Symsdraw: A Desktop Application for Digital Design with Radial Symmetry to Enhance Geometric Precision and Visual Aesthetics

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Abstract. This research introduced Symsdraw, a lightweight desktop application for creating radial symmetry-based patterns. The system supported geometric primitives, pens, closed area colouring, and rotational replication up to high orders through transformations. The interface placed all controls on the top ribbon (colour, thickness, number of sectors, and canvas dimensions) so that the workflow was straightforward: draw one example on the reference sector, review the replication preview, then colour and export. Results showed that the combination of core parameters is sufficient to generate consistent layered motifs, with anti-aliasing maintaining readability at high sector counts. In addition to generating digital patterns, Symsdraw line templates are effective as a medium for colour play, and colour variations can be evaluated in a focused manner.

Keywords: radial symmetry, geometric design, desktop graphics applications, rotational replication, user interface, colouring.

1 Introduction

Radial symmetry-based design, characterized by regular repetition around a single center, is applied to various forms, including rosettes and medallions for visual identity, architectural ornaments, rotational icons in interfaces, and concentric sector diagrams for data communication. Within the framework of empirical aesthetics, this kind of regularity is related to what is called processing fluency, i.e., the easier a pattern is to process, the greater the chance it will be appreciated positively [1], [2]. Neurocognitive evidence reinforces this relationship. Electroencephalography/event-related potentials (EEG/ERP) studies have identified Sustained Posterior Negativity (SPN) as a characteristic marker when the visual system responds to symmetry [3], [4]; functional MRI (fMRI) studies show that extra striate areas are sensitive to the order of rotation in repetitive patterns, with responses increasing parametrically as the level of regularity increases [5], [6], [7]. Therefore, maintaining geometric precision in radial patterns aligns with the organizational principles of the human visual system.

In computing, research on star and rosette patterns demonstrates that parameterization, including the number of sectors, the angle between sectors, and the ring radius, enables shape modification while preserving overall coherence. The absolute geometry framework and the polygons-in-contact approach [8], [9] establish that radial motifs can be systematically constructed, reapplied, and extended to multiple complexity levels. This parametric methodology underpins the development of drawing tools designed to ensure both regularity and adaptability.

Research in Human–Computer Interaction (HCI) and Computer-Aided Design (CAD) demonstrates that constraint-based drawing, which applies explicit geometric constraints such as equal angles, equal radii, and parallel or perpendicular relations combined with snapping, improves shape consistency without increasing user workload [10], [11], [12]. Interactive beautification techniques refine freehand sketches into geometrically valid constructions. Design intent recognition preserves stability during sketch re-parameterization. In educational contexts, dynamic geometry software (DGS) tools enhance geometry comprehension and visual representation skills by providing immediate feedback and enabling hands-on manipulation [13].

Based on these three foundations—empirical aesthetics and neuroscience of perception, algorithmic construction of radial patterns, and constraint-based HCI/CAD—Symsdraw is designed as a lightweight desktop application for Windows and macOS. Rather than functioning as a comprehensive CAD package, Symsdraw emphasizes accessibility. It is straightforward to install and operates efficiently on mid-range devices. Symsdraw provides a streamlined set of features suitable for studios, classrooms, and creative practices. Core functionalities include geometric primitives such as triangles, circles, quadrilaterals, and lines. All primitives can be filled with color. The application also offers a freehand pen for sketching and a fill tool to expedite coloring. The primary distinguishing feature is the capacity for radial symmetry with up to 1000 rotations. This enables the exploration of high rotation orders pertinent to the visual system's sensitivity to regularity. This design eliminates the steep learning curve associated with traditional CAD software. As a result, Symsdraw facilitates the creation of structured motifs for decorative design, identity asset development, educational materials, and pattern experiments that require precise replication within limited timeframes. The high rotation order capability aligns with findings from studies on wallpaper symmetries regarding visual regularity [6], [7].

Compared to 'paint-like' editors that generally prioritize freehand strokes and manual repetition, Symsdraw offers programmed radial reproduction with an explicit number of sectors. In generic raster editors, attempts to mimic symmetry through manual duplication/rotation are prone to accumulating errors, especially at high rotation orders, and make it difficult to re-audit when revisions are needed. HCI/CAD literature indicates that when constraints and snapping are available, users can maintain symmetry, similarity, and proportion without excessive procedural burden [10], [11], [12]. Symsdraw's position is in the middle: the interface remains simple and familiar, but its radial structure is supported by established construction principles, so that the geometric quality of the pattern, including up to a thousand sectors, is better maintained.

Symsdraw incorporates fillable geometric primitives, a freehand pen, and large-scale radial symmetry to achieve robustness, broad usability, and alignment with common drawing practices. These features position Symsdraw as an intermediary between intuitive freehand

drawing and the precision required by both the human visual system and established geometric design standards.

