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RESEARCH

Bridging Traditional Woodcraft and Algorithmic Design: A Computational Approach to the Kundekari Technique

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Abstract

This article examines the digital reconstruction of kundekari, a traditional woodworking craft characterised by geometric patterning and interlocking wooden elements. The study reinterprets the craft's design and fabrication processes using contemporary tools such as AutoCAD and Rhino–Grasshopper, supported by workshop observations and geometric analyses carried out with practising artisans. Through this combined approach, the research proposes a systematic method for reproducing kundekari in a digital environment. The study reframes an embodied, practice-based tradition—transmitted through intergenerational learning—as a form of local knowledge adaptable to contemporary design workflows. By translating tacit craft knowledge into computational processes, the research highlights how digital tools can help preserve endangered crafts. The developed algorithm generates geometrically accurate digital models and supports the creation of new variations derived from traditional logic.

Keywords Kundekari · Islamic geometric patterns · Detail design · Craft · Design analysis · Design computation

Introduction

Traditional craft techniques passed down through generations can be reinterpreted within contemporary design disciplines to form systematic and adaptable models (Muslimin 2014). This idea also shaped the Bauhaus movement, which integrated craft, design, and art, transforming twentieth-century design education (Marcus

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2008). Today, interest in crafts extends beyond cultural symbolism to the transfer of embodied, practice-based knowledge into modern creative processes.

Within this context, this study examines the digitisation of kundekari, a traditional wooden joinery technique whose name is commonly associated with the idea of interlocking or assembled wooden components. In this technique, small laths and filling pieces are interlocked to form geometric surfaces for architectural elements such as doors, windows, and mosque minbars. The aim is to reinterpret the craft's locally embedded learning practices within contemporary design methodologies and to construct a systematic framework for new generative applications. By analysing the cultural logic and production methods of kundekari and decoding the algorithmic reasoning observed in workshops, the study develops a design algorithm with innovative form features. This approach demonstrates how computational tools can benefit from step-by-step knowledge traditionally transmitted through apprenticeship.

The kundekari craft, documented in Egypt, Aleppo, and Anatolia as early as the twelfth century, occupies a significant place in traditional woodworking (Hattap 2019). The technique relies entirely on interlocking components, without the use of nails or adhesives (Fig. 1), and its construction is governed by geometric composition. Practitioners must therefore possess strong geometric knowledge, as the method serves both as decorative and structural joinery.

Fig. 1 Front and rear views of a door made using the kundekari technique by İsmet Terzi, a Kundekari Artisan

Kundekari works are notably durable: small geometric wooden pieces are fitted together with their grain orientations intentionally varied, limiting surface stresses caused by wood movement in different directions (Bozer 1992).

This study first identified Islamic geometric patterns (IGP) used in kundekari by examining examples in the Pattern in Islamic Art archive (Wade, n.d.), which documents works from Iran, Turkey, and Egypt, as well as collections from the Louvre, the Museum of Islamic Art in Berlin, and the Victoria and Albert Museum. Complementing the archive review, field observations and interviews were conducted with three experienced artisans in active kundekari workshops in Istanbul. During these visits, production stages were documented through direct observation and digital reconstruction of workshop practices. The procedural steps followed by the artisans were then systematised and translated into a digital workflow, summarised in Fig. 2.

A key challenge encountered in this study was the need for occasional user intervention to maintain the workflow of the developed algorithm, highlighting the limits of fully automating a craft rooted in intuitive expertise.

The research aims to establish a reproducible algorithm for generating new pattern configurations by examining IGP and their construction principles in three dimensions. It introduces a digital method that reinterprets the spatial logic of traditional kundekari, an artisanal wood-joining technique, within a contemporary computational design framework. In this context, the study contributes to ongoing discussions on the computational reinterpretation of traditional craft knowledge and the digital documentation of intangible cultural heritage, while aligning with

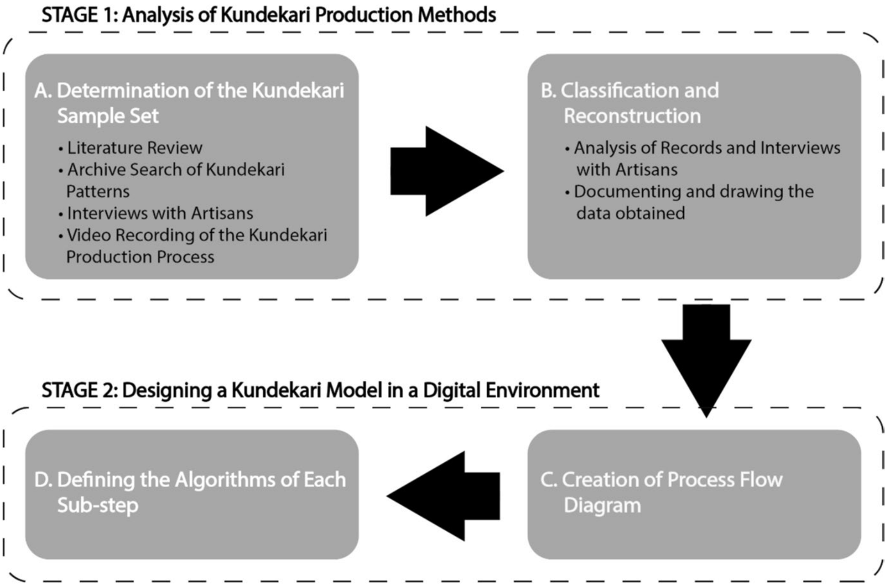

Fig. 2 Work stages followed to create the algorithm for the Kundekari technique

Global Goal 11.4, which emphasises the protection of the world's cultural and natural heritage (Global Goals 2024).

Theoretical Background

IGP—widely appreciated for their aesthetic and symbolic richness—form a core component of traditional Islamic art. Their broad geographical use and application across diverse craft traditions has inspired extensive research on structural analysis, computational reconstruction, and the generation of new designs. Grünbaum and Shephard (1992) established a foundational mathematical framework demonstrating that despite their visual intricacy, most Islamic interlace designs reduce to compositions of only one or two distinct strand shapes. Cenani and Cagdas (2006) formalised the generative logic of geometric Islamic ornaments using shape grammar rules, illustrating their applicability within computational design environments. Cromwell (2010a, 2010b) offered complementary structural insights through his analysis of the Topkapı Scroll, identifying both the constraints imposed by rectangular templates and a modular tile system capable of producing periodic and non-periodic designs. Alani (2018) developed representational codes for hexagonal IGP revealing deep morphological connections between historically and geographically distinct patterns. Korur and Erbaş (2025) proposed a kaleidoscopic imaging method identifying a minimal unit smaller than the conventional fundamental region, simplifying both analysis and digital reproduction. Agirbas and Aydin (2024) extended pattern analysis into machine learning, training a model to automatically detect and classify star polygon types across historical IGP. Ekizler Sönmez (2025) proposed a novel combinatorial system integrating additive pattern logic with polygonal structures, extending the generative design space of IGP beyond historically documented configurations.

Kaplan (2005) expanded Hankin's (1925a; 1925b) polygons-in-contact technique into a systematic computational framework for the algorithmic generation of star-derived IGP. Kaplan and Salesin (2004) complemented this by constructing Islamic star patterns in absolute geometry, freeing pattern generation from dependence on any specific embedding space. Cromwell et al. (2012) demonstrated that a modular system derived from the star-and-cross pattern can yield an extensive range of traditional compositions from a limited tile vocabulary. Lee et al. (2015) established that digital algorithms enable systematic control over the geometric variables of Islamic star designs, and Refalian et al. (2022) extended rule-based generation by applying formal grammar methodology within parametric design contexts. Ma et al. (2024) combined Grasshopper-based parametric modelling with AI image synthesis tools to generate contextually adapted IGP, demonstrating the viability of combining generative AI with traditional geometric principles.

