BG Pulse Journal USA

ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg

BG PULSE JOURNAL

INTEGRATING TRADITIONAL GEOMETRIC PROPORTIONS INTO CONTEMPORARY PARAMETRIC FAÇADE DESIGN: THE CASE OF UZBEK ARCHITECTURE

Yuldasheva Bahora Rustamovna

Doi: https://doi.org/10.5281/zenodo.24241098

Abstract. This paper examines a conceptual approach to integrating geometric proportion principles found in Central Asian architectural heritage into contemporary parametric façade design. The study focuses on the "Perfect Square" model presented in F.U. Jumakulov's research: a geometric system of 12 × 12 units derived from the construction of a right triangle with a 3:4:5 ratio. The model is not treated as a historically universal module; rather, it is interpreted as an analytical geometric framework that can be translated into parametric relationships. Qualitative analysis, comparative analysis and conceptual synthesis are used to identify links between historical façade composition, modularity, proportion, rhythm and contemporary digital design. The proposed methodology consists of documenting historical sources, geometrically abstracting compositional principles, defining parameters, generating design alternatives algorithmically and evaluating them using multiple architectural criteria. Five groups of assessment criteria are identified: geometric consistency, compositional coherence, cultural identity, functional and climatic suitability, and constructability. The paper does not claim to present completed digital simulations or measured environmental-performance results. Instead, it establishes a reproducible conceptual workflow for subsequent computational testing.

Keywords: Uzbek architecture; geometric proportion; parametric façade; Perfect Square; digital design; cultural identity; façade composition.

Abstract in Uzbek: This paper considers a conceptual approach to integrating the principles of geometric proportion found in Central Asian architectural heritage into contemporary parametric façade design. The study focuses on the "Perfect Square" model described in F.U. Jumakulov's work, namely a 12 × 12-unit geometric system derived from the construction of a right triangle with a 3:4:5 ratio. The model is not presented as a proven universal module used in historical architecture, but as an analytical geometric basis that can be translated into parametric relationships. The study employs qualitative analysis, comparative analysis and conceptual synthesis to identify connections between historical façade composition, module, proportion, rhythm and contemporary digital design. As a result, a methodological sequence is proposed, comprising documentation of historical sources, geometric abstraction, parameter definition, algorithmic generation of alternatives and multi-criteria architectural evaluation. Five groups of assessment criteria are identified: geometric consistency, compositional coherence, cultural identity, functional and climatic suitability, and constructability. The paper does not claim to provide digital simulations that were not performed or measured environmental-performance results; instead, it establishes a reproducible conceptual workflow for subsequent computational testing.

Keywords: Uzbek architecture; geometric proportion; parametric façade; Perfect Square; digital design; cultural identity; façade composition.

Introduction

An architectural façade is an important compositional layer that expresses the relationship between a building's volume, function and urban context. Its architectural character is shaped not only by decorative elements but also by proportion, rhythm, module, symmetry, the ratio of solid to void, materiality, and the relationship between light and shadow. In the historical architecture of Uzbekistan, portals, arches, iwans, domes, courtyards and geometric ornaments were integrated according to specific compositional and spatial principles. Therefore, expressing a national architectural identity in contemporary buildings should not be limited to directly reproducing historical decoration; it requires identifying the geometric and compositional principles underlying it.

Contemporary parametric design makes it possible to define relationships between façade elements through parameters and rules. In this approach, façade width and height, module size, spacing between elements, rhythmic intervals, opening ratio and shading depth are treated as interrelated variables. A change in a parameter value leads to the corresponding geometric elements being recalculated. Woodbury describes parametric design as a way of thinking and modelling that controls design elements and the relationships between them [1]. Kolarevic highlights the links between digital design, form generation and digital fabrication [2].

The relevance of this issue is also reflected in international research. A systematic review of geometric patterns and façade tessellation identifies research into the effects of façade geometry on daylighting and thermal performance, while also noting remaining gaps concerning climatic diversity and dynamic systems [3]. Recent work on solar-responsive and reusable façades demonstrates the potential to connect parametric design with contextual adaptation, solar control and circular use [4].

