation of geometric patterns and the ways possible to make this process faster and more efficient in the work of today's designer and architects.

The study purpose is to investigate the source of making geometric design patterns, in terms of employing them in decorating interior spaces and in architecture in general by a brief exploration in historical samples. Furthermore, to comprehend the correlation between the methods employed in the past and present. In order to fulfill this objective, while adhering to a deduction-based investigation approach of the case study an example will be presented by generating geometric patterns with a software in 2D format. Nevertheless, to apply these pattern in architectural designs, architects and designers necessitate 3D elements. In order to be able to accomplish the transformation we would use a different modeling software.

It will be explained how Taprats designs are imported into 3ds MAX to use all generated patterns and further transforming them into 3D forms with the help of software programs. The rest of the paper is organized as follows. Section two discusses about the history of using patterns in Moorish architecture and design. Section three gives an explanation about Taprats program and its capabilities. A graphical environment is explained in this section and how 2D patterns are created. Section four shows how those patterns can be transformed into 3D patterns and can be manipulated as objects in architectural design and product design. The last section concludes by summarizing the main aspects of this work and explaining points for further improvements.

This article is oriented towards those sharing an interest in the design and architectural modelling- particularly Moorish geometric based designs- from educational, academic, professional, or simply general interest areas.

History of Moorish geometric patterns

For centuries, intricate patterns have been crafted onto architectural surfaces, most notably in Islamic culture but also in many other parts of the world like Europe and Asia. Examples include the Alhambra in Granada, Spain (*Irwin, 2004*) (*Figures 1*; *Figure 2*) and many North African landmarks.

These patterns have also been studied extensively by artists, designers, engineers and mathematicians, as they can be used for various applications in tilings, carpets and woodcraft in cultures around the world, from China to South America and from Asia to Europe (*El-Bouri & Critchlow, 1993*; *Bourgoin, 1973*; *Grünbaum & Shephard, 1987*). In Islamic cultures, due to religious restrictions, more complex geometric patterns were used in place of sculptures and portraits.

The development of these patterns was strongly influenced by the ancient Greek philosophical and mathematical works of Euclid and Pythagoras, which were translated into Arabic and drove an enthusiasm for astronomy and the creation of infinite decorative patterns. Each pattern offers a distinct technique of composition employed in forming each repeat unit. These patterns are typically created by adjusting regular polygons such as squares, equilateral triangles, hexagons, etc. by equally partitioning the circumference of a circle into the necessary number of parts. A wide array of patterns generated by the division of the circle into equal parts such as four, multiples of four, six, multiples of six, and so forth. Although the exact methods used by Islamic artisans to create these designs remains a secret passed from one craftsman to another, there are some written evidences like The Topkapı script (*Necipoglu, 1996*). The script was used in a variety of contexts, from art to architecture. The design of the script is based on geometric shapes and patterns drawn by hand but nowadays computer systems have been developed to generate similar patterns, thereby allowing for further exploration and study (*Figure 3*; *Figure 4*).

Numerous computer scientists have also conducted mathematical descriptions and analyses of these patterns, such as Grünbaum and Shephard (*Grünbaum & Shephard, 1987*), as well as Craig Kaplan's java applet, Taprats (*Kaplan, n.d.*), which implements a design technique for 2D Islamic star patterns and produces extensive scientific articles.

As a result, it is of utmost importance to understand the past in order to make progress in the future. By looking at the history of design, we can gain valuable insight into the patterns and principles that have been used to create successful designs. By using this knowledge, we can create more effective computer-aided designs that not only look great, but also function better, mistakes are easier to fix and changes are not so time consuming as in the hand-maid designs from the past.

Patterns generation in Taprats

Geometric patterns have been a common sight throughout the history of art and architectural design. In order to study and explore these ornamental styles, Craig S. Kaplan (*Kaplan, 2002*). in his dissertation, he presents his research in the area of computer-generated geometric art and ornament. In the process of writing his PhD dissertation, he develops a collection of tools and methods for producing traditional Islamic star patterns, utilize modern mathematics, algorithms, and technology.

