

A Pattern Based 3D Modeling Tool

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ABSTRACT: Historically human beings have tried to decorate their environment with various elements such as symbols, shapes, textures and so on. Therefore, in various cultures and periods beautiful patterns and textures have been created by humans. Geometry helps us not only to understand also to recreate existing patterns in nature. Our aim was developing a 3D modeling tool for patterns deployment in design. Not to reinvent the wheel, we based our development on Maya one of the best existing graphical modeling software. Developed tool eases and facilitates deployment of patterns in design. Our tool's features and functions help users to create patterns, to transform patterns into design objects such as building blocks, green areas, water ponds and so on, also to create final design from a few initial patterns using some kind of spatial transformations. We do believe introducing this tool to the community of designers, like architects, urban planners and site constructors, will be appreciated by them as a desirable modeling tool they need.

1 INTRODUCTION

Throughout history human beings have been trying to decorate their environment. To decorate, we need some elements like symbols, shapes and forms. Humans always are inspired by nature for creating such elements for decoration. Geometric patterns have been an important part of art and ornamental design. Artists began to decorate architectural surfaces with geometric patterns since few thousand years ago. Geometry has always been a part of the process of designing and constructing buildings. Many attempts have been made to formulate the design concepts for generating geometric patterns and to understand how craftsmen and master builders in Islamic art and architecture created those patterns over the centuries without general concepts of composition and principles of design. Geometry helps us to understand and recreate many existing patterns in nature. Therefore, producing geometric patterns have been an important part of art and ornamental design. Trying to find out a design process for recreating ornamental patterns results some programs for generating patterns with computer aided tools.

The mathematical concepts of geometric patterns are not discussed here so readers are referred to some related works like Grünbaum & Shephard (1987), Abas & Salman (1992, 1995), and Dunham (1999). Many attempts have been made to reinvent

the design process for generating ornamental patterns. Also many efforts are made to develop programs for generating patterns with computer aided tools. Taprats is a Java applet that implements one such program to construct Islamic star patterns developed by Kaplan (2003).

Normally generated patterns are represented in a 2D formats. However, in order to deploy these patterns in architectural designs, architects and designers need 3D elements. In other words those patterns should be transformed into 3D forms to serve our purpose in architectural design. To be able to do the transformation a graphical environment is needed. For this purpose we use Maya advanced modeling software.

Through Maya programming we can create tools to increase our productivity and also to gain far greater control of it. Maya's programming language called Maya Embedded Language, MEL, is a scripting language. We can automate many operations, develop own custom tools, features and commands and execute all of them in Maya.

In this paper we attempt to exemplify the implications of architectural design with geometric patterns, and in particular, to demonstrate how patterns can be used for form generation in architectural design. It will be explained how Taprats Java applet is integrated into Maya to use all generated patterns and further transforming them into 3D forms with the help of Maya's scripting language.

The rest of the paper is organized as follows. Section two discusses about the history of using patterns in design. Section three gives a bit explanation about a 3D graphical environment needed for developing our tool. Our pattern based modeling tool is explained in section four also its features and functions are discussed in details. The last section concludes by summarizing the main aspects of this work and explaining points for further improvements.

2 PATTERNS IN DESIGNS

Patterns have been used in architecture throughout history. Especially in Islamic art and architecture complex geometrical patterns have been used as decorative elements. Therefore, artists, designers, engineers and mathematicians have been inspired by the study of geometric patterns. The inspiration source for them is mainly nature, technology, geometry and other designers' works which are precedents. During recent decades, computer scientists have become interested in generating complex Islamic geometric patterns. Patterns are used for various purposes, such as in tilings, carpets, window decoration, woodcraft, book covers, textile and etc.

Every human society in the history has made use of geometrical patterns, from China to South America, from Asia to Europe. Various cultures emphasize different aspects. Patterns are used for various purposes, such as in tilings, carpets, window decoration, woodcraft, book covers, textile and etc. These patterns have not only been used to decorate buildings, but also to arrange load-bearing structures.

In Islamic cultures, Arabs, Moors and Turks used more complex geometric patterns, because it is not allowed to use sculptures and portraits of human beings or animals according to the Islamic religion. The wide spectrum of intellectual treasures allowed Islamic scholars to quickly embrace Greek philosophy and mathematics, translating and disseminating this knowledge for posterity. The works of Euclid and Pythagoras were among the first to be translated into Arabic. The study of geometry also fed an ardent preoccupation with the stars and astronomy. All this in turn nourished the Arabic passion for creating infinite decorative patterns.