The aim of this paper is to develop a conceptual methodological approach for abstracting geometric and proportional principles of traditional Uzbek architecture through the "Perfect Square" model and integrating them into contemporary parametric façade design.

The research addresses the following questions: (1) Which geometric and rhythmic principles of historical architectural composition can be translated into a parametric system? (2) How can the 12 × 12-unit "Perfect Square" model serve as a parametric coordination framework? (3) Which architectural criteria should be used to evaluate the resulting façade alternatives?

2. Materials and Methods

2.1. Research design

This study is theoretical and conceptual in nature. The main materials comprise scholarly literature on Uzbek architectural heritage, façade composition and geometric harmony; F.U. Jumakulov's research on the "Perfect Square" model; and academic sources on parametric design. The methods include document analysis, abstraction of geometric relationships, a comparative-typological approach and conceptual modelling.

The study does not claim that a complete algorithm was developed in Grasshopper or another software environment for a specific building façade, or that solar-radiation simulations, structural

calculations or user surveys were conducted. Accordingly, the findings are presented not as a finished parametric product or a quantified performance result, but as a methodological model for subsequent empirical verification.

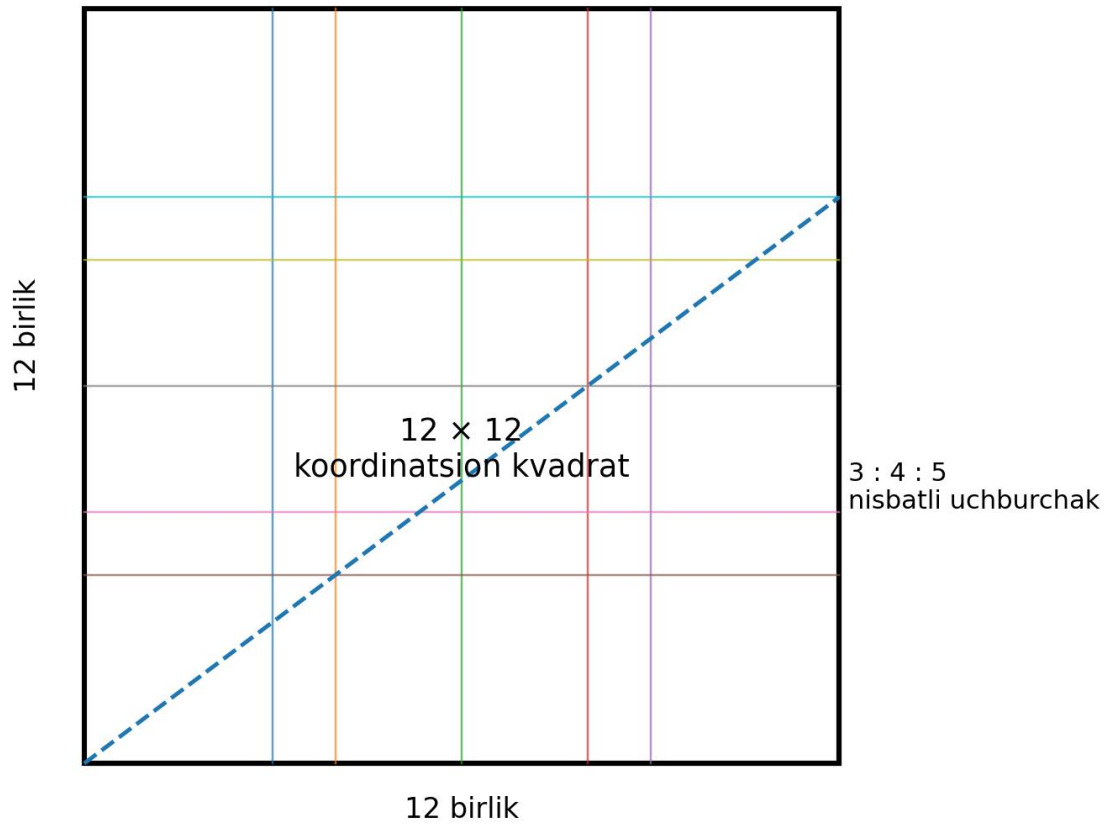


Figure 1. The 12 × 12 coordinate structure and 3:4:5 geometric basis of the “Perfect Square” model.