Taprats is a computer program for constructing and generating Islamic star patterns, developed by Kaplan at the University of Washington's Department of Computer Science and Engineering. This program provides a user-friendly interface for browsing available tilings and choosing one on which to create a design. After a few more steps, a design is created based on the selected tile and parameters (*Figure 5*; *Figure 6*). The generated design can be exported in EPS (Encapsulated Post Script) or SVG format for further analysis and study.

With the help of Taprats, a software with a simple interface, designers can generate a wide variety of geometric designs. There is a set of available tilings to choose from, and designers can change the following parameters to explore and achieve their desired results. Islamic patterns are a complicated subject, and the implementation of periodic forms with the help of a software

offers tremendous freedom in the construction of tilings with regular polygons, resulting in numerous easily-modified and enriched designs.

Collaboration between 2D patters and 3D objects and their use in architecture and interior design

Computer-aided design (CAD) is a powerful tool for crafting innovative designs. With the rise of 3D printing technology and vector drawing software, CAD offers ample opportunity for users to explore different design ideas. CAD makes it possible to create complex designs with accuracy, speed, and precision.

Highly complex patterns can be represented in two-dimensional (2D) formats. When translating these patterns for use in architectural designs, however, three-dimensional (3D) elements are required. In other words, these patterns must be transformed into 3D structures to be applied to architectural design purposes. To facilitate this transformation, a graphical environment such as 3ds MAX software can be used with the help of a script written for use in 3ds max. Taprats saves generated patterns in an output file in SVG format; however, when importing this file into 3ds MAX, with the various modifiers' lines and vertex, can be recognized. Software programs like 3ds MAX provide a wide range of features for creating, editing, and deleting graphical elements, as well as offering the ability to customize the form in a way you can create architectural elements (*Figure 7*; *Figure 8*; *Figure 9*).

Automation processes, custom utilities, and commands can be executed in 3ds MAX. Designs are created using Taprats and refined in 3ds MAX for architectural design. The integration of Taprats and 3ds MAX permits designers to plan and later render their projects containing Moorish geometric design. 3ds Max has import and export features for certain data formats, and designs in EPS format can be read in Adobe Photoshop and exported like an AI files that can be imported into 3ds MAX.

The 3ds MAX software provides an easy way to create accurate and high-quality 3D models from a variety of sources. With its powerful tools, architects and designers can easily modify and customize existing models to create complex architectural elements such as fences and balusters. Additionally, 3ds MAX is compatible with the STL (Stereo Lithography interface format or Standard Triangulation Language) file format, which is widely used in the 3D printing industry. To ensure that the 3D printing process goes smoothly, it is important to check that all surfaces and meshes in the STL file are closed. This file format also allows for complex 3D models to be created with a combination of tiny triangles, which are defined by three vertices.

Thus, Computer-Aided Design (CAD) is a powerful tool for crafting innovative designs. Taprats and 3ds MAX integration allows designers to plan, render, and refine their projects containing Moorish geometric designs. Overall, CAD is an efficient tool for creating extraordinary designs with accuracy, speed, and precision which makes it a popular and desirable tool for the community of architectural design users.

Discussion

This method of collaboration between a software like Taprats and a further development of the model in an environment like a 3ds Max allow access to a wide variety of designs based on Moorish geometric patterns.

The available selection of 3d modelling software for architectural planning is expansive. Further exploration could be achieved by leveraging applications like Maya to manipulate patterns into 3D shapes with the utilization of Maya's scripting language. Or by writing a system similar to Taprats that could move away from periodicity through the implementation of aperiodic tessellations composed of regular polygons.

Conclusion

This paper is an attempt to demonstrate the implications of architectural design utilizing geometric patterns, and to show how patterns can be employed in the formation of architecture (*Figure 10*). The integration of Taprats' Java applet into 3ds MAX has been explored, allowing for the reuse of generated patterns and their transformation into 3D objects. This integration has several advantages for users, including the ability to work within one environment and to manipulate generated patterns from Taprats as architectural design objects within other software programs. By using computer-aided design, designers can quickly generate complex geometric patterns and easily modify them to their exact specifications.