Many attempts have been made to formulate the design concepts for generating geometric patterns and to understand how craftsmen and master builders in Islamic art and architecture created those patterns over the centuries without general concepts of composition and principles of design. One such attempt has been done by El-Said. In his earlier work (1976), he developed a unique analytic approach to understand the geometry that inspires Islamic art. He worked on the methodology of geometric proportioning in Islamic architecture, as the subject of doctoral thesis. He considered in his work the relation-

ship between geometry and number and its application to provide a practical method for pattern making. He tried to find out how craftsmen measured and outlined the geometric concepts of composition and the process of their application in different fields of Islamic art.

We still don't know for sure how Islamic artisans figured out these designs. However, we can invent computer systems that create design similar to theirs that enable exploration of these patterns. Therefore, an old craftsman is replaced by a new craftsman, namely that of a machine. Many computer scientists are interested in the generation of complex geometric patterns. Grünbaum & Shephard (1987) have done mathematical descriptions and analyses of these patterns. Kaplan developed a java applet, named Taprats, which implements a design technique for 2D Islamic star patterns, and produces valuable scientific articles about his work (Kaplan 2003).

Creation of building forms and structures can be inspired by patterns due to their geometrical properties. The 3D considerations of patterns are useful aids for generating building designs due to a pattern's ability to create form and structure. Therefore, the use of patterns in the architectural practice for support the generation of site planning, architecture and building structures within computational environment always are concern of designers in this field.

Geometric patterns have formed an important part of art and ornamental design. Today we are able to understand ornamental style of the past, to recreate traditional designs, and to innovate with new interpretations of old styles and with new styles together. Kaplan in his PhD dissertation (2002) presents a research work in the area of computer generated geometric art and ornament. Throughout this work he shows how modern mathematics, algorithms and technology can be applied to the study of these ornamental styles.

Taprats is a computer program for constructing Islamic star patterns. A sequence of steps must be followed to generate a pattern using this program. It is a tool that gives us a narrow channel through which to interact with Islamic designs. This is not a general-purpose drawing tool, but it is a tool that understands the set of possible drawing subject to very specific constraints.

Although Taprats is a sophisticated tool but its user interface is fairly simple. The interface allows browsing the available tilings and choosing one you want to create a design. Following few more steps a design will be created based on the chosen tile and the given parameters. The generated design can be saved into a file with EPS, Encapsulated Post Script format. For detail of how to work with Taprats see the given reference. In section four we explain how

a site planning can be design based on patterns using our proposed modeling tool.

3 A 3D GRAPHICAL ENVIRONMENT

One approach in providing new software tools is writing necessary computer programs from scratch. Besides its some benefits certainly the procedure is costly and more time consuming. Another way is to use the existing tools and try to modify them to serve our purposes in developing new tools. Definitely the second approach is faster and needs less time for writing programs and perhaps with fewer development costs. Since in this research work our main aim was to develop a new modeling environment as quick as possible and also we didn't have enough financial means therefore we based our tool development on the existing software in the group. For this purpose we use Maya advanced modeling software. Although Maya graphical user interface (GUI) boasts a very extensive feature set for creation, editing and deletion of all graphical elements. Fortunately Maya allows us to add our own features and functionality. This software has been designed so that users are free to customize and extend the package as they need. New features work seamlessly with the rest of Maya.

The entire Maya is written and controlled using MEL that is an acronym for Maya Embedded Language. Maya's programming language is a scripting language. We can automate many operations, develop own custom tools, features and commands and execute all of them in Maya. By using MEL we can control the Maya interface, in other words Maya GUI can be customized to meet our needs. We can also hide or remove a lot of Maya interface elements to reduce the complexity of the interface for certain users. A graphical user interface provides tools and features like menus, dialog boxes, buttons and so on to give users a visual means for creating and manipulating graphic objects.