Scholars have also explored methods for representing these two-dimensional patterns in three dimensions. Sayed et al. (2016) applied shape grammar to introduce a third dimension into Islamic geometric designs, while Bonner (2016) and Kasraei et al. (2016) examined how patterns can be mapped onto curved surfaces such as domes. Agirbas (2020) developed a three-dimensional parametric generator to reproduce stone-carved patterns digitally, and Agirbas and Basogul (2021) extended this into reciprocal structures. More recently, Alani and Alaçam (2023) explored non-planar surface applications, and Nazarzadeh Ansaroudi et al. (2026) investigated the geometric feasibility of kinetic IGP configurations.

Despite the extensive scholarship on IGP, research focusing specifically on kundekari—the wooden interlocking technique that incorporates these patterns—remains limited. Soysal (2007) documented the contributions and works of master artisan Mevlüt Çiller through interviews. Kürklü (2011) explored the production of kundekari using modern technologies. Söğütlü and Sönmez (2008) analysed the dimensional changes of kundekari components over time, demonstrating the superior durability of architectural elements made with this technique. Similarly, Yüksel et al. (2016) compared kundekari panels with those produced using alternative methods and reported greater longevity in kundekari-made furniture. Complementing these structural analyses, Kucukkaya (2003) further addressed conservation approaches specific to kundekari panel elements, noting the high level of geometric precision required in restoration work. Kılıç (2021) systematically documented kundekari construction processes using process-modelling techniques. Doğruer (2022) examined the architectural history and conservation of a kundekari minbar in the Taşkın Pasha Mosque, demonstrating how the technique's interlocking logic minimises internal stress and prevents deformation caused by wood movement. Özsait-Kocabaş (2024) situated kundekari within the broader context of Turkish wooden decorative arts, emphasising the accelerating risk of the technique's extinction due to the diminishing number of competent masters and the breakdown of intergenerational transmission.

However, the literature review conducted for this study indicates an apparent absence of research on translating kundekari into contemporary design thinking through digital or computational methods. In this respect, the present study seeks to address an apparent gap within the field of computational design by offering a computational reinterpretation of kundekari.

Methodology

This study followed a two-stage research process (Fig. 2). The first stage of the research involved the systematic examination of kundekari design and production methods based on data collection and analysis. The findings obtained from this stage were evaluated in the second stage, which focused on the digital modelling of the kundekari technique.

During the data collection phase, three kundekari artisans and their workshops in Istanbul were selected based on criteria such as generational continuity, educational background, and modes of transmitting craft knowledge. During the visits, all artisans noted that they had learned the craft in childhood through the traditional master–apprentice system, while also emphasising that apprenticeship training has vastly diminished today. The profiles of the selected artisans are summarised below. Written informed consent for the use of full names, biographical details, and workshop information was obtained from all three artisan participants prior to data collection.

Sample 1: Enis Türk Workshop

Born in Istanbul in 1969, Enis Türk graduated from the Vocational High School of Furniture and Interior Design. He began learning kundekari at the age of five or six through the traditional apprentice model. His primary expertise lies in mother-of-pearl inlay, though he has contributed to numerous kundekari restoration projects over nearly three decades. His workshop operates in Kağıthane, Istanbul.

Sample 2: Hasan Ercan Workshop

Hasan Ercan was born in Sinop in 1960 and learned the craft from his grandfather. With roughly forty years of experience, he has participated in notable restoration projects, including the 2001 restoration of the Al-Aqsa Mosque's minbar. His workshop is located in Beykoz, Istanbul.

Sample 3: İsmet Terzi Workshop

Born in Samsun in 1958, İsmet Terzi graduated from Istanbul Technical University, Electrical Engineering Department, but chose to continue his father's woodworking profession. He has practised kundekari for about twenty years, incorporating contemporary methods including AutoCAD and three-axis CNC machines. His workshop is in Bahçeşehir, Istanbul.

Across the three workshops, the fundamental construction logic, joint typologies, and component dimensions were largely consistent. The most notable distinction was observed in the İsmet Terzi workshop, where contemporary tools have been integrated into the traditional workflow: patterns are drawn in AutoCAD rather than by hand, and components are cut using three-axis CNC machines rather than hand tools — with profiles shaped externally at specialist workshops in the case of the other two artisans. A further difference concerns tolerance gaps: while Enis Türk and Hasan Ercan follow the conventional practice of leaving small gaps between components to accommodate wood movement, İsmet Terzi reported not applying tolerance gaps in his work. Despite these variations, the three workshops share the same underlying craft logic, and no significant differences were observed in terms of pattern construction principles or the geometric properties of individual components.

The production and design processes in the designated workshops were monitored with the artisans, and all stages were recorded with explanations from them. Recorded interviews and workshop observations were analysed using computer-aided drawings and descriptive annotations. Analytical drawings of the design stages were created with AutoCAD, chosen for its vector-based drawing capabilities.

Rhinoceros and the Grasshopper add-on, a visual coding interface for this programme, were used to model and recreate kundekari fabrication in a digital environment. However, design interventions that required human decision-making in certain stages of the modelling process were carried out using AutoCAD.

The study employed geometric elements in scripting the kundekari model to ensure clarity and ease of implementation. Grasshopper scripts were developed through direct observation of design and production processes in kundekari workshops.

Analysis of Kundekari Production Methods

To learn kundekari production methods, it is first necessary to recognise the parts used in this craft:

In this joinery-based technique, the inner filling pieces and the structural laths—with bevelled edges and profiled upper surfaces—are interlocked without nails or adhesives. The laths, typically 25–40 mm thick and 20–35 mm wide, vary in length and end geometry depending on the chosen pattern. Although each lath appears to be a single piece, its cross-section reveals a layered structure created by channels carved at different levels along its sides (Fig. 3). The inner filling pieces fit into these channels, occupying the geometric fields defined by the laths. A mortise-and-tenon profile (an interlocking joint in which a projecting tenon fits into a corresponding recessed cavity) on the underside enables the laths to connect to one another (Fig. 4) (Sönmez and Söğütlü 2006). Two types of joints are used: a corner joint, formed by

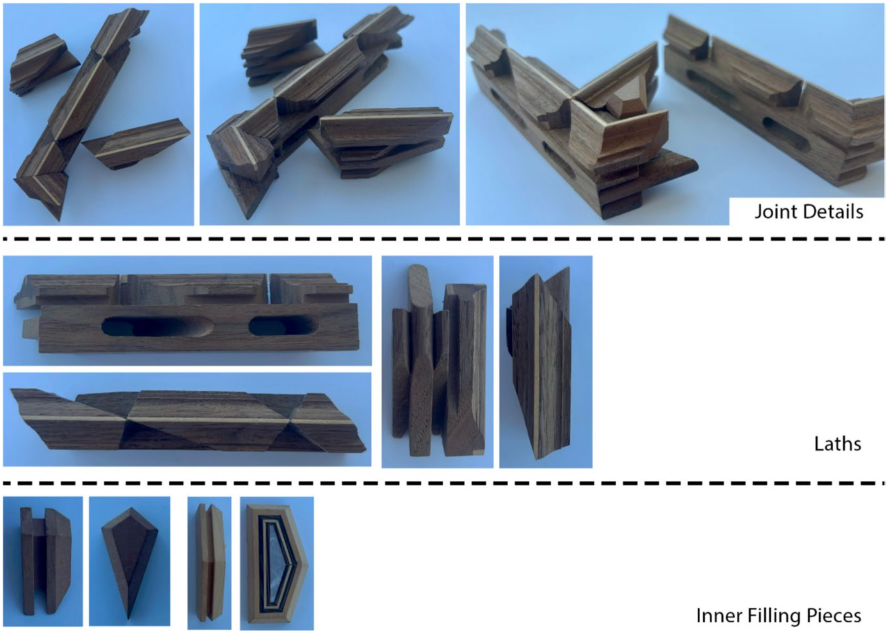

Fig. 3 Examples of different lath and inner filling pieces produced by İsmet Terzi, along with their joint configurations

