Evolution of Islamic geometric patterns

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Abstract
This research demonstrates the suitability of applying Islamic geometrical patterns (IGPs) to architectural elements in terms of time scale accuracy and style matching. To this end, a detailed survey is conducted on the decorative patterns of 100 surviving buildings in the Muslim architectural world. The patterns are analyzed and chronologically organized to determine the earliest surviving examples of these adorable ornaments. The origins and radical artistic movements throughout the history of IGPs are identified. With consideration for regional impact, this study depicts the evolution of IGPs, from the early stages to the late 18th century.

1. Introduction
For centuries, Islamic geometrical patterns (IGPs) have been used as decorative elements on walls, ceilings, doors, domes, and minarets. However, the absence of guidelines and codes on the application of these ornaments often leads to inappropriate use in terms of time scale accuracy and architectural style matching.

This study investigates IGPs under historical and regional perspectives to elucidate the issues related to their suitability and appropriate use as decorative elements for buildings. The three questions that guide this work are as follows. (1) When were IGPs introduced to Islamic architecture? (2) When was each type of IGP introduced to Muslim architects and artisans? (3) Where were the patterns developed and by whom? A sketch that demonstrates the evolution of IGPs throughout the history of Islamic architecture is also presented.

2. Method
This research is based on descriptive approaches, for which our goals were to collect data on surviving geometrical patterns and classify them on the basis of time scale and regionalism. Such approaches provide dialectic answers to a wide range of philosophical and architectural questions, such as when or where a particular pattern was extensively used. The literature review presents a selected collection of 100 well-known surviving buildings from West Africa to the Indian subcontinent; the collection historically spans nearly 12 centuries, dating back to the early stages of Islam up to the 18th century. It covers the most important classic
architectural treasures of the Islamic world. For this reason, this study comprehensively referred to not only encyclopedias on architectural history, but also regional/local architectural studies.

3. When and how did geometry penetrate Islamic architecture?

The expansion and development of geometry through Islamic art and architecture can be related to the significant growth of science and technology in the Middle East, Iran, and Central Asia during the 8th and 9th centuries; such progress was prompted by translations of ancient texts from languages such as Greek and Sanskrit (Turner, 1997). By the 10th century, original Muslim contributions to science became significant. The earliest written document on geometry in the Islamic history of science is that authored by Khwarizmi in the early 9th century (Mohamed, 2000). Thus, history of Islamic geometrical ornaments is characterized by a gap of nearly three centuries—from the rise of Islam in the early 7th century to the late 9th century, when the earliest example of geometrical decorations can be traced from the surviving buildings of the Muslim world (Table 1).

4. Types of Islamic geometrical patterns

The definitions and classifications of IGPs are beyond the scope of this article, but a brief description of IGP types is provided.

<table>
<thead>
<tr>
<th>6-point Geometrical pattern</th>
<th>8-point Geometrical pattern</th>
<th>10-point Geometrical pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexagon</td>
<td>Octagon</td>
<td>Decagon</td>
</tr>
<tr>
<td>6-point Star</td>
<td>8-point Star</td>
<td>10-point Star</td>
</tr>
<tr>
<td>8-fold Rosette</td>
<td>10-fold Rosette</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1 First level of IGP classification.
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