2 Method

This study employed an iterative software development methodology to produce lightweight desktop applications designed for straightforward installation, operational stability on mid-range devices, and functionality sufficient for constructing radial patterns. Testing procedures were implemented on Windows and macOS platforms using reference hardware configurations of 8 to 16 GB RAM and integrated or mid-range graphics processing units. Input devices included a mouse or trackpad. All environmental parameters were systematically documented to ensure replicability of graphical behavior.

2.1 Geometric Models and Representations

Supported vector entities are lines (segments (p_1, p_2)), triangles and quadrilaterals (sequential polygons $(v_1, \ldots, v_m)$), and circles (centre c, radius r). Basic transformations, namely translation, uniform scaling, and rotation, are applied to the vector data and then rasterised on the canvas. Area fill uses the even–odd / winding number rule to determine the interior of a closed region. The implementation follows the point-in-polygon strategy, which is capable of solving boundary cases [14] and computational analysis [15]. The winding number $w(p, \gamma)$ for point p relative to closed path γ is defined (discretely) as the sum of the directed angles between neighbouring point pairs (v_i, v_{i+1}) on the path:

$$w(p, \gamma) = \frac{1}{2\pi} \sum_{i=1}^{m} \text{atan2}(\det(u_i, u_{i+1}) u_i . u_{i+1}), \quad u_i = v_i - p, \tag{1}$$

with $\det(a, b) = a_x b_y - a_y b_x$ dan $a \cdot b = a_x b_x + a_y b_y$; a point is considered to be inside if $w \neq 0$ (winding rule), or the number of odd ray segments (even–odd rule). As an internal verification of closed topology and polygon orientation consistency, the area is calculated using the shoelace formula (surveyor's area formula):

$$A = \frac{1}{2} \left| \sum_{i=1}^{m} (x_i y_{i+1} - x_{i+1} y_i) \right|, \quad (x_{m+1} y_{m+1}) \equiv (x_1 y_1), \tag{2}$$

based on [16].

2.2 Radial Symmetry Module

The number of sectors $n \in [1, 1000]$ is set by the user, with the angle between sectors $\Delta\theta = 2\pi/n$. The user draws a prototype on one reference sector; the system then replicates it to the k sector by rotating it by $k\Delta\theta$ relative to the centre $C = (c_x, c_y)$. For each point p on the prototype entity, the position of the replication is obtained by

$$p_k = C + R(k\Delta\theta)(p - C), \quad R(\phi) = \begin{bmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{bmatrix}. \tag{3}$$

To maintain high-order numerical stability, each replica is calculated directly from $k\Delta\theta$ (rather than repeated rotational composition). The transformation is processed in double-precision floating-point, in accordance with the principle of rounding error mitigation in floating-point arithmetic [17].

2.3 Interaction Pipeline

The interaction pipeline operates as follows. The user selects a tool or primitive, such as a triangle, circle, square, line, pen, or fill. This selection determines the working parameters, including the number of sectors $n \in [1,1000]$, rotation center, line color, line thickness, and preview options. The prototype constructs a single reference sector, either by shape or pen stroke. The system then displays a real-time radial replication as a preview and finalizes the result upon completion of the action. Closed areas are colored using either even–odd or winding rules. If micro gaps are present in the pen sketch, a small epsilon-closing threshold is applied to ensure stable coloring. The completed work is saved or archived in a project file, preserving both the vector entities and radial parameters. PNG export is available for quick previews, while SVG export maintains the vector structure and transformations for further editing in external applications.

2.4 Rendering, Edge Quality, and Portability

The rasterisation process in Symsdraw employs anti-aliasing to minimise jagged edges on curved boundaries, particularly when the number of sectors is high. This process references cubic filter-based reconstruction principles to determine sample coverage and guide post-filtering. The display and implementation are intentionally simplified to maintain a lightweight system. For quality control, the system assesses sector angle consistency by measuring the deviation $|\hat{\theta}^k - k\Delta\theta|$ at control points. If an anomaly is detected, the shape is realigned (snapped) to $\Delta\theta$. Radius consistency is ensured by comparing the distance of replica points to the centre with the prototype, using a small pixel threshold suitable for the canvas resolution. Closed region validation occurs before filling; if micro-gaps are detected in the image path, local ε closure is applied to stabilise colouring. Workflow stability is evaluated through a sequence of actions: pen $\rightarrow$ shape $\rightarrow$ fill $\rightarrow$ and erase, to prevent rendering artefacts. For file management and portability, the project structure records a list of vector entities (including type, parameters, and transformations), symmetry parameters (such as n value, centre, and orientation), and action history. This approach enables high-fidelity session restoration.