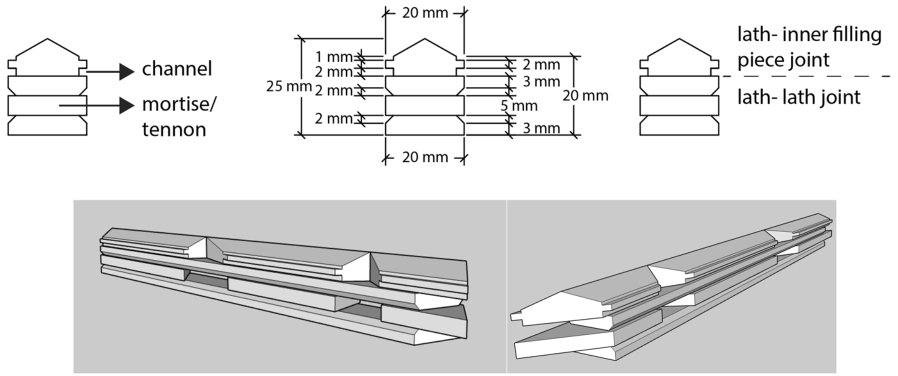

Fig. 4 Lath cross-section, dimensions, joint details, and 3D view of mortise–tenon connection

interlocking the ends of two laths (Fig. 5), and an internal joint, where the end of one lath passes into the body of another (Fig. 6).

The inner filling pieces are wooden elements of various geometric shapes, typically 10–12 mm thick, with edge channels measuring 3–4 mm in depth and 5–6 mm in width. These pieces, which form the geometric surfaces between the joined laths, are slid into the lath channels (Fig. 7). Importantly, they are not fitted tightly; small tolerance gaps must be left to accommodate wood movement. This prevents deformation and protects the joint details from stress caused by swelling or shrinking due to changes in moisture (Sönmez and Söğütlü 2006).

The outer locking frame is the system that surrounds all elements of the kundekari system. The laths of the outer locking frame are wider than the structural laths that form the pattern. The kundekari technique varies across different geographical areas while maintaining its general principles and rules.

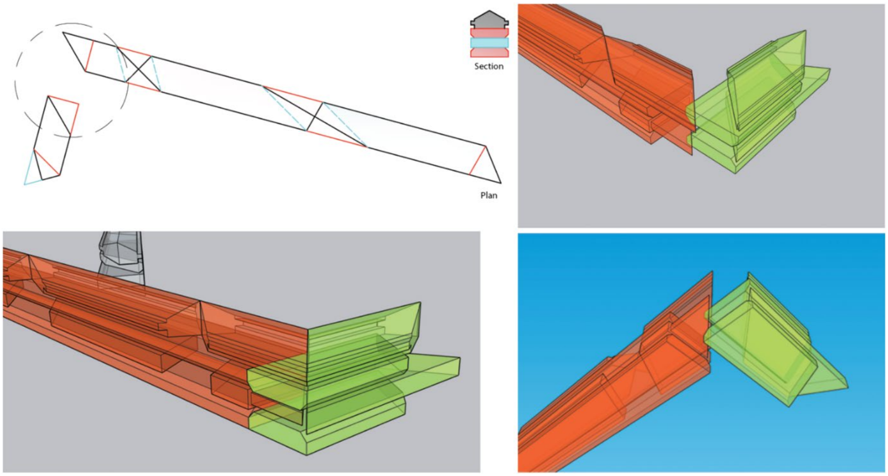

Fig. 5 Example of lath corner joint detail

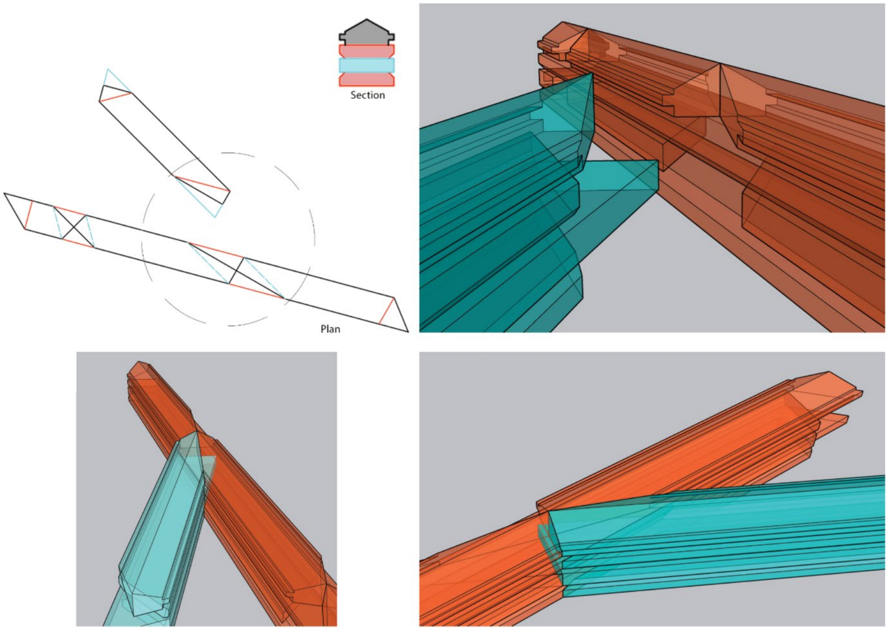

Fig. 6 Example of lath internal joint detail

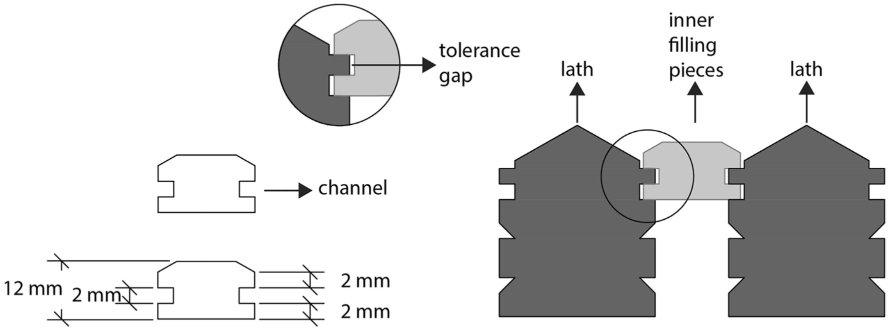

Fig. 7 Inner filling piece cross-section, dimensions, and lath- inner filling piece joint details

Archive Search and Analysis of Kundekari Patterns

To analyse the patterns used in kundekari, examples were examined through the Patterns in Islamic Art archive (Wade, n.d.). This review showed that kundekari compositions are predominantly generated from multi-pointed star geometries that expand outward through successive additions, while the remaining gaps are completed by the artisan with secondary polygons (Fig. 8). The resulting compositions are invariably symmetrical, reflecting the geometric logic inherent to the star-based construction method.

