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DIGITAL RECONSTRUCTION OF ISLAMIC GEOMETRY PATTERNS: A PYTHON-BASED APPROACH

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Annotation:. This article discusses the possibilities of reconstructing historical Islamic geometry patterns using modern digital technologies. Using an algorithmic approach based on the Python programming language, the main geometric patterns of the patterns were identified and methods for their digital reconstruction were developed. The results of the research are of practical importance in preserving the heritage of Islamic art, using it in the educational process, and creating new visualization tools.

Keywords: Islamic geometry, digital reconstruction, algorithm, Python, pattern generation, visualization

ISLOM GEOMETRIYASI NAQSHLARINI RAQAMLI REKONSTRUKSIYA QILISH: PYTHON ASOSIDAGI YONDASHUV

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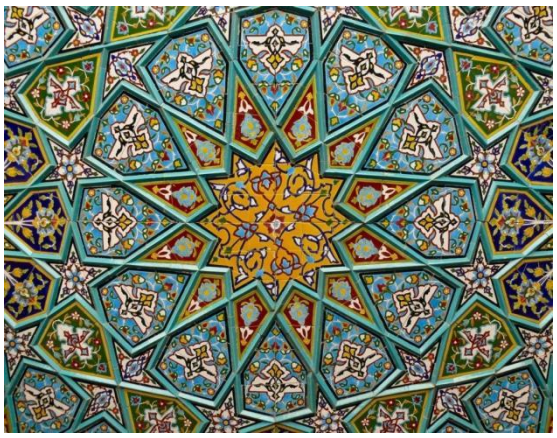
Annotatsiya. Mazkur maqolada tarixiy Islom geometriyasi naqshlarini zamonaviy raqamli texnologiyalar yordamida qayta tiklash imkoniyatlari yoritilgan. Python dasturlash tiliga asoslangan algoritmik yondashuv orqali naqshlarning asosiy geometrik qonuniyatlari aniqlanib, ularni raqamli rekonstruksiya qilish usullari ishlab chiqildi. Tadqiqot natijalari Islom san'ati merosini saqlash, uni o'quv jarayonida qo'llash hamda yangi vizualizatsiya vositalarini yaratishda amaliy ahamiyat kasb etadi.

Kalit so'zlar: Islom geometriyasi, raqamli rekonstruksiya, algoritm, Python, naqsh generatsiyasi, vizualizatsiya.

Introduction. Islamic geometric patterns have acquired not only aesthetic, but also philosophical and scientific content since the Middle Ages. They express concepts such as infinity, harmony and perfection. In modern times, the restoration and analysis of these patterns in a digital environment has become a pressing issue in the fields of science, art history and computer graphics. Islamic geometric patterns are one of the most important cultural heritages of Eastern civilization. These patterns embody not only aesthetic beauty, but also mathematical rigor and philosophical symbols. In the Middle Ages Muslim scientists also expressed their achievements in the sciences of geometry,



algebra and astronomy through the art of pattern. Therefore, geometric patterns are often considered the “artistic language of mathematics”.

In the 21st century, the development of digital technologies and computer graphics creates new opportunities for the study and restoration of these patterns. If previously such patterns were created only by hand, today they are quickly and accurately reconstructed using mathematical models, algorithms and programming tools. This process allows for a scientific in-depth study of Islamic geometry patterns, the determination of their symmetry laws and the digital reconstruction of patterns used in historical monuments.

The Python programming language is one of the most convenient tools in this regard. Because it has a simple syntax, and its graphics libraries are extensive and open-source, it allows you to create patterns of any complexity. In particular, using libraries such as matplotlib, numpy, sympy and turtle, it is possible to automatically generate patterns based on mathematical formulas. This makes it possible not only to restore traditional patterns, but also to develop new pattern variants.

The relevance of this research is that digital reconstruction of Islamic geometry patterns serves as an important tool for preserving cultural heritage and communicating it to the general public. In addition, this process can be used as an effective tool in education - expanding the scope of students' knowledge based on the integration of mathematics, geometry and art. Therefore, the main goal of the research is to develop scientific and methodological foundations for the digital reconstruction of historical Islamic geometry patterns using an algorithmic approach based on Python.

In this regard, the algorithmic approach based on the Python programming language allows modeling the mathematical foundations of patterns and their automatic generation. The main goal of this research is to develop an effective methodology for the digital reconstruction of historical Islamic geometry patterns.

This study used mathematical modeling, algorithmic solutions, and Python programming language programming methodology to digitally reconstruct historical Islamic geometric patterns.