A user interface consists of many tools and features. Each one does certain tasks and provides facility for manipulating graphic objects. As said before, patterns can be seen as objects or elements in architectural and urban form. Our main concern here is providing some extra utilities in the chosen graphical environment for transforming generated patterns to 3D objects and further deploying them as elements in designs. Maya doesn't support directly these utilities but we can add new features and functions to its user interface to facilitate almost any kind of object manipulations we want. In doing so, required functions have been added to Maya user interface. Normal appearance of the interface doesn't show such addition, but looking closely to it reveals extra added things.

Maya's shelves are user-customizable areas to hold the actions and tools you use most often. You use shelves to put all tool or action icons you use in one place. A shelf can be customized for specific needs. It is used to organize commonly used functions and tools into groups called tab. Provided shelves consists of some tabs, from left to right, *Animation*, *Curves*, *Custom*, *Deformation*, *Dynamics* and so on . Each tab supports certain related group of functions.

Vastly generated patterns are represented in a 2D formats. However, in order to deploy these patterns in architectural designs, architects and designers need 3D elements. In other words those patterns should be transformed into 3D forms to serve our purpose in architectural design. To be able to do the transformation a graphical environment is needed. As mentioned in the previous section Taprats saves generated patterns in EPS format into an output file, when such file is imported to Maya only the joint points between lines or just lines are recognizable. We must redraw those patterns or shapes in order to reuse them in Maya. In the next section our tool will be explained that help users to do the job.

To facilitate creating patterns we have integrated pattern generation software, Taprats, with Maya interface so users can run Taprats within Maya. Therefore, users generate patterns using Taprats first and then they work further on the generated patterns in Maya to create a design. Integration of Taprats and Maya allows users working only in one environment. There is no need to pass into and out of Maya from other external package. While Maya has features to export and import certain data formats, the generated patterns in EPS format can be read in Maya using these features.

4 PATTERN BASED MODELING PACKAGE

In this section we exemplify an application which will be developed using our modeling environment. As said before, our approach in developing new modeling environment was using an existing modern graphical package and adding to it what we need in our tool. Since most graphical packages offer the same functionalities and also not to reinvent the wheel again we decided to base our development on advanced existing modeling software, Maya. Using MEL, Maya Embedded Language, we can add new features and functions to it. Through Maya programming we can create tools to increase our productivity and also to gain far greater control of it. This is the direction that we chosen in tool development phase. In doing so the development time is shortened and its costs reduced dramatically. This section devoted to the explanation of proposed modeling tool, its user interface, features and functions. For detailed discussion about our tool and how it

does work readers are referred to papers from authors, (Chitchian & Sariyildiz 2008a, b), published before.

4.1 Proposed modeling tool

As said before the entire Maya is written and controlled using MEL. With Maya's programming language we can develop own custom tools, features and commands and execute all of them in Maya, in other words Maya GUI can be customized to meet our needs. A graphical user interface provides tools and features like menus, dialog boxes, buttons and so on to give users a visual means for creating and manipulating graphic objects. Next section explains the user interface of our tool and how it works.

4.2 User interface

The GUI, Graphical User Interface, of any package is where users of the software interact and work with it. Since our tool is developed on Maya therefore its user interface is the entry point of the tool. Those who are familiar with Maya know how to work with it. Clicking on the shortcut starts up our modelling tool then the user interface is up and running. Part of the user interface is shown in Figure 1, it's exactly the GUI of Maya. Closely looking at it, as depicted in the figure, an extra item so called *Patterns* is added to the shelves.

Maya's shelves are user-customizable areas to hold the actions and tools you use most often. You use shelves to put all the tool or action icons you use in one place. A shelf can be customized for specific needs. It is used to organize commonly used functions and tools into groups. The last tab in the shelf part so called *Patterns* is added to the user interface to facilitate working with patterns. In this and next sections we explain some provided *buttons* in this shelf related to deployment of patterns and what they do.

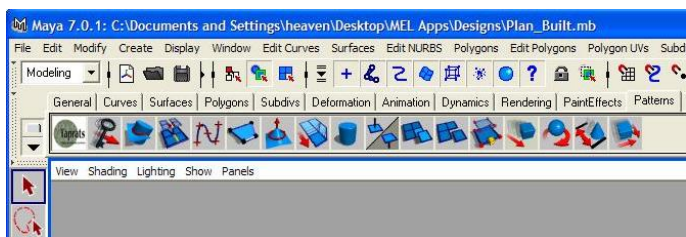


Figure 1. User interface of the tool.