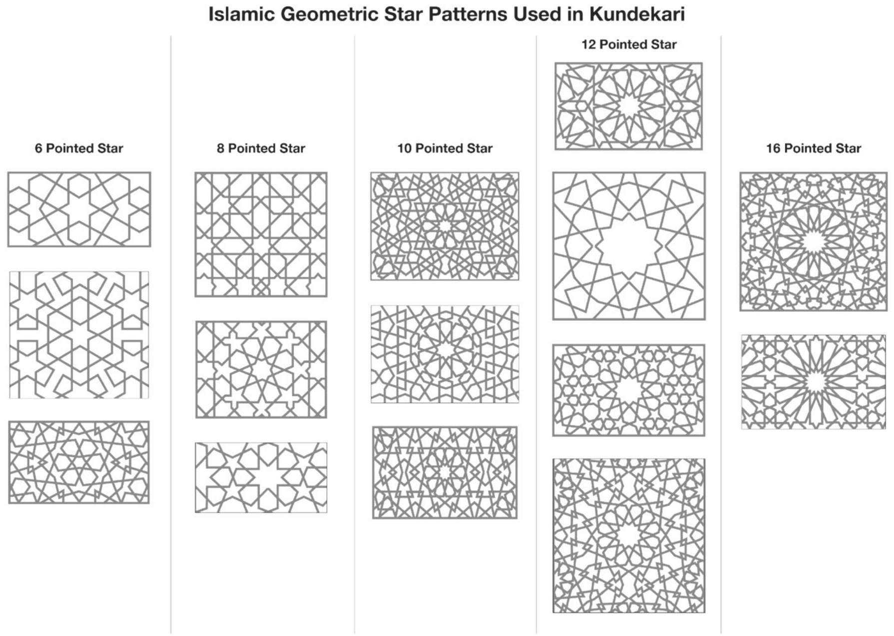

Fig. 8 Classification of kundekari patterns according to the number of star arms, compiled and redrawn by the author based on examples documented in the Pattern in Islamic Art archive. Image: authors based on Wade 2024

Analysis of Workshop Visits and Artisan Interviews

As a result of the workshop visits and interviews, a common analysis was obtained, and consequently, the kundekari production process was divided into two main categories: design and fabrication.

1. Design stage.

The design phase begins with artisans drawing the pattern at a 1:1 scale on paper or plywood. Using the traditional ruler-and-compass method, the layout is constructed in relation to the size and function of the surface. The process starts by locating the centre point, from which circles are drawn at measured intervals to define the structure of the pattern. Auxiliary rays are then projected from the centre at angles determined by the star geometry — 30° for six points, 18° for ten points, and 15° for twelve points. The outermost lines of the pattern are then extended until they intersect with one another, generating additional points that define the geometry of the intermediate stage. By connecting these intersection points, the full pattern emerges, and the rays are extended to meet the outer locking frame. Figure 9a shows this procedure through a ten-pointed star composition, chosen because artisans describe it as both highly common and comparatively straightforward to generate.

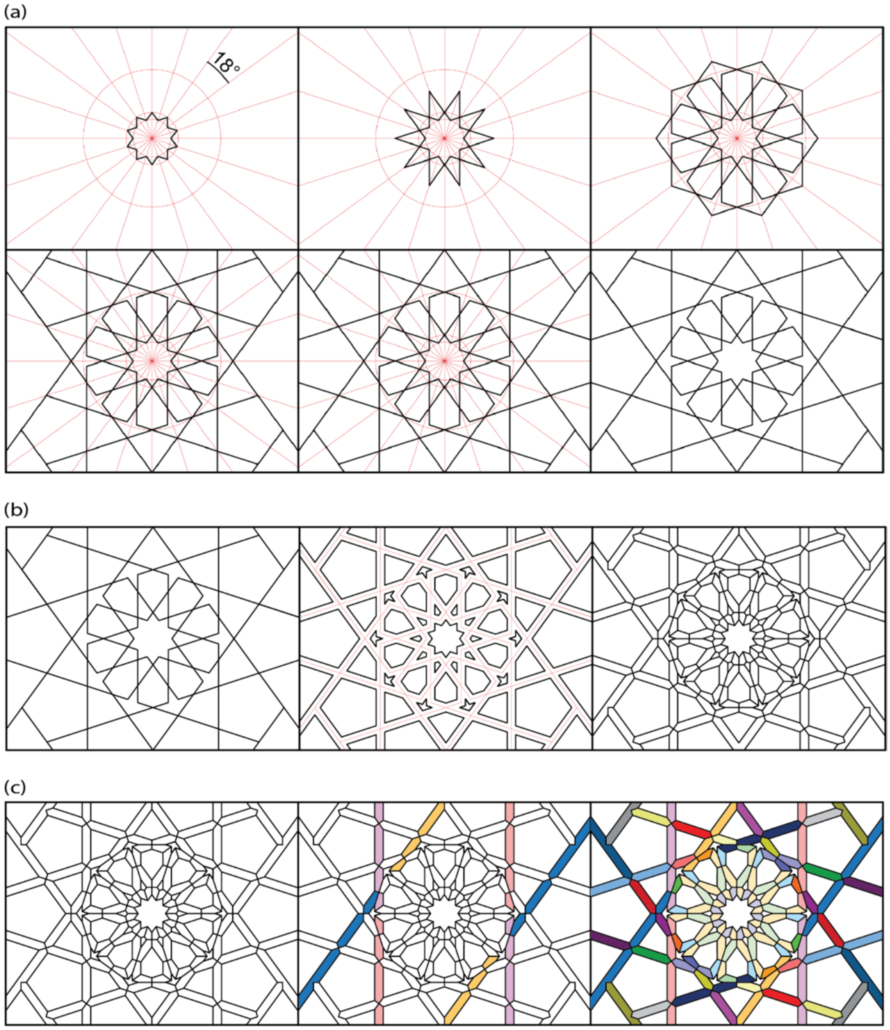

Fig. 9 Design stages of the kundekari pattern: **a** construction of the ten-pointed star pattern, **b** definition of lath axes and thickness, and **c** separation and colour-coding of lath pieces

The second stage of the design phase involves defining the laths. The lines of the geometric pattern are taken as symmetry axes, and the lath thickness—typically around 20 mm—is drawn accordingly. Bisector lines are added to identify the joint points (Fig. 9b).

Next, the long laths that extend to the boundary frame and form the structural backbone are identified, colour-coded. Once these primary laths are established, the remaining pieces are marked in the same way. Even within a symmetrical pattern, variations in lath size may emerge during this process; identical pieces are therefore assigned matching colours and, in practice, numerical identifiers (Fig. 9c). As the scale of the figure renders numerical labels illegible, colour-coding alone is used for visual identification in the illustration.

The following step is to define the joint details of the laths. Beginning from the overall pattern layout shown in Fig. 9c, the process moves to the level of individual lath pieces: the corners of each piece are cut at angles determined by their specific connection points within the pattern. This cutting detail — shown in both plan and 3D in Fig. 10 — is a defining characteristic of kundekari, as it enables the precise interlocking of laths without the use of nails or adhesives. The bisector lines at each intersection determine the cut angle for the adjoining pieces. In practice, angles smaller than 8° are avoided due to fabrication constraints, as such acute angles would compromise the structural integrity of the joint.

The design phase then turns to the inner filling pieces, which occupy the voids created at the intersections of the laths. Each filling piece is shaped to slide into the channels cut along the laths, and a small tolerance is intentionally left to allow for natural expansion and contraction of the wood (Fig. 11).

2. Fabrication stage.

All geometric components are numbered according to their positions within the pattern, and these identifiers are written on the reverse side of each piece. In the fabrication phase, the wooden slats are cut to size and left to dry in the workshop. After drying, the female joints (recessed cavities drilled to receive the tenon) are drilled, and the mortise–tenon connections are shaped according to the required angles and refined with a saw to match the pattern.

