Toward Proccedural Decorative Ornamentation in Games

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ABSTRACT
Castles, palaces, temples and cathedrals in the real world are densely decorated with ornamentation. Computer games, in contrast, usually have much less and appear Spartan in comparison. Game worlds, whether hand-made or procedural, require greater decorative ornamentation to increase their realism and beauty. Currently artists create this ornament by hand; this doesn't scale. In order to have more decorative artwork in games, procedural algorithms must be developed to generate it, for only this approach will create sufficient quantities, quickly, and at low cost. This paper justifies the importance of decorative ornamentation in computer games and provides an overview of existing research on algorithmic generation of patterns and ornamentation. A series of open research issues demonstrates the breadth of potential research that can be performed in this area. Together, these make the case that procedural decorative ornamentation is a new and interesting research subdomain within the area of procedural content generation for computer games.

Categories and Subject Descriptors
I.2.1 [**Artificial Intelligence**]: Applications and Expert Systems – *Games* I.3.7 [**Three Dimensional Graphics and Realism**] – *Virtual Reality* J.5 [**Arts and Humanities**] – *Fine Arts*

General Terms
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1. INTRODUCTION
Computer games frequently take place inside elaborate built environments, such as castles, palaces, churches, and temples. In real life, these places have exceptional architecture defining the space they occupy, and frequently have expansive and intricate ornamentation on both internal and external surfaces. Throughout human history, when a person or group has amassed sufficient wealth to build a spectacular structure, they almost always desire that structure to be impressive both on the outside and on the inside. Ornamentation serves as an impressive marker of wealth and power, since it is expensive to create and install, especially in large scale. It is also aesthetically pleasing, adding interest and complexity to broad expanses of bare walls, transforming the ordinary into the sublime. Ornamentation often carries religious and political significance, with ornamental elements chosen for spiritual or propagandistic goals.

Across an astonishing range of times and cultures, powerful humans have created structures featuring a dazzling array of beautiful ornamentation. A far from exhaustive list includes decorative scenes from the Assyrian palaces at Nimrud and scores of ancient Egyptian temples and tombs, Islamic star patterns and arabesques in sites such as the Alhambra (Granada), Mesquita (Cordoba), and Real Alcazar (Seville), Mughal ornamentation at the Taj Mahal, the Khmer style of Angkor Wat, and Christian cathedrals across multiple architectural styles. The desire for ornamental decoration reaches into the homes of aristocrats and the middle class as well, with examples including the floor mosaics and decorative wall drawings from Roman houses (in Pompeii, and other Roman cities), the Victorian style of dense arrangements of decorative art elements, to modern day use of wallpaper, wall stencils, and bathroom and floor tile. While modern architecture and interior design emphasize clean, unornamented spaces, this stands at odds with historical desires for ornamentation.

Due to the prevalence of decorative ornamentation in large religious and governmental buildings throughout history, one would expect that their virtual counterparts inside computer games would have similar levels of ornamentation. This is not the case. Whether due to insufficient graphics capability, lack of time to create extensive ornamentation, or insufficient education of game artists concerning major styles of ornamental art, the interiors and exteriors of castles, palaces, churches, temples, etc. in computer games are sparsely ornamented as compared to their historical counterparts. Figure 1 (following page) shows a decorated wall in the Alhambra, a real-life Islamic palace located in Granada, Spain, while Figure 2 shows a scene from a palace in the game Prince of Persia. Compared with many computer games, Prince of Persia pays strong attention to decorative ornament, with windows featuring Islamic star patterns, Islamic inspired architectural elements, and, at times, use of decorative patterns on walls and floors in various locations. In this respect, Prince of Persia is an exemplar of how decorative ornamentation can enhance the ambience of a virtual world. However, even at its best, the decoration in Prince of Persia is not as densely detailed, nor as varied in style, as just one wall at the Alhambra.