2.2. Geometric basis: the “Perfect Square” model

In F.U. Jumakulov’s research, the “Perfect Square” is explained through the geometry of a 3:4:5 right triangle. A rectangle measuring 3 × 4 units is formed using legs of 3 and 4 units; the repeated arrangement of this rectangle produces a square measuring 12 × 12 units [5]. The practical value of the model lies in the possibility of generating different subdivisions and proportional relationships through the divisors of 12: 1, 2, 3, 4, 6 and 12.

In this paper, the model is not interpreted as a universal measurement system used by historical architects in all buildings. It is adopted as an analytical coordinate model proposed for examining façade geometry and generating new compositional alternatives. This distinction is important to avoid conflating historical evidence with contemporary design interpretation.

For parametric application, the base square is defined as a = 12 conventional units. Its subdivisions produce steps of a/2 = 6, a/3 = 4, a/4 = 3, a/6 = 2 and a/12 = 1 unit. A scale coefficient s is introduced when transferring the model to the dimensions of an actual façade: $x_r = s \cdot x_m$, $y_r = s \cdot y_m$. Here, x_m and y_m are dimensionless model coordinates, while x_r and y_r are coordinates in the actual design. This preserves geometric proportions while adapting physical dimensions to the selected façade.

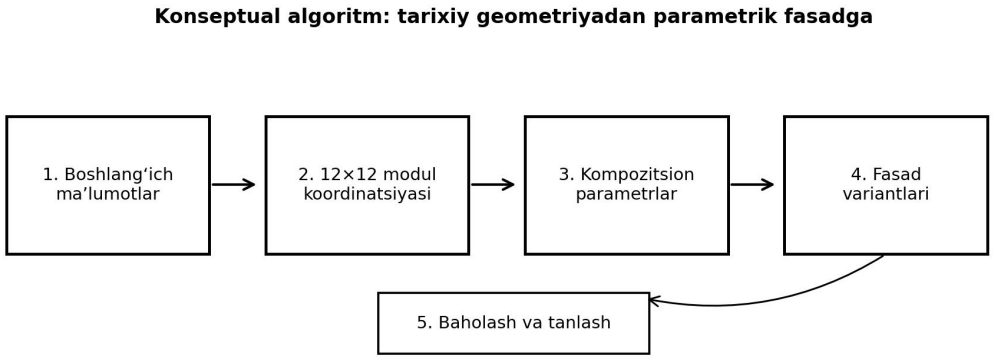


Figure 2. Conceptual workflow for translating historical geometric principles into a parametric façade.

2.3. Parameter definition and algorithmic sequence

The proposed system divides parameters into four levels. The first level comprises initial dimensions: façade width L, height H, number of storeys and primary coordinate axes. The second level comprises modular parameters: module a, the number of module repetitions and the coordination grid. The third level comprises compositional parameters: panel width p, spacing q, rhythmic interval r, opening ratio o, and rules of symmetry or asymmetry. The fourth level comprises functional and micro-geometric façade parameters: screen depth d, louvre angle θ, perforation density ρ and element transformation coefficients.

The conceptual algorithm consists of the following stages: (1) entering the initial data of the building and façade; (2) creating the 12 × 12 geometric coordination framework; (3) scaling the coordination grid to dimensions L and H; (4) defining relationships between primary and derived parameters; (5) generating façade panels, screens or louvres; (6) producing alternatives through geometric transformations; (7) checking climatic, functional and structural constraints; and (8) evaluating the alternatives using multiple criteria and selecting the most appropriate solution.

This sequence is a conceptual description of the parametric system. Its software implementation, exact formulas and parameter ranges should be determined in a subsequent research stage according to the selected building, materials, façade orientation and climatic data.

3. Results

3.1. Translating historical compositional principles into parametric variables

The analysis identified five principal characteristics of historical façade composition that can be transferred into a parametric system: module, proportion, rhythm, central axis and hierarchy. The module regulates the dimensions of façade elements; proportion defines the relationships between elements; rhythm controls repetition and spacing; the central axis establishes compositional balance; and hierarchy visually distinguishes entrances, principal halls or significant façade zones.