Next, the laths are assembled, and the grooves for the inner filling pieces are cut. The assembly is then dismantled so that surface treatments—such as varnishing and

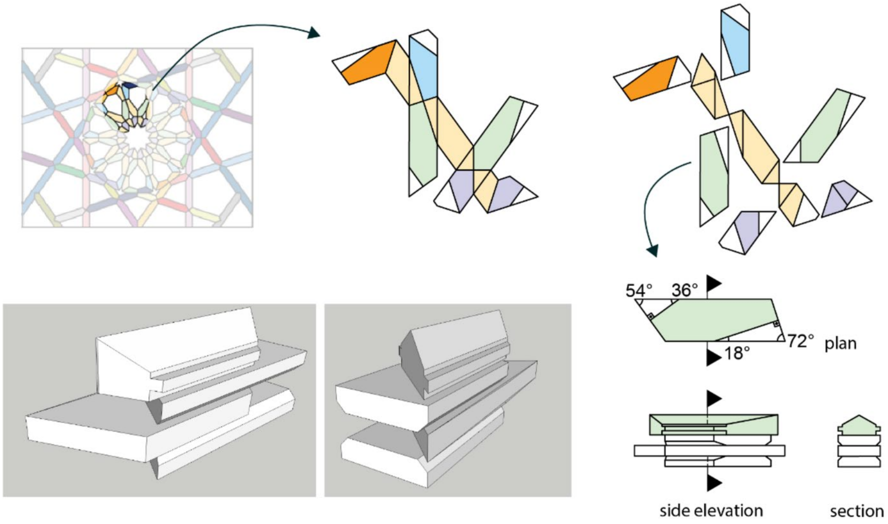

Fig. 10 Stages of lath joint detail design, shown in technical drawings and 3D view

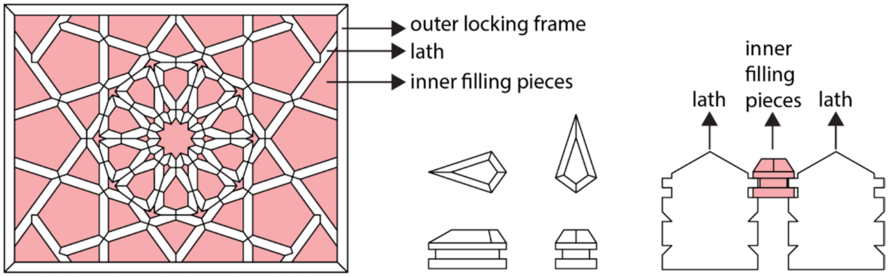

Fig. 11 Example of the inner filling piece detail design stage

carving—can be applied. After these treatments, the components are reassembled together with the inner filling pieces, beginning from the centre of the composition and moving outward. Finally, the outer locking frame is added, and sanding completes the production process.

Designing a Kundekari Model in a Digital Environment

This study translated the design and fabrication logic of kundekari—built around star-based geometric systems—into an algorithmic framework. A flow diagram outlining the main stages was first developed, and each sub-step was subsequently defined. The final workflow consists of seven stages: (1) formation of the unit module, (2) pattern generation, (3) boundary definition, (4) 3D model construction, (5) definition of lath elements, (6) definition of lath joint details, and (7) formation of inner filling pieces.

User input is required in the third and fifth stages (Fig. 12). All stages were implemented in Rhino–Grasshopper, where the script was deliberately structured through clear and straightforward geometric rules. This approach enabled the creation of compact, manageable definitions that efficiently produce the intended results.

1. Formation of the Unit Module

The unit modules in the examined kundekari examples generally consist of 6-, 8-, 10-, and 12-pointed stars. The process of recreating the unit module in a digital

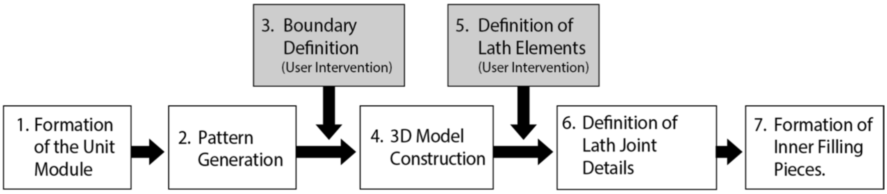

Fig. 12 Process flow diagram for creating a Kundekari model in a digital environment

environment using Rhino and Grasshopper, along with its visual outputs, is shown in Fig. 13a.

This reconstruction is conceptually based on Kaplan (2000), who formulated the formation of unit elements derived from the star with a diagram, building on Lee (1987)'s research into simplifying and analysing IGP. Beginning with a simple

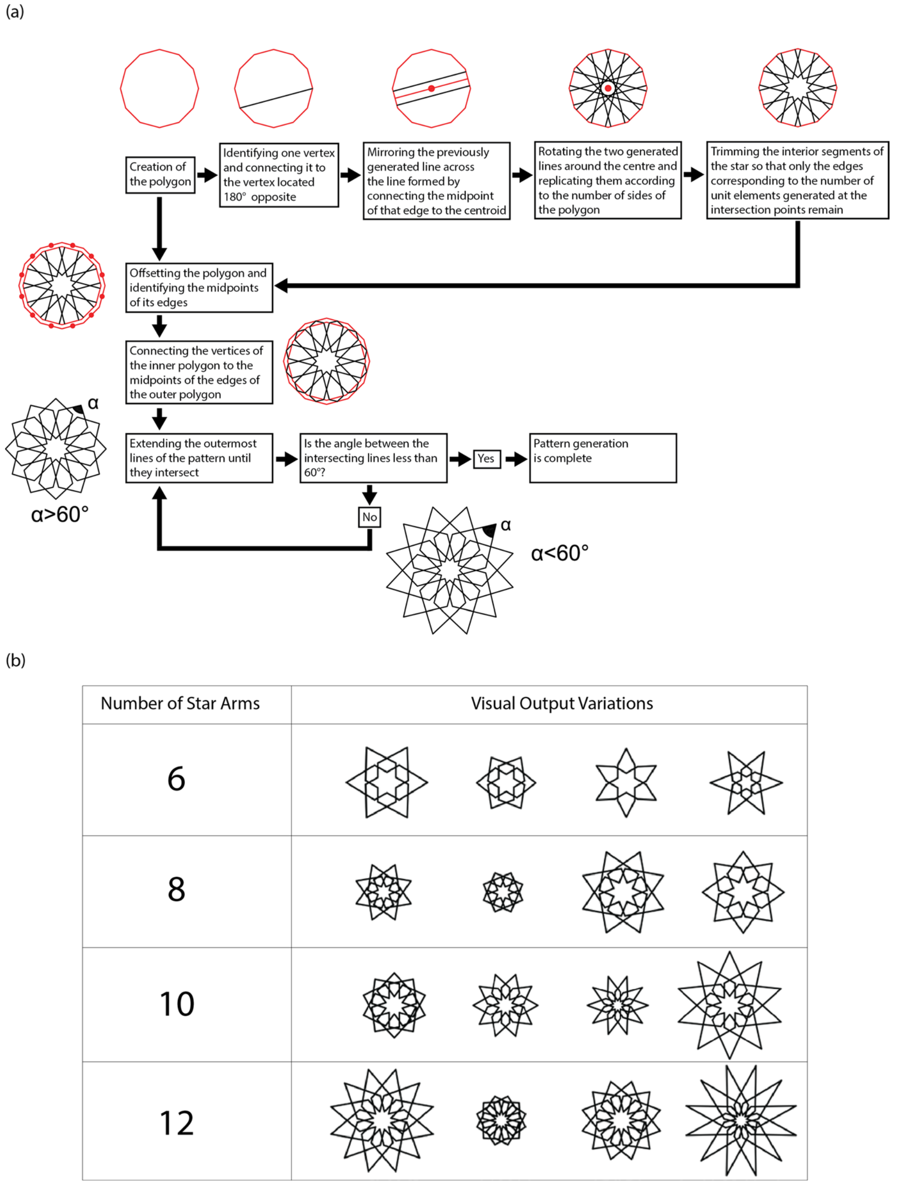

Fig. 13 Formation of the unit module in Grasshopper: **a** computational workflow and visual outputs, **b** variations generated for 6-, 8-, 10-, and 12-pointed stars

polygonal base, one end of this polygon is connected to the opposite end and shifted relative to the centre point. This process is repeated as many times as there are sides to the polygon, and then the pieces remaining inside the star are removed. The polygon created at the beginning is then shifted outward, and the midpoints of its sides are connected to the corners of the remaining polygon. In the final step, the created lines are extended until they intersect, and this process continues until the angle between intersecting lines is less than 60°. Figure 13b shows variations obtained by assigning different values to the variables.