It would be beneficial if the architecture inside computer games had more elaborately decorated surfaces. At present, the lack of this ornamentation makes the interior spaces of computer games seem overly sparse and artificial. More ornamentation would make the synthetic virtual spaces of games seem more real. Furthermore, by including ornamentation games would be able to take advantage

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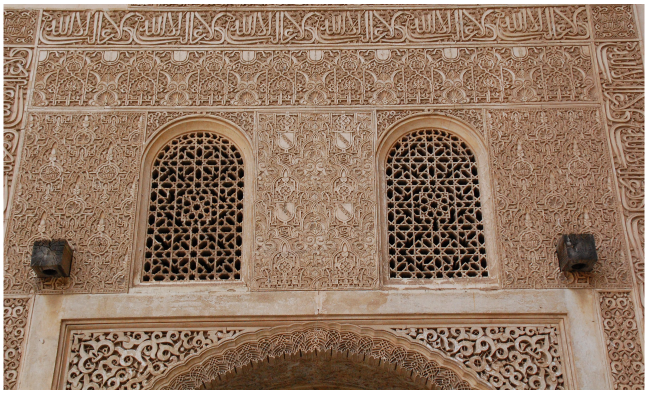

Figure 1. A wall at the Alhambra (Granada, Spain) decorated with Islamic patterns. The windows contain star patterns; at the very top is a calligraphic pattern.

Figure 2. Scene from the Spire of Dreams Royal Palace in the game Prince of Persia (2008, Ubisoft). Windows have Islamic star patterns; Islamic inspired archways are at back.

of ornamentation's ability to convey a particular culture and time; Gothic ornamentation is very distinct from Celtic and Arabic, and each ornamental style clearly implies a specific culture and historical time. Ornamentation would also increase the beauty of virtual worlds, enhancing replay value, and perhaps promoting virtual tourism just to experience the game's built environment without the distraction of needing to play the game. Indeed, there is some evidence (summarized in [11]) that humans find symmetric decorative patterns very pleasing, and that symmetric patterns create a kind of visual puzzle that engages our brains in an effort to determine the underlying rules.

Ornamentation is especially important for procedurally generated buildings inside computer games. At present, despite the impressive range of building types that can be procedurally generated [22], their lack of ornamentation makes it easier to detect the underlying regularity of these buildings, since their facades and interiors are plain. As well, procedurally generated buildings would benefit just the same as human-created structures from the increased realism, sense of culture and time, and beauty afforded by ornamentation.

As hardware graphics capabilities continue to improve, the key limiting factor for the inclusion of rich ornamentation in the built structures of computer games is the time it takes a human artist to create such patterns. More than available polygons or texture memory, what will control the quantity and quality of ornamentation is the amount of effort required by an artist to compose a unique ornamentation scheme for a given room, archway, or building façade. Procedural techniques for creating ornamentation, in which the computer uses one or more algorithms to generate decorative ornamentation, offer the promise of substantially reducing the effort required to create decoration.

Procedural ornamentation support can take two forms, either fully automated, or a part of a mixed-initiative content generation system. In the fully automated case the input is the geometry of a room or building facade, yielding as output a set of polygons and/or textures representing that room's decorative ornamentation. In this case, a human designer can only provide input parameters and the selection of ornamentation algorithm, but has no ability to modify the final output beyond calling for another one to be generated. The fully automated approach is ideal for the automated generation of towns and cities, where the computer must quickly create a large virtual space without human guidance. In contrast, a mixed-initiative ornamentation system would allow a human artist to work interactively with the ornamentation generator. The artist could select a region to fill and an algorithm to fill it, and perform minor touch-up operations directly on the created patterns. This would be ideal for artists creating designed spaces to fit specific needs in computer game levels. The mixed-initiative approach provides much greater choice for the final ornamentation, and permits greater artistic control over the symbolic content of the decoration.

2. THE STATE OF PROCEDURAL DECORATIVE ORNAMENTATION

There is no one academic community that focuses exclusively on the synthetic creation of decorative patterns. Instead, there have been two broad threads of inquiry, largely disjoint. The mathematic/computer scientific thread has focused on the study of understanding and replicating existing known geometric decorative patterns. Exemplars of this line of inquiry include work to generate Islamic star patterns [13], Celtic knot patterns [5], and Gothic window patterns [10]. The goal of this work is to develop style-specific algorithms that can reproduce a subset of a particular ornamental style, with algorithms evaluated based on their expressive range across known samples of patterns. The second thread is artistic in focus, and involves the creation of algorithms that generate novel abstract patterns. These pieces are evaluated based on their novelty and aesthetic qualities. These two currents of work are described further in the sections below.