3 Results and Discussion

3.1 The Symsdraw User Interface

The Symsdraw interface features a streamlined layout with all tools organized in the top bar (see Figure 1). The leftmost section displays the Symsdraw logo. Next are geometric primitive icons for circle, square, triangle, and line. The pen tool enables freehand drawing, and the fill tool colours closed areas. Visual controls follow, including a colour picker, line thickness adjustment, and radial symmetry settings. The symmetry section includes an input for the number of sectors n, indicated by a symmetry symbol. To the right, two labelled boxes "688" and "688" display the canvas dimensions (width × height), which users can modify to adjust the

workspace. The reset icon (↻) is positioned at the far right to restore the canvas to its default state.
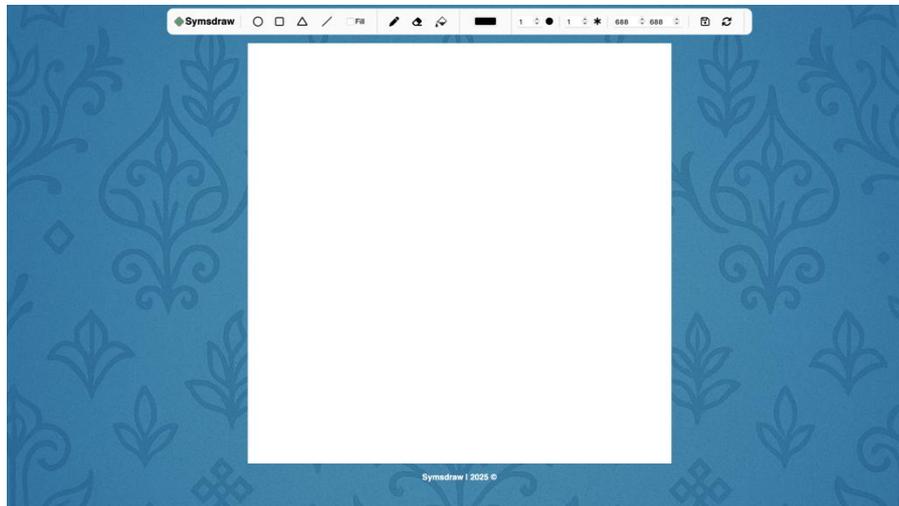

Fig. 1. The Symsdraw User Interface.

The canvas, positioned centrally as the primary workspace, is a white square that stands out against the background. The footer at the bottom displays 'Symsdraw | 2025 ©' to reinforce the application's identity. The workflow is straightforward: select a tool → set the value of n and visual parameters such as colour and thickness → draw a prototype in one sector → review the real-time radial replication preview → fill closed areas → then save or export the result. When $n = 1$, the canvas functions like a standard image editor, ensuring an easy transition for beginners. As n increases, the direct replication preview and anti-aliased edges maintain pattern clarity. Canvas size can be adjusted at any time using the width and height number boxes in the top bar; the workspace updates immediately, allowing users to switch between different composition sizes without leaving the session.

3.2 Validation and Testing of Symsdraw Feature

Figure 2 summarises Symsdraw's core workflow through four simultaneous demonstrations. First, colour and line thickness selection is performed directly on the control bar (open popover palette; thickness value appears as '25'), the effect of which is visible in the purple strokes on the right: thin lines and thick bars result from different width settings but use the same active colour. Second, the filling of closed areas is demonstrated by two overlapping yellow and orange shapes at the top left, confirming that closed areas, whether primitives or strokes, can be filled without duplicating the procedure. Third, rotational replication is visualised by the rosette in the centre of the canvas; the radial parameter on the control bar is set to $n = 8$ (visible next to the symmetry icon), so that an example on one segment is multiplied eight times around the centre and forms a folded motif. Fourth, the bottom of the canvas shows the difference between unfilled primitives (green outline: circle, square, triangle) and filled primitives (blue solid for the same set), making the relationship between the contour and the colouring result clear. The 688×688 workspace dimensions on the right side of the control strip indicate that the canvas