As show in above Figure, shelves consists of these tabs, from left to right, *Animation*, *Curves*, *Custom*, *Deformation*, *Dynamics* and so on. Each tab supports certain related group of functions. Clicking on *Patterns*, the last tab in the shelves menu bar, the group of related functions in this tab is displayed. Each function represented by an icon in this tab does

certain task to facilitate working with patterns and objects manipulations. The first thirteen functions in this tab that facilitate objects manipulation are not explained here so for detailed discussion and how they work see previously mentioned papers from authors. But the rest of the functions which are mainly for patterns manipulation will be discussed in the next sections.

4.3 Features and functions

In this section we exemplify an application which will be developed using the provided functions of our tool for patterns manipulation. We assume that users know how to create 2D or 3D objects and patterns using utilities of Maya and the added features to it. This is the first step to generate patterns that seem suitable for further development in architectural and urban designs. For patterns generation users can either use the integrated program into modeling environment or they deploy normal utilities of the software.

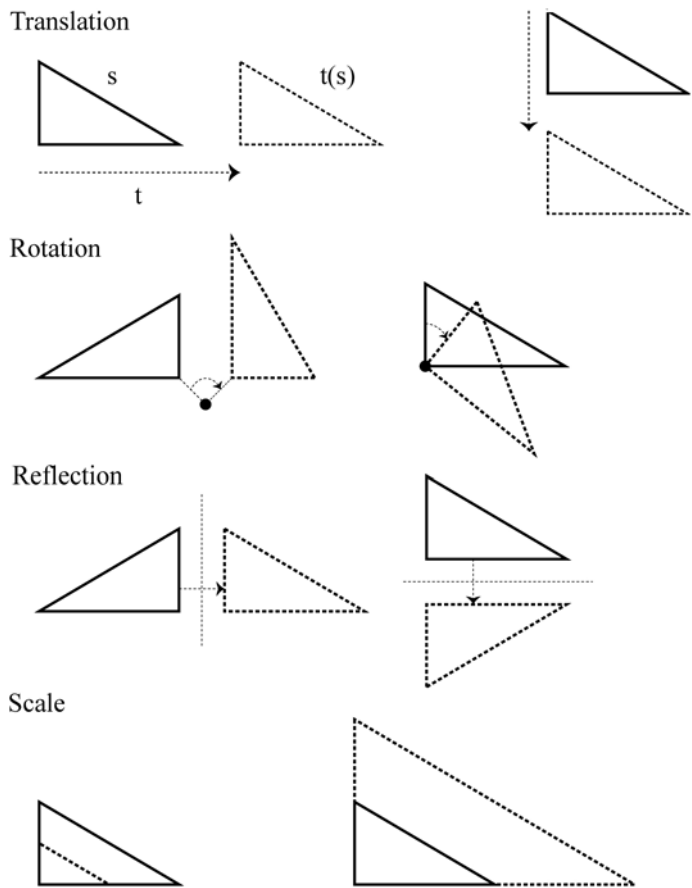


Figure 2. Translation & rotation transformation

Before going further, we explain provided functions of the tool for patterns manipulations. An object or pattern manipulation means the available transformation that can be done on that object to derive a new object by achieving an operation on the selected object. The operation here means a spatial relation, 2D or 3D transformation, which can be ap-

plied on an object. Four different spatial relations or transformations are supported in this tool. They are *Translation*, *Rotation*, *Reflection* and *Scale*. A transformation can be done on a 2D or 3D object so the derived object is also a 2D or 3D object respectively. We can achieve more than one transformation on an object in other words combination of transformation can be done on a selected object or group of the selected objects. As the name of a transformation conveys the associated operation is achieved on the selected object(s). As shown in Figure 2, a dotted object is resulted as a transformation done on the selected solid object.

To achieve any four transformations, namely *Translation*, *Rotation*, *Reflection* or *Scale* on an object certain information must be given such as X, Y, and Z values for *Translation* transformation also X, Y, and Z values of rotation point plus the rotation degree value for *Rotation* transformation. For instance, in case of *Rotation* and *Translation* transformations depicted menus in Figure 3 pop up by clicking on the associated icon with them and allow users to enter required values respectively.