2. Pattern Generation.

This study examines patterns formed by the repetition of unit modules that multiply from a single type of star. To analyse the patterns, the polygons-in-contact technique developed by Kaplan (2005), based on Hankin's (1925a; 1925b) work, was used. As the number of arms of the star changes, the unit module changes, and therefore the method of bringing each unit module together also changes, resulting in different patterns in each case. In this study, a pattern was created using a 12-armed star as an example, following the general design stages described in Fig. 14a.

At this stage, polygons that divide the outermost lines of the unit module into two equal parts are identified, and the pattern is created by placing these polygons side by side. The different results obtained are shown in Fig. 14b.

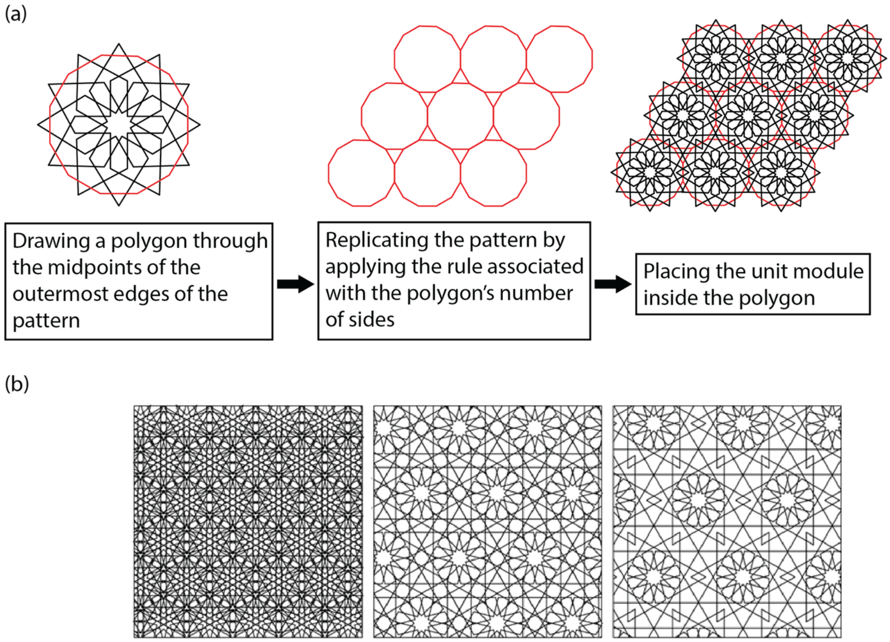

Fig. 14 Pattern generation process: **a** computational workflow and **b** resulting pattern variations

3. Boundary Definition.

In the third step, which defines the creation of the kundekari model in a digital environment, the user defines the boundaries of the infinite pattern obtained. Depending on the user's selection, a specific part is transferred to the CAD environment (Fig. 15). Once this process is complete, it is reintroduced to the Grasshopper environment in the next step.

4. 3D Model Construction.

In this step, the pattern, which has been a single line up to this point, is converted into volumes. Since the pattern is symmetrical, all computational operations were performed on one quarter of the composition, reducing processing steps and allowing the lath logic to be defined more clearly before being extended to the full design.

At this stage, the pattern lines were categorised into two groups according to their geometric behaviour: open-ended and closed-ended lines. For each group, the lath profile was swept along the selected curves, and the lines were offset on both sides to derive bisector directions. These bisectors were used to define cutting planes, which were then applied to generate the final lath geometry. Closed-ended lines required an additional step to resolve termination conditions at connection points, reflecting the different topology of these curves.

In the final assembly, the lath geometries from both groups were merged, cleaned, and sorted. The complete quarter-pattern assembly was then mirrored across both

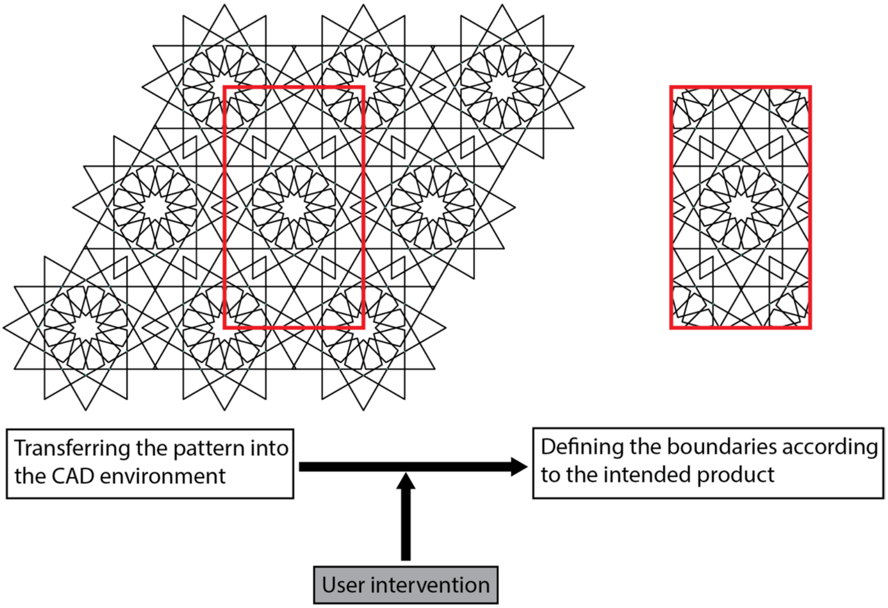

Fig. 15 Process followed for determining the plan and visual outputs

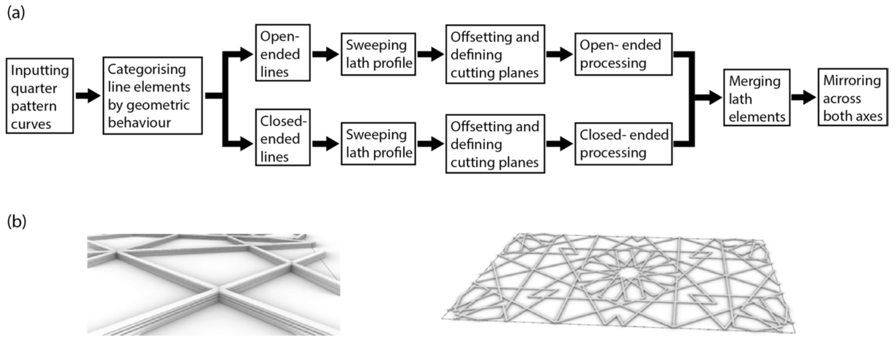

Fig. 16 Construction of three-dimensional lath elements: **a** computational workflow and, **b** resulting composition

axes to produce the full symmetrical composition of lath elements. The process followed at this stage is shown in Fig. 16a, and the results are shown in Fig. 16b.

5. Definition of Lath Elements.

To determine the lath sections, different colours and numbers are assigned to the sections on the pattern by following the flow chart in Fig. 17a. One of the intersecting laths continues in the same colour, while the other takes on two different colours from the intersection point onwards. This process continues from the centre to the end of the frame (Fig. 17b). The process may yield different results depending on the selection of the starting point.