2.1 Mathematic/Scientific Ornamentation

Work to replicate existing styles of decorative patterns builds upon the mathematically formalized notion of symmetry and tilings, extensively covered in foundational books by Weyl [21] and Grünbaum & Shephard [8], with Kaplan writing a recent book offering an introduction to tiling theory for computer scientists [12].

Several researchers have been intrigued by the rules underlying Islamic star patterns. Grünbaum & Shephard appear to be the first to provide a mathematic explanation for how to generate Islamic star patterns, describing them in terms of interlace patterns in which pattern strands alternately go over and under one another [9]. Ostromoukhov extends this analysis to the 17 planar symmetry groups [17]. Kaplan is the first to create Islamic star patterns using computer graphics, using an algorithm that first selects a tiling, and then fills the tilings with decorative motifs [11, 13]. Lu and Steinhardt [16] observe that these patterns can be created via tessellations of a set of equilateral polygons decorated with lines, similar to the fundamental regions described in [9]. Critchlow [4] and Chorbachi [3] both provide descriptions of how the original artisans might have created these patterns, along with some background on their symbolic significance.

Documentation of techniques for creating Gothic style design emerged during the Gothic revival during the 19th century in a book by Billings, which provides detailed how-to drawings for 100 Gothic decorative patterns [1]. Recently, Havemann and Fellner developed a programming language for the procedural generation of complex 3D shapes called Generative Modeling Language (GML), using it to write a generator capable of producing a range of Gothic window traceries [10]. However, the majority of complex Gothic patterns have not yet been converted into algorithmic form to support procedural generation.

A mechanical technique for creating Celtic knot patterns was first developed by Cromwell [5]. Fisher and Mellor explore the topology of Celtic knots in [7]. Kaplan documents two efforts to implement this technique in a computer (by Zongker for linear lattices and then for any planar graph by Mercat), but these citations are to currently inactive web pages [11]. Browne adopts a different, tile-based approach that fits Celtic knot tiles to arbitrary outlines [2].

Dunham has developed algorithms to generate patterns in the style of M. C. Escher using notions of hyperbolic geometry, tessellations, and symmetry [6]. Other geometric pattern styles have been generated procedurally using shape grammars as the basic formalism. These include Chinese lattice designs [18] (with later implementation in AutoLISP [15]), and Heppelwhite chair-back designs [14].

2.2 Artistic Algorithmic Ornamentation

Algorithmic computer artists frequently create images that can be considered decorative ornamentation, or decorative patterns. Early algorithmic artists (and pieces) that characterize this style of work include Herbert W. Franke (Quadrate (Squares)), Frieder Nake (Walk-through-Raster, series 2.1-4), and Manuel Barbadillo (Adefera) [20]. Verotsko has a particularly good website documenting his algorithmic artworks, with pieces such as the Cyberflower series and Diamond Lake Apocalypse, Burning Bush having ornamental qualities [19]. Unfortunately, algorithmic computer artists rarely publish detailed descriptions of the algorithms or source code that creates their art, and in any event, the hardware/software platforms used to create this art are frequently obsolete and unavailable. We know more about how to replicate Islamic and Gothic art from hundreds of years ago than most algorithmic art from the 1970s. Thus, for the purposes of procedural decorative ornamentation for computer games, algorithmic art can, at present, serve best as an inspiration for algorithms reverse-engineered from the original art forms.

3. RESEARCH ISSUES

As shown in the previous section, many researchers have developed algorithms for generating existing historical decorative patterns. However, this work is by no means definitive. There are many examples of existing decorative styles that cannot be generated by current algorithms, and tools for creating these patterns are not available outside of research labs. The following sections highlight multiple research issues and potentials in the space of procedural decorative ornamentation.

3.1 Greater Coverage of Existing Historical Styles

To date, research attention has focused primarily on understanding and replicating known Islamic, Gothic, and Celtic decorative patterns. However, despite the impressive results obtained by these algorithms, it is still very easy to find pattern examples in real sites that are outside the expressive range of existing algorithms. It remains an open question as to how to generate these remaining examples, and whether it requires minor tweaks or major overhaul to existing algorithms to accomplish this. Furthermore, there are many other historical decorative traditions that have not yet been analyzed algorithmically.