Rather than directly copying the forms of historical portals, arches or geometric ornaments, the study proposes abstracting their underlying geometric logic. For example, the contour of an arch can be represented by a parametric curve, an ornament by a repeating geometric cell, and the central emphasis of a portal by symmetry and a hierarchy of dimensions. This approach aims to reinterpret compositional principles in a contemporary form rather than reproduce decorative motifs, thereby supporting the expression of cultural identity.

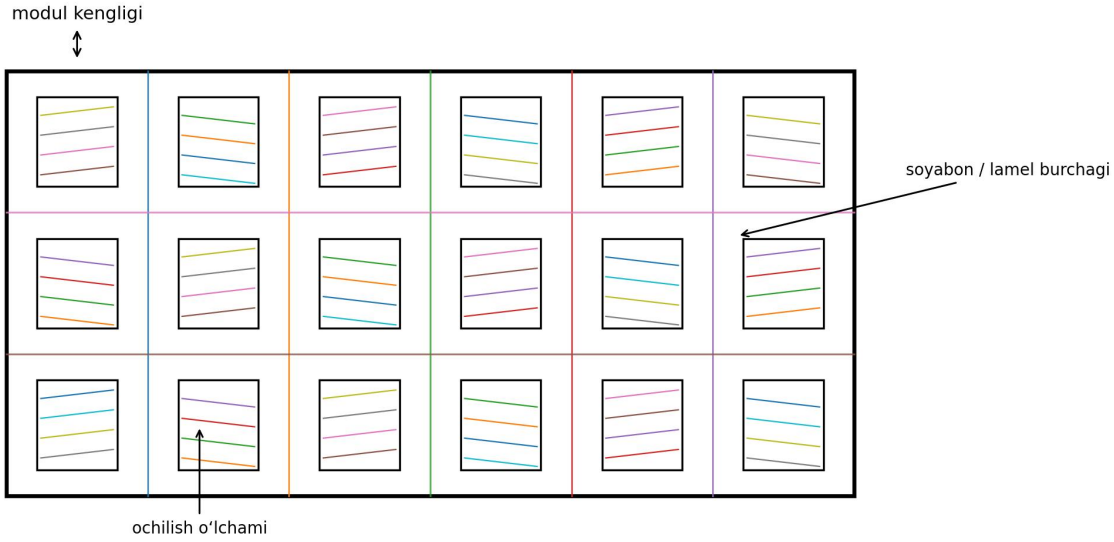


Figure 3. Schematic representation of a parametric façade in which the module, opening dimensions and shading louvres are controlled by parameters.

3.2. A model for generating façade alternatives based on the "Perfect Square"

The 12 × 12-unit coordinate framework makes it possible to organise a façade at several scales. The overall 12-unit square can define the primary compositional boundary; subdivisions of 6 and 4 units can define major façade zones; steps of 3 and 2 units can organise secondary elements; and a 1-unit step can define fine rhythmic or perforated elements. These values are not mandatory architectural dimensions but conventional subdivisions within the model.

At least three types of façade composition can be generated using this coordinate framework. The first is a symmetrical-axial composition, in which repeating elements are arranged around a central

axis. The second is a rhythmic-modular composition, in which the same module is repeated with different spacing and density. The third is a gradient composition, in which the size, openness or depth of elements changes progressively across the façade. These alternatives may be generated from the same geometric basis, while differing in their visual character and functional properties.

The parametric variables of a façade should not be limited to artistic composition. Screen depth, opening ratio, louvre angle and perforation density can be linked to solar orientation, room function, daylighting and ventilation requirements. A systematic review of geometric patterns and tessellation indicates the potential of façade patterns in relation to daylight and thermal performance, while also emphasising the need for further research on climatic context and dynamic systems [3].

Taklif etilayotgan baholash mezonlari (natijalar emas, tekshiruv yo‘nalishlari)

	Geometrik izchillik	Kompozitsion uyg‘unlik	Madaniy identifikatsiya	Iqlimiy-funksional moslik	Qurilish imkoniyati
Baholash mezoni	Tekshiriladi	Tekshiriladi	Tekshiriladi	Simulyatsiya bilan tekshiriladi	Konstruktiv hisob bilan

Figure 4. Proposed assessment criteria for the model and the corresponding verification pathways.