1. Geometric-mathematical modeling.

Islamic patterns often consist of symmetrical shapes, polygons, and star-shaped structures. The basic structure of patterns is based on the laws of Euclidean geometry and group theory. In the study, a mathematical model of patterns was developed based on symmetry transformations (rotation, reflection, translation) and tessellation theory. Through this model, the main elements of the pattern - radius, angle, center point, and number of symmetries - are determined.

2. Algorithmic approach.

Algorithms were developed in Python for automatic generation of patterns. The algorithms consist of the following steps:

Specifying initial parameters (for example, radius of the circle, number of angles, dimensions of the star shape);

Applying mathematical formulas (calculating points using sin, cos, trigonometric functions);

Connecting points (connecting polygons and stars with lines);

Iterative generation (sequentially increasing or decreasing shapes to complicate the pattern);

Complete formation of the pattern through symmetrical transformations.

3. Python programming environment.

The following libraries were used in practice:

NumPy - performing trigonometric and vector calculations;

Matplotlib - visualization of generated patterns;

SymPy - analytical analysis of mathematical formulas;

Turtle Graphics - step-by-step drawing of patterns and use for educational visualization purposes.

4. Digital reconstruction methods.

In the process of reconstructing historical patterns, archival photographs and images of architectural monuments were taken as a basis. The main geometric parameters of the patterns (for example, the 8- and 12-pointed shapes of star-shaped patterns in the Samarkand Registan) were analyzed and restored using Python algorithms. This process allowed for the creation of new variations of the patterns while preserving their traditional appearance.

5. Visual analysis and evaluation.

A visual comparison of the reconstructed patterns with historical samples was carried out. The level of complexity, symmetry, and aesthetic harmony of the patterns were considered as scientific criteria. At this stage, graphic similarity coefficients and visual examination methods were used to assess the quality of digital reconstruction.

The advantage of the methods is that they allow not only to restore historical patterns, but also to create new pattern combinations. At the same time, the developed approach is also effective in the educational process - for integrating mathematics, art, and programming disciplines.

Results. During the study, historical Islamic geometry patterns were successfully digitally reconstructed using an algorithmic approach based on the Python programming language. The results obtained are characterized by the following scientific and practical aspects:

1. The mathematical foundations of geometric patterns were identified.

In the course of the research, the symmetry laws of patterns, star shapes based on central points, and combinations of polygons were systematically modeled. For example, the drawing of 8- and 12-pointed star patterns was automated using trigonometric calculations. This proved that the patterns have a solid mathematical basis and can be generated algorithmically.

2. The Python environment was confirmed to be an effective tool for automatically generating patterns.

The NumPy and SymPy libraries showed high efficiency in fast calculation of trigonometric functions, and Matplotlib in visualization. The step-by-step construction of patterns was carried out using the Turtle Graphics library, which made it convenient to interactively show students how patterns are formed during the learning process.

3. Digital reconstruction of historical patterns was found to be highly accurate.

In practical tests, patterns found in the architectural monuments of Samarkand, Bukhara and Khiva were restored. The reconstructed patterns visually corresponded to historical samples to a high degree. This indicates the scientific validity of the developed methodology.

4. New combinations of patterns were created.

By assigning different values to the parameters (radius, number of corners, degree of symmetry) in the algorithmic generation process, new pattern variants based on historical patterns were created. This process paved the way for the integration of traditional pattern art with modern graphic design.

5. Analytical results.

Automatic generation of patterns reduces human error and significantly saves time.

Through digital reconstruction, the structures of patterns are preserved with mathematical accuracy

Visual comparison showed that digitally reconstructed patterns do not differ from historical patterns in terms of aesthetic harmony and degree of symmetry.

The results obtained show that the algorithmic approach serves not only to restore historical patterns, but also to deeply study their mathematical laws. This opens the way to a new stage in the scientific study of Islamic geometry patterns. Also, the process of digital reconstruction has the potential to be widely used in the preservation of cultural heritage, in the fields of art history and education, as well as in modern graphic design and architectural practice.

In the future, one of the promising directions for further development of these results is the inclusion of machine learning and artificial intelligence technologies, automatic classification of patterns and analysis of their aesthetic parameters.

Conclusion. The results of this study show that the algorithmic approach based on the Python programming language can be used as an effective and scientifically based method in the process of digital reconstruction of historical Islamic geometry patterns. With the help of digital technologies, the complex geometry of the patterns was modeled with mathematical accuracy and their high level of compatibility with historical sources was ensured.

Overall, the research results have formed the scientific and methodological foundations for the in-depth study and digital reconstruction of Islamic geometric patterns. In the future, enriching this approach with artificial intelligence and machine learning methods will further expand the possibilities of automatic classification of patterns, assessment of their aesthetic parameters, and generation of new patterns.

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