6. Definition of Lath Joint Details.

In determining the joint details of the lath pieces, a height value is assigned to each layer of the lath with a layered cross-section on the plan. Unlike the traditional method — in which the lath is produced as a single piece of timber with indentations and protrusions carved directly into it — the digital model represents the same geometry by decomposing the lath cross-section into four discrete layer blocks. This decomposition was necessitated by the requirements of parametric modelling, enabling the complex joint profile to be defined computationally. The four layers are subsequently combined to form a unified lath block that accurately replicates the traditional cross-sectional geometry.

It is important to note that this stage differs in nature from the preceding parametric steps. Rather than generating design options through variable input, this stage translates the decisions already established in the previous phases into three-dimensional fabrication detail. The joint geometry at this point is a determinate outcome of the pattern logic defined earlier — not a site of parametric variation but a necessary consequence of it. In this sense, the stage functions as a detail resolution phase within a parametric workflow: the system moves from generative design

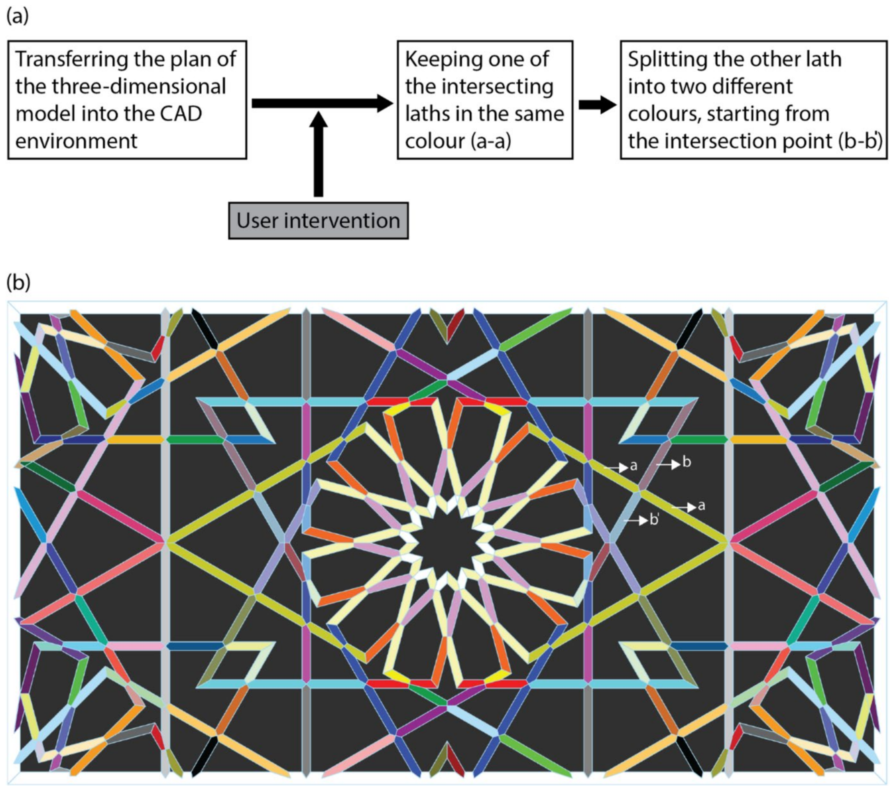

Fig. 17 Definition of lath elements: **a** workflow for determining lath pieces and colour-coded continuity rules, and **b** resulting lath piece classification

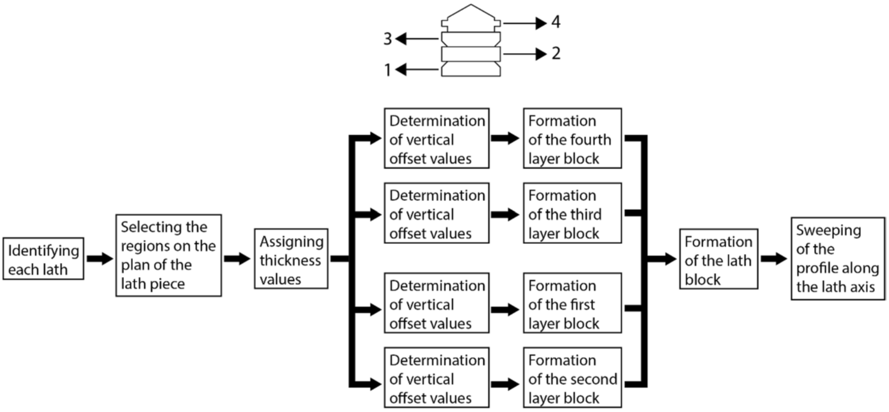

Fig. 18 Section view illustrating the four-layer decomposition used to digitally represent the lath cross-section and joint profile (above), and the corresponding workflow (below)

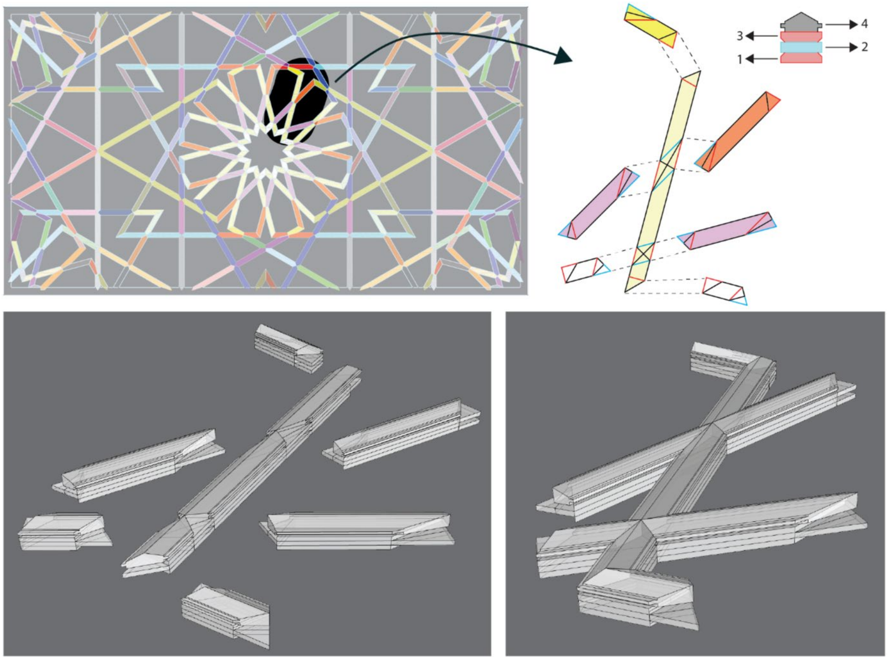

Fig. 19 Results of the Definition of Lath Joint Details stage: pattern plan view (top left), individual lath components with layer numbering (top right), and 3D views showing the integrated joint assembly of multiple laths forming a complete unit module (bottom)

space into the fixed constraints of constructional logic, producing the precise cross-sectional profiles required for physical fabrication.

The process followed at this stage is shown in Fig. 18, and the results shown in Fig. 19 were obtained.

7. Formation of Inner Filling Pieces.

In the final step, the geometric areas between the lath blocks are identified and converted into volumetric inner filling pieces. Following the same computational logic as the 3D Model Construction stage, the boundary curves of each filling area are offset and exploded to extract endpoint data. Bisector directions are derived and defined as cutting planes, which are then used to generate and trim the filling piece geometry. The process followed at this stage is shown in Fig. 20a, and the results are shown in Fig. 20b.