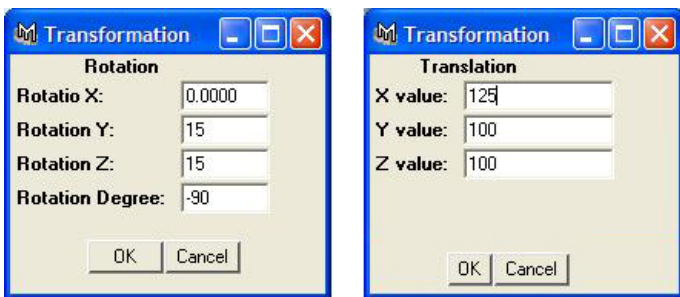


Figure 3. Menus for entering required values

All features and functions of the tool explained so far plus others that we didn't mention at all have been written using MEL, Maya's development language, which is a scripting language. As said before, a tab so called *Patterns*, we named deliberately to remind us it includes required utilities for deploying patterns, in the shelves menu bar consists of these features and each icon in this tab corresponds to one feature. Meanwhile, including lines of source codes is not so instructive therefore in this section we only discussed a few features relevant to the subject of the paper. In the next section the core logical diagram will be discussed.

4.4 Core logical diagram of the tool

Design generation based on patterns can be done in two ways. There exist one or more patterns which suite well to your design as they are without changing any arrangement of their constituent shapes in those patterns and we use them as they are in the final design. But sometimes there is no such pattern that can be used exactly as its constituent shapes are

in the final design, or the existing pattern doesn't suite well to our design and we want to use only few shapes from that pattern and we arrange them in the final design as we want. Also in the second way we may create few basic shapes and from these shapes we create our own pattern as we want to use in the final design. Creation of the pattern from few basic shapes is done by means of some transformation operations on these basic shapes.

What explained briefly above is in fact the main concept behind the core functionality of the developed tool. The core logical diagram of the tool is depicted in Figure 4 shows this concept. Note that this is not like a normal flowchart where represents each decision or task that users follow from the start to the end, rather it represents core logical steps of the tool in generating architectural and urban designs using patterns. To facilitate these steps in a modeling environment was our concern in developing this tool and we have elaborated this concept in the paper so far.

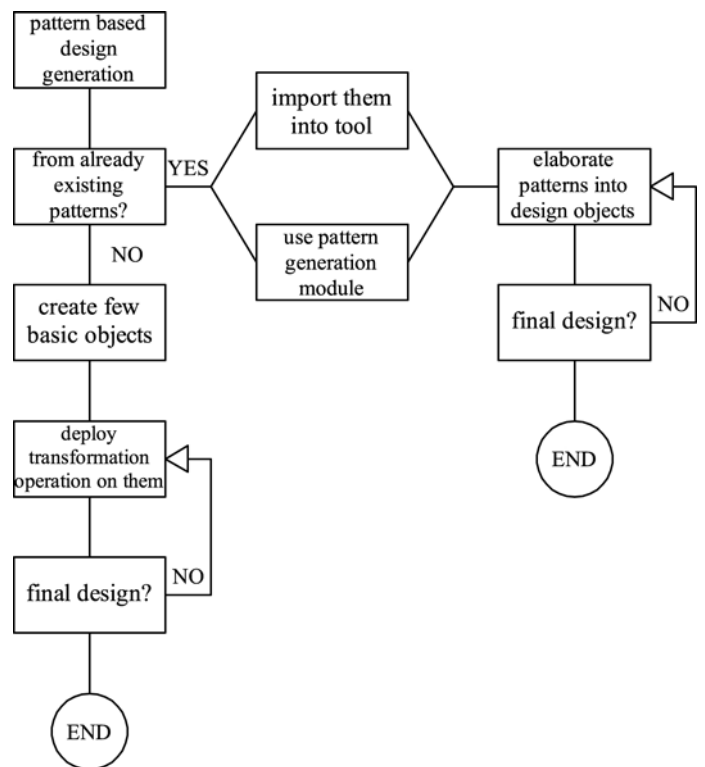


Figure 4. Core logical diagram of the tool

A considerable discussion about the core logical diagram will be given here. As said before, in two ways we can generate design based on patterns. First, we use completely an existing or generated pattern as it is and deploy its constituent shapes as certain elements or objects in the final architectural and urban designs such as building blocks, green areas, pavements, streets and so on. In this way, users choose one of the existing or generated patterns which are suitable to use in their final design. Therefore, if such pattern exists in an electronic form it can be imported that form into our tool. Otherwise