As this work is still in progress, more features and facilities should be added before it can become a popular and desirable tool for the architectural design community.

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Appendix

Figure 1. Examples of Moorish geometric design in history- A geometric design of a ceiling in the Alhambra palace, Granada, Spain- picture taken 2016

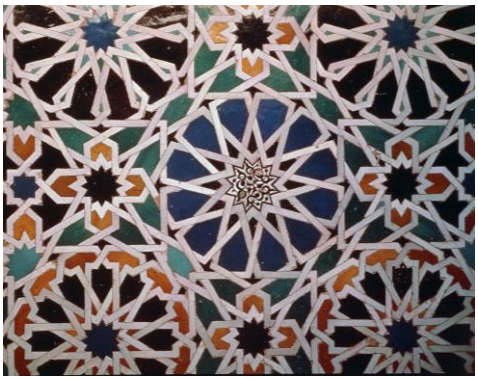

Figure 2. Examples of Moorish geometric design in history- A geometric design in the Alhambra palace, Granada, Spain-picture taken-2016

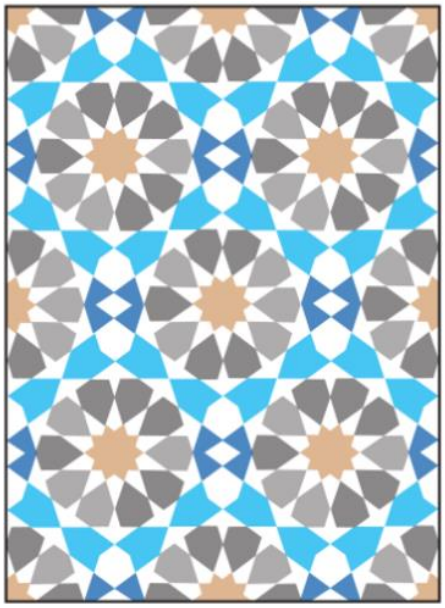

Figure 3. Examples of Moorish geometric design in history- the pattern expanded (translatation repetition) to four units. Note the inclusion of the rhomb in this version. It is nested in the "bow" shape located in middle of each edge of the repeat unit

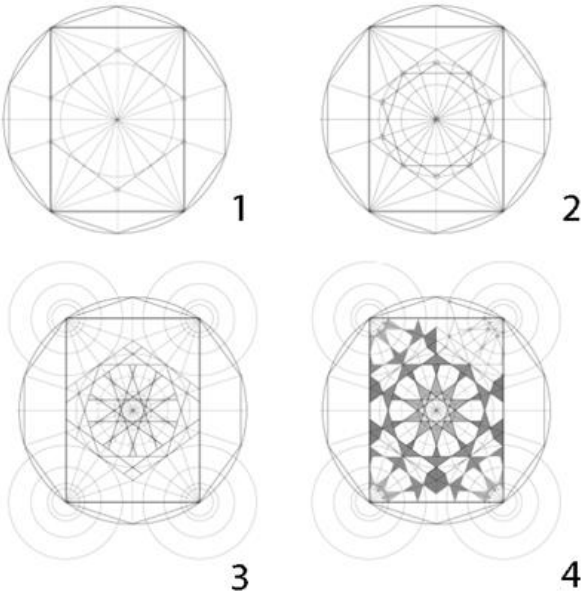

Figure 4. Examples of Moorish geometric design in history- A design made by hand from panel 73 of the Topkapı Scroll. Example step by step of the long process of making the previous figure 3