3.2 Adapting Algorithms to Fit Existing Spaces

Most existing algorithms for generating decorative ornamentation assume there are no constraints on the space to be filled with the pattern. However, in most architectural uses, there are walls, doors, archways, columns, pictures, etc. that form constraints for the decoration. Ceilings are very commonly covered with instances of Islamic and Gothic decoration, yet existing algorithms are not capable of creating patterns to fit arched or domed ceilings. Frequently, multiple facets of a decorative style are used to fill a given space. For example, in Figure 1 there is a star pattern for the window traceries, which can perhaps be generated by Kaplan's algorithm. However, in the same row as the windows there are 3 other distinct decorative patterns with two separate styles (above the window arches is one, and the panels to the left and right of the windows are another). Also visible is a calligraphic pattern (top row), another decorative style in the row below it, and yet another above the archway at the bottom of the picture. None of these decorative patterns can be algorithmically generated at present.

3.3 Creating New Decorative Styles

Most decorative styles have style-specific algorithms for their creation. If a common underlying representation capable of generating multiple styles were developed, it should be possible to create hybrid decorative styles, combining, say, elements of Gothic with Islamic, etc. This is important for computer games, since they typically take place in fantasy settings that are evocative of, but not quite the same as, existing historical periods. Games will need to develop specific decorative traditions for each non-human race, and even for specific historical periods. It would make sense to start with existing decorative styles and then modify them to make them sufficiently different. Existing algorithms do not make decorative style a first class entity, capable of manipulation. Once a decorative style can be represented, an interesting direction to explore is whether an evolutionary algorithm could automatically explore a wide design space of potential decorative pattern styles.

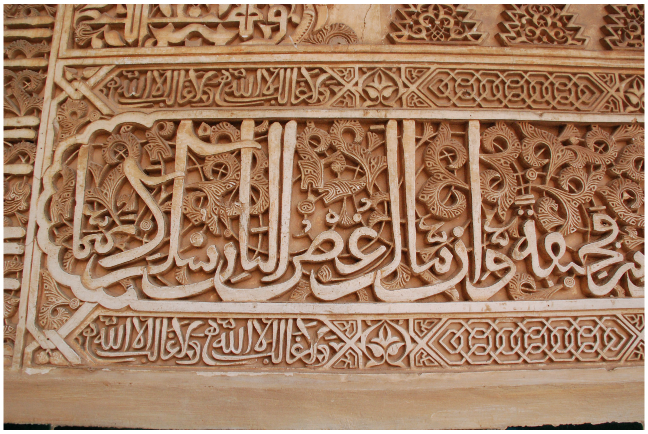

Figure 3. Non-symmetric calligraphic pattern.

3.4 Non-symmetric decoration

Islamic wall decorations include many examples of decorative elements that are highly stylized calligraphy. Interesting qualities of this decoration are that they are frequently not based in any type of symmetry, and include a large amount of subsidiary decoration interspersed with the main calligraphy (see Figure 3 above). Can an algorithm generate decorative patterns in this calligraphic style?

3.5 Reverse engineering computer art algorithms

As noted above, computer artists typically do not describe their algorithms for creating algorithmic decorative art. It would be useful to reverse engineer an algorithm capable of generating specific decorative computer art pieces.

3.6 Mixed-initiative decoration systems

Decorative pattern algorithms should be created in a way that humans can interact with them, so artists can work hand-in-hand with the generator to create a final pattern. It is currently unclear what affordances a human might ideally want. That is, how should an artist provide feedback to a decorative pattern generator? Potential ideas include the ability to pick parts of the decoration and move them, with the rest of the decoration morphing in a reasonable way. But, what would reasonable mean in this context? As well, it is unclear how decorative ornamentation algorithms should interact with existing bitmap editing, line drawing and 3D modeling tools.

4. CONCLUSION

Procedural decorative ornamentation is a rich area for further research, with multiple deep, open research questions. It offers the promise of making it economically feasible to have virtual worlds with intricately decorated spaces, increasing their beauty, and providing a way to express the distinctive nature of novel cultures within these worlds. Decorative ornamentation is not limited to just buildings: it can be used to create ornate etchings on weapons, armor, and shields, as well as to design interesting patterns for clothing. Outside of virtual worlds, this research has the possibility to influence decorative ornamentation for real-world structures and items; Kaplan has demonstrated the ability to drive computer-aided manufacturing machinery to create physical versions of algorithmically generated patterns [13]. Here too there is the potential for beautiful algorithmic decoration at high scale and low cost. It's a potential worth exploring.

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