size can be changed as needed without disrupting the repetition structure. Generally, the combination of colour settings, line width, and number of sectors on the control strip with a single drawing action on one segment produces consistent radial output, while distinguishing the behaviour of outlines and fills in basic shapes and freehand strokes.
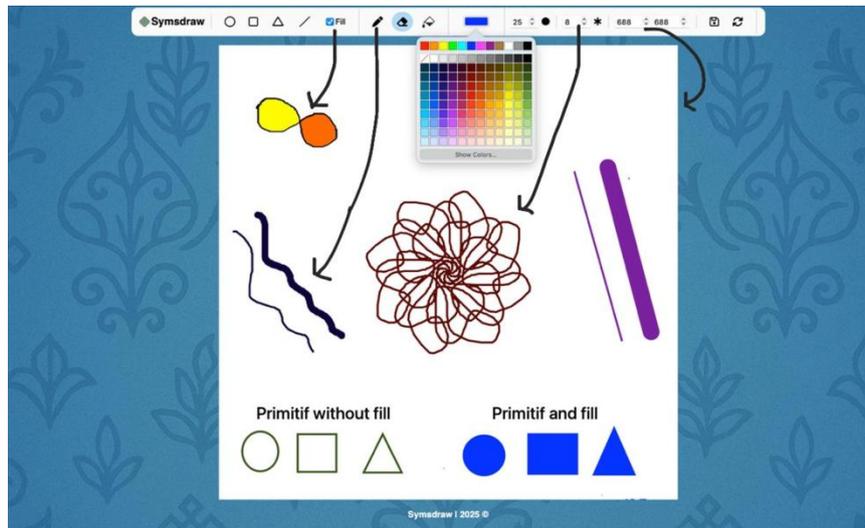

Fig. 2. Symsdraw workspace.

Figure 3 presents a radial composition on a 688×688 pixel square plane. The symmetry parameter is set to $n = 8$, resulting in each stroke on a single segment being replicated eight times around the center at 45° increments. The working plane is initially filled with a background color, creating a uniform surface that provides stable contrast for subsequent lines and shapes. Pen strokes are then applied to one reference sector and immediately replicated by the symmetry module. This process produces a dark brown rosette at the center of the composition. The rosette contains several curvilinear paths that intersect and remain coherent after replication, demonstrating that the example drawn on the reference sector is fully enclosed before distribution to other sectors.

A green ring with uniform wavy contours, divided into eight sectors, encircles the centre. Accents in the form of green dots are generated by short pen strokes on the reference sector and distributed throughout the circle. This arrangement produces a rhythmic texture that distinguishes the green ring from adjacent layers. In the outer region, blue lines with increased sweep amplitude function as compositional binders. The blue lines are thicker than the central contours, establishing a clear visual hierarchy: the dense center attracts initial attention, the green band serves as a transitional element, and the blue lines direct the viewer's gaze back to the center. The variation in line thickness is determined by the line width setting on the control bar and the selection of active colors from the swatch.

Purple strokes at each corner define the image boundaries. Replication toward the center places some fragments outside the square, suggesting pattern continuity without overwhelming the main field. Adjusting the nn value on the control strip directly changes replication density. Here, $n = 8$ maintains readable line spacing; increasing line thickness at this value quickly densifies

the pattern. The balance of background contrast, line thickness, and color selection ensures the figure and background remain distinct.

The procedure for creating the composition can be summarized as a unified sequence of steps: setting the dimensions of the field and n; selecting the color and line thickness; drawing a sample on one sector until the required shape is covered; observing the replication that appears instantly; adding accent points or additional curves to the reference sector if necessary; and closing it by coloring the field or certain parts using the fill command. All results are stored in a single project file that contains vector entities and radial parameters, so that the composition can be readjusted, for example, by changing colors or thinning lines on certain layers, without altering the established symmetry structure. The results in the snippet show that the combination of pen, fill, color-thickness selection, and n setting on the control strip is sufficient to produce consistent and legible folded patterns, without the need for manual duplication or complicated post-processing steps.
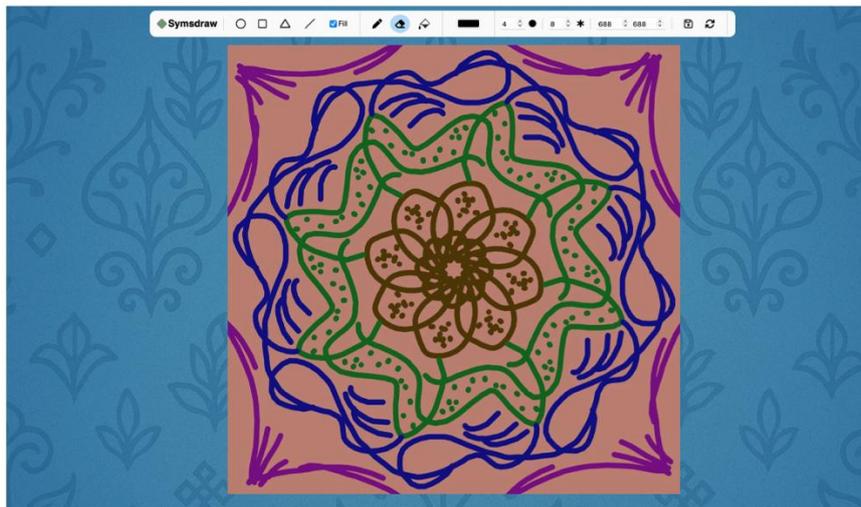

Fig. 3. Example of a sketch using Symsdraw.

Symsdraw can serve as a colouring medium that combines digital and