users should create such a pattern using Maya or other graphical packages, and then they further modify pattern's shapes as design elements in the final design. To ease this patterns creation phase we integrate a pattern generation module into our tool. This module helps users and facilitates the patterns generation phase. In either pattern creation cases, importing or generating, users must deploy the constituent shapes of the pattern as design objects. In this step, users may use Maya's utilities plus extra provided features in our tool. As shown in the above figure, elaborating a pattern and deployment of its shapes as design objects in the final design is a repetitive task. Because in each turn we work on one or more objects having the same characteristic such as being a certain design object or their height must have the same value and so on. Since the design objects are normally in 3D forms so if the created patterns are in 2D shape, they must be transformed into 3D shapes before using them as design objects. Provided features in our tool plus Maya's functions help users in this step to facilitate all required repetitive tasks for them.

The second way of design generation using patterns is based on one of the characteristics of a pattern. Carefully looking to a pattern we realize that it's created from certain shapes or objects. In other words, a pattern is made of a lot of objects where some of these objects exactly are the same and they are combined in a certain way to form that pattern. Therefore, to have a certain pattern on a final design we need to create only the main constituent shapes of that pattern and let the pattern evolves by using some operations on these constituent shapes. Meaning that instead of creating the whole pattern as it will be in final design, we generate only these basic shapes which a pattern is made of and then by means of some transformation operations on these basic shapes we can create the complete pattern that we need them in our final design. The logical steps of the second way, as also shown in the logical diagram, users must first create these basic objects and then with the help of transforming operations users generate any kind of patterns as they want to have in the final design. Obviously this transforming operation is also a sort of repetitive task which must be achieved before coming to the final design. At each step one or more objects, representing a certain design element such as a building block, a street, public spaces and so on, will be transformed using specific operation on them. Apparently, if the basic shapes are in 2D form they must be converted to 3D shapes before using them as design elements in the final architectural and urban designs.

4.5 The process of pattern based design generation

A design generation can be viewed as a stepwise process. In this view, a design process starts at an

initial design containing zero or more objects in it. At later steps or stages new objects are added to that design until it becomes the last design. In each step this partial design, we may call it intermediate design too, is transformed to another design by applying one of the transformation rules. The final design is either a design that designers are satisfied with it or we cannot apply any transformation rule further.

Viewed upon this point a design is an iterative sequence of actions. In this sense a design process is seen as a derivational process. In fact derivation is a sequence of designs where each design is generated from the previous design by applying a single transformation rule on it. Therefore, a design process looks like what depicted in Figure 5.

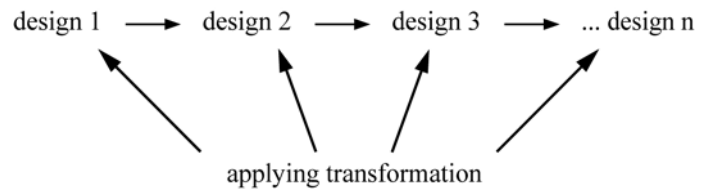


Figure 5. Derivation steps in a design process

The final design consists of lots of objects in it. Usually a design comprises few basic elements where combination and repetition of these elements in certain ways makes it the final design. Simplifying a final design this way makes the generation process of the design an easy task. With respect to this point an architectural or urban design process can be seen as a patterns generation process which from a few basic elements the final design constructed where all its comprising objects are made from these basic elements. Like patterns, when we look carefully to them we can realize how a pattern is made of certain objects. The arrangement of the objects in that pattern is done by using some kind of transformation on these certain elements.

To prepare a design we should start with an initial design consisting of few preliminary 2D or 3D objects in it. To create these preliminary objects users can generate them using the utilities of the graphical modeling environment. To facilitate users of our tool we integrated a pattern generation package into the tool for creating the initial patterns or objects. For explanation of using this package readers are referred to other publications of the authors as given before.

4.6 A case study

In this section we exemplify a case study where an urban area will be designed using patterns. Assume what depicted in Figure 6 is an urban area including many design objects such as various buildings, high rises, green areas, water ponds and so on. In this figure all design objects are shown as 2D shapes, it's in

fact a top view, the perspective of the area when we look from above. As you see in this figure there is a kind of regularity among these design objects. For instance some of them have exactly the same shape; some share this characteristic plus having different orientation meaning that they are rotated in a direction by some rotation degrees; also some having the same shape but in different scales which means they are generated by reducing or enlargement on a certain object.