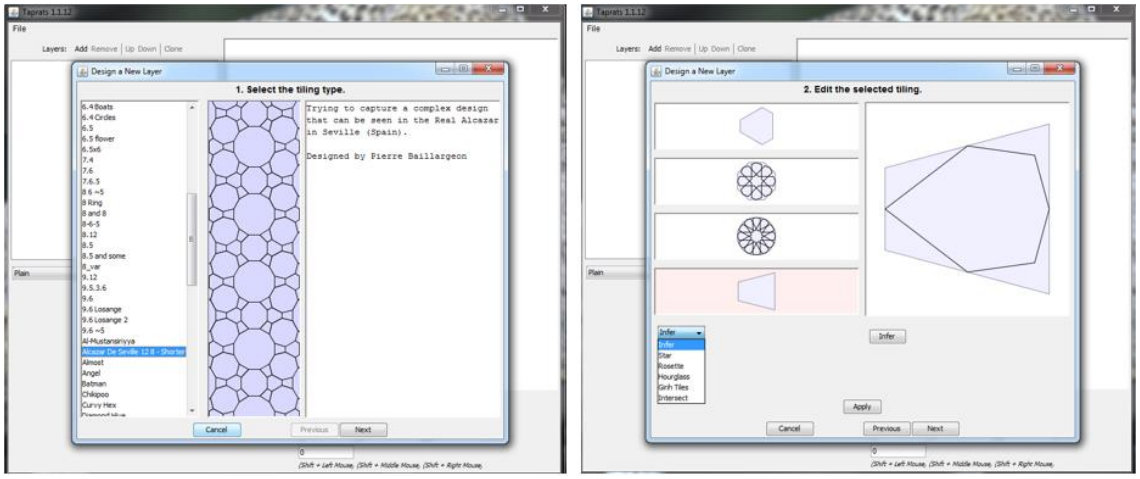

Figure 5. Interface of Taprats

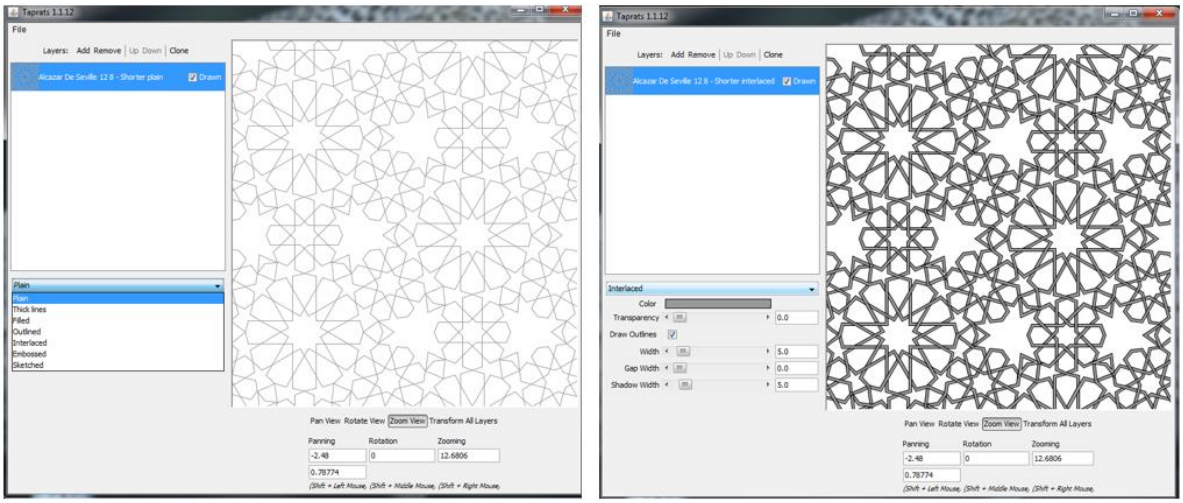

Figure 6. Examples of geometric designs generated in Taprats

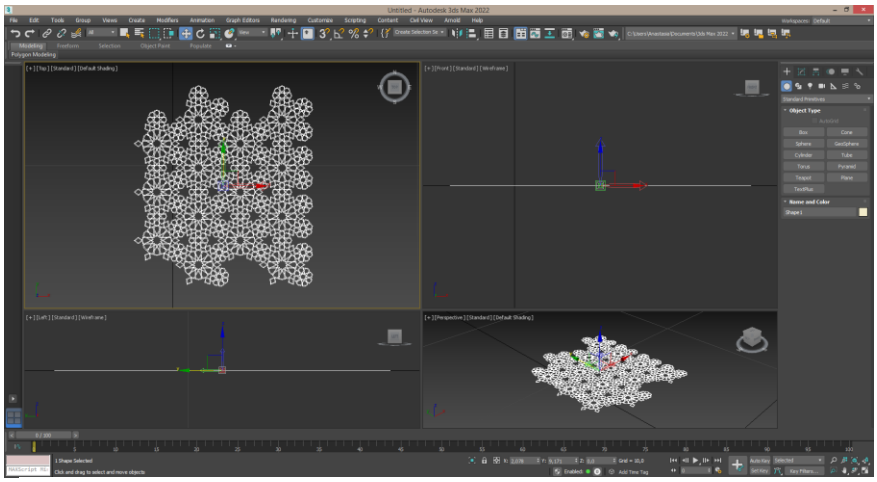

Figure 7. Generated patterns in Taprats and imported to 3ds MAX

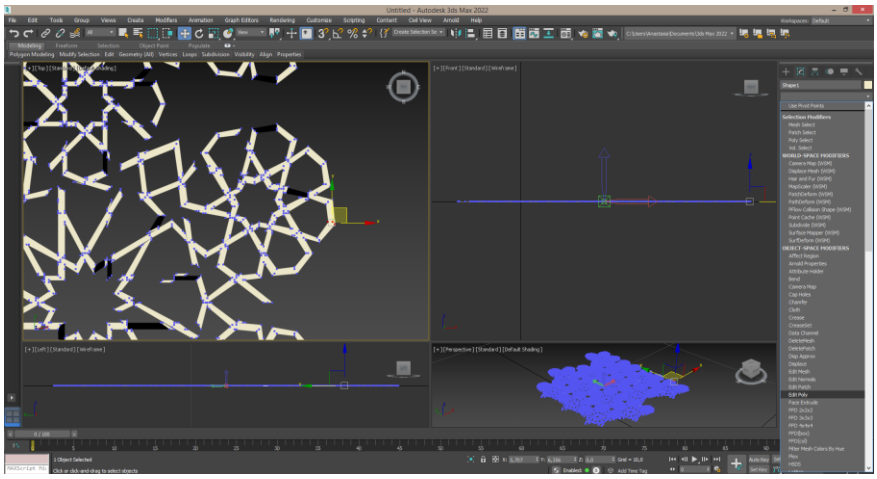

Figure 8. Generated patterns in Taprats and imported to 3ds MAX- using modifiers