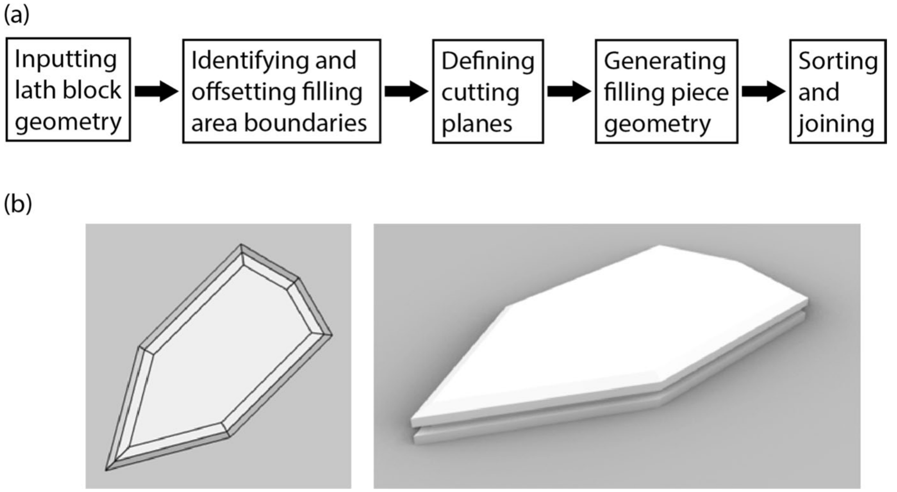

Fig. 20 Formation of inner filling pieces: **a** computational workflow, and **b** resulting volumetric inner filling pieces

Discussion

The computational reconstruction of kundekari presented in this study reveals both the potential and the inherent limits of translating embodied craft knowledge into algorithmic frameworks. A comparison of traditional and digital workflows exposes several fundamental differences that merit discussion.

In traditional kundekari practice, the design process begins with full-scale drawing directly onto paper or plywood using ruler and compass — a method that encodes geometric knowledge through physical action rather than explicit instruction. The artisan's decision-making at each stage is inseparable from material experience: the feel of wood grain, the resistance of a joint, the visual judgment of proportional balance. This tacit dimension, accumulated through years of master–apprentice transmission, cannot be fully captured in parametric logic. As observed across all three workshops, even experienced artisans occasionally deviate from geometric rules in response to material behaviour — a form of situated knowledge that resists formalisation.

The digital workflow mirrors the sequential logic of traditional production while restructuring it into seven discrete, reproducible stages. The Grasshopper-based algorithm automates geometric operations through parametric rules derived from direct observation, maintaining accuracy across pattern variations and substantially lowering the threshold of craft expertise required.

However, the two workflows diverge most sharply at points requiring compositional judgment. In traditional practice, the selection of primary laths — those that extend to the boundary frame and define the structural backbone — emerges intuitively from the artisan's reading of the pattern as a whole. In the digital environment, this step requires explicit user intervention, as the algorithm cannot autonomously determine which intersecting lath continues and which splits. Similarly, boundary definition depends on the intended application context, a decision that remains outside the scope of parametric logic. These two intervention points are not incidental limitations but structural features: they mark precisely where craft intuition exceeds what rule-based computation can replicate.

This distinction aligns with broader discussions in computational design research on the nature of tacit knowledge in craft traditions. The algorithm developed here does not replace the artisan's judgment — it redistributes it, concentrating human decision-making at critical junctures while automating geometrically deterministic operations. In this sense, the proposed framework functions less as a substitute for craft expertise and more as a scaffold that makes the underlying geometric logic of kundekari accessible to users without traditional training.

The 3D-printed prototype (Fig. 21) validated the geometric accuracy of the digital model and confirmed the method's potential for rapid fabrication. Nevertheless, the prototypes also exposed a material gap: the structural behaviour of 3D-printed PVC components differs substantially from that of timber, particularly regarding the tolerance gaps required to accommodate wood movement. Future applications of this method in actual timber production would require recalibration of joint tolerances and cross-sectional dimensions to account for material-specific properties — a process that would necessarily reintroduce craft knowledge at the fabrication stage.

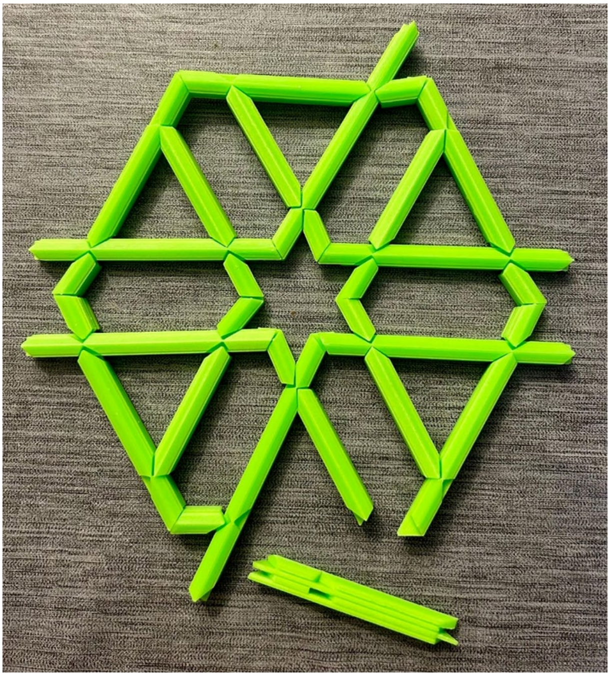

Fig. 21 Kundekari prototype printed with a 3D printer

These findings suggest that the proposed workflow can function not only as a documentation tool for kundekari, but also as a framework for exploring how traditional craft knowledge may be reinterpreted in computational design and education. It contributes to the digital preservation of intangible cultural heritage by translating craft-based, ethnically rooted knowledge into reusable algorithmic data. The proposed approach also holds potential for integrating traditional modes of thinking into contemporary design education. Future research may extend this framework in four directions: developing modules for different star geometries; testing the algorithm on curved or amorphous surfaces; integrating AI-supported variation generation with fabrication workflows; and examining material-specific adaptations, including recyclable or eco-friendly alternatives to solid wood.

Conclusion

This study examined the kundekari technique by analysing its traditional design and fabrication logic and translating this knowledge into a computational workflow within the Rhino–Grasshopper environment. The research identified the geometric rules, lath configurations, joint principles, and inner filling piece logic that structure kundekari production, and reformulated these as a seven-stage digital modelling process.

The findings show that kundekari can be represented as a rule-based yet partly user-directed computational system. While deterministic geometric operations can be translated into parametric procedures, certain decisions—such as the selection of primary laths and boundary conditions—still require human judgment. This confirms that the proposed model does not replace craft expertise, but makes selected aspects of tacit craft knowledge explicit, transferable, and reusable.

The developed workflow contributes to the digital documentation and reinterpretation of kundekari by linking traditional interlocking wooden joinery with algorithmic design methods.

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Data availability The interview records and workshop observation notes supporting the findings of this study are kept in the authors' archive and are available from the corresponding author upon reasonable request, subject to participant consent and ethical considerations. The supplementary computational material related to the Grasshopper workflow is openly available via Figshare at: https://doi.org/10.6084/m9.figshare.32101591.

Code availability The Grasshopper scripts developed for this study are openly available via Figshare at: https://doi.org/10.6084/m9.figshare.32101591.

Declarations

Conflicts of interest Not applicable.

Ethical approval This study involved interviews and workshop observations with three artisans. The research was conducted in accordance with the principles of voluntary participation, informed consent, and the responsible use of personal and professional information. No experimental intervention was conducted, and no biomedical or sensitive personal data were collected.

Consent to participate The artisans who contributed to this study participated voluntarily. Written informed consent was obtained from all participants prior to the interviews and workshop observations.

Consent for publication Written consent was obtained from all participating artisans for the inclusion and publication of their names, workshop information, biographical details, professional background, and craft-related knowledge shared during interviews and workshop observations.

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