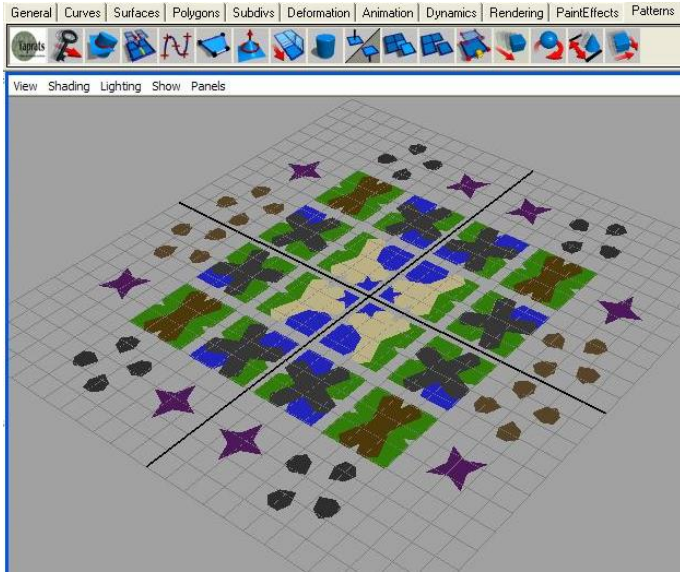


Figure 6. An urban area in 2D form

This urban area is depicted again in Figure 7, but this time shown in 3D form. Obviously, design objects like green areas and water ponds are still presented as 2D shape because their height value is given zero in this example.

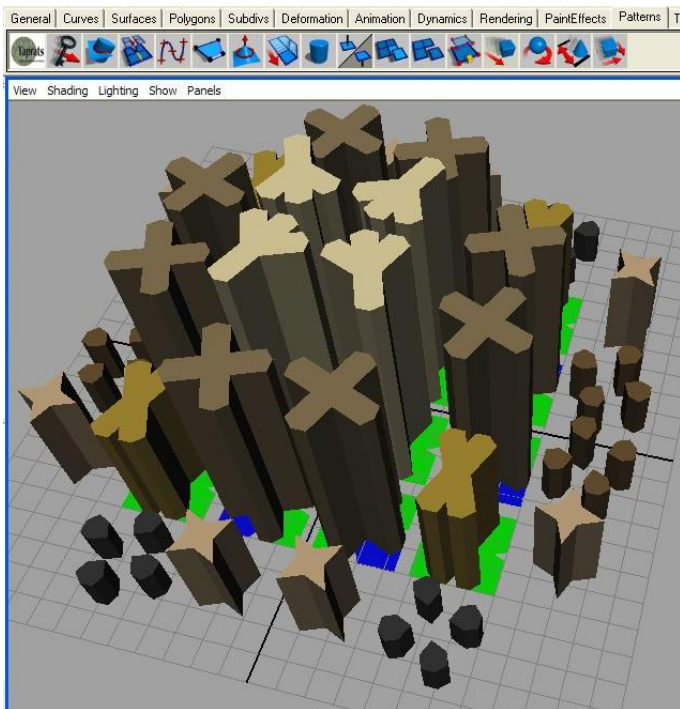


Figure 7. That urban area in 3D form

As said before, patterns are used as design objects can be either in 2D or 3D shapes. Design objects in the final design are mainly building blocks, streets, pavements, green areas and etc. Also in the previous section we explained two different ways for design generation using patterns. In the first approach we use the whole patterns as they are. So in this way the main task is deciding which pattern or patterns represent what type of design objects in the final design. Users can do this selection process plus other required repetitive tasks using utilities of the graphical environment. Also we must convert all 2D shapes into 3D forms before using them as objects in final design. In this way of design generation, patterns which are used in final design are existing patterns and we either import them, in an electronic format, into design or we create them using some means like the integrated pattern generation module into our tool or any graphical software they are familiar with.

In the second way, we will create the required patterns for using in final design from some initial elements. As shown in the Figure 8 and 9 these initial elements are in 2D and 3D forms respectively. The initial elements can be either 2D or 3D shapes as represented here. From these elements the required patterns for final design must be generated.