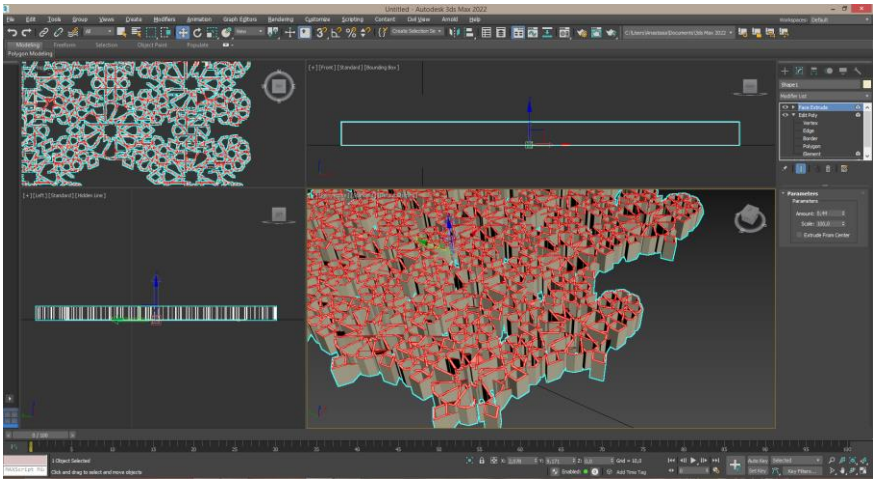

Figure 9. Generated patterns in Taprats and imported to 3ds MAX - few shapes of patterns converted into 3D objects

Figure 10. Example of the integration of Moorish style inspired architectural elements and modern technologies into the realization a contemporary building in Sofia, Bulgaria. pictures taken 2022