3.3. Criteria for evaluating parametric façades

The proposed model identifies five groups of criteria for selecting façade alternatives. The first is geometric consistency: the conformity of the generated elements with the selected module and coordinate framework. The second is compositional coherence: rhythm, proportion, symmetry, hierarchy and the relationship with the building volume. The third is cultural identity: a meaningful and context-sensitive interpretation of historical geometric principles. The fourth is functional and climatic suitability: compliance with requirements for solar protection, daylight, views and ventilation. The fifth is constructability: the feasibility of materials, connections, fabrication, installation and maintenance.

At the next stage of assessment, measurable indicators and weighting coefficients may be developed for each criterion. However, numerical values are not assigned in this theoretical paper because they must be substantiated through expert evaluation, specific façade geometry, climatic calculations and structural solutions. The study by Dervishaj and Gudmundsson demonstrates that solar-responsive and reusable façades can be integrated within a single workflow [4]. This further underlines the need to include environmental and operational criteria in parametric evaluation.

4. Discussion

The main advantage of the proposed approach is that it interprets historical architectural heritage not as a repository of ready-made decorative forms, but as a system of geometric and compositional knowledge. In this context, the "Perfect Square" is not itself a national ornament; rather, it serves as an analytical framework for organising relationships of module, proportion and repetition. This distinction makes it possible to continue the underlying logic of historical forms without turning contemporary façades into direct copies of historical architecture.

Nevertheless, several limitations apply to the model. First, the 12 × 12-unit system cannot be considered a universal measure for all historical monuments or contemporary buildings. The dimensions, construction periods, local units of measurement and structural conditions of historical monuments vary. Second, a geometrically consistent façade is not automatically climatically or structurally efficient. Third, cultural identity cannot be measured solely through ornament or geometric form; it is also related to historical context, material, space, urban environment and cultural reception.

International literature increasingly connects parametric façades with solar control, reuse and multi-criteria design [3,4]. Therefore, the geometric algorithm based on the "Perfect Square" should, at the next stage, be linked to solar radiation, daylighting, views, ventilation, material consumption and fabrication feasibility. Until this stage is completed, no quantitative conclusion about environmental performance can be drawn.

For subsequent practical verification, several public buildings in Samarkand or another Uzbek city could be selected, and their façade dimensions and compositional structures documented. Several parametric alternatives could then be generated using the 12 × 12 coordinate model and compared through expert evaluation and, where appropriate, simulation. Such a study would make it possible to empirically test the conceptual method proposed in this paper.

5. Conclusion

This study has developed a conceptual methodological approach for integrating geometric and proportional principles of traditional Uzbek architecture into contemporary parametric façade design. The analysis leads to the following conclusions:

1) Expressing national architectural identity in contemporary façades is better achieved by reinterpreting module, proportion, rhythm, symmetry, the central axis and hierarchy of forms than by directly copying historical decoration.

2) The 12 × 12-unit "Perfect Square" model described by F.U. Jumakulov can be used as an analytical coordination framework for parametric façades. However, it should not be presented as a proven universal module in historical architecture.

3) The model's subdivisions of 1, 2, 3, 4, 6 and 12 units make it possible to relate façade elements at different scales within a single geometric system.

4) The parametric workflow should include documentation of historical sources, geometric abstraction, parameter definition, algorithmic generation of alternatives and multi-criteria evaluation.

5) In evaluating façade alternatives, geometric consistency and compositional coherence should be considered alongside cultural identity, functional and climatic suitability, and constructability.

The limitation of this paper is that the proposed method is currently presented at a conceptual level. No algorithmic prototype for an actual building, digital simulation or quantitative performance test has been conducted. Future research should test the method on specific façade projects, implement the parametric algorithm in a software environment and establish quantitative foundations for the assessment criteria.

Note: Figures 1–4 are schematic illustrations developed by the author on the basis of the theoretical model discussed in this paper. They should not be interpreted as measured drawings of an actual building or as results of completed digital simulations.

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