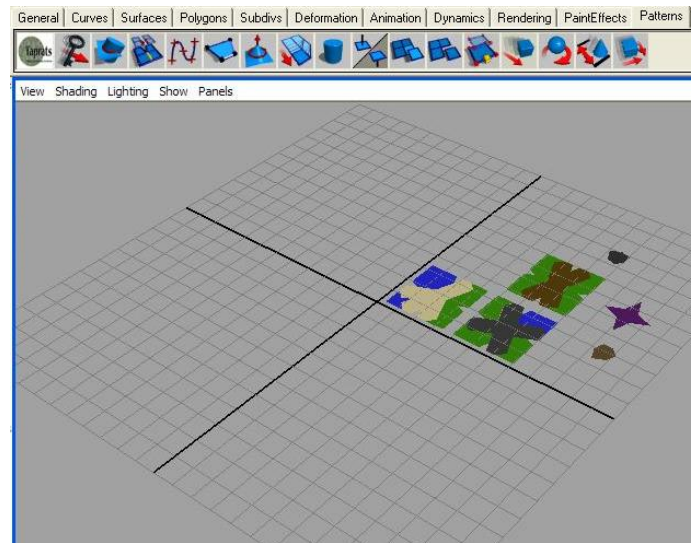


Figure 8. Required initial elements in 2D form

Carefully comparing Figures 6 with 8 also Figures 7 with 9, we can realize that it's possible to derive the design depicted in the first figures, 6 and 7, in both cases from the second one by doing certain transformation operations on the initial elements shown in Figures 8 and 9.

Provided transformation operations in our tool help users to perform required transformations on one or more design objects which will be used in the final design. Although at first it may not be so obvious how the final design can be generated from the

initial elements. But as explained so far by comparing deeply both figures reveals a stepwise manner to generate the final design, shown in figure 7, from the initial objects, shown in figure 9, using spatial transformations which have been explained so far in this paper.

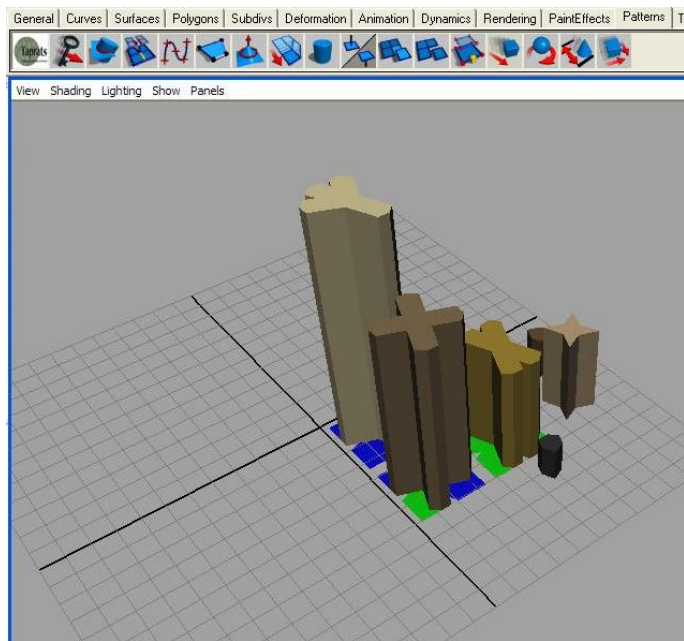


Figure 9. Required initial elements in 3D form

5 CONCLUSIONS

In this paper we introduced our 3D modeling tool enables deployment of patterns. Not to develop our tool from scratch we based development on Maya one of the best existing graphical modeling software. The main motive in selecting this software is its flexibility in adding new features and functions to it. Using Maya's own development scripting language called MEL developers can add to it almost any capability they can envisage. Historically patterns have been used in ornamental design, tilings, window and wall decorations, woodcrafts and etc. Our tool provides an environment for deploying patterns in design. Developed tool's features and functions help users to create patterns, to transform patterns into design objects such as building blocks, green areas, streets, pavements, water ponds and so on, also to generate a design from a few initial patterns using some kind of spatial transformations.

Since any new software development package needs more efforts to be fully adapted to the needs of the end users and there is no exception for our development. We do believe that some extra facilities and features should be added to it before making it as a popular and desirable tool for the community of architectural design, urban modeling and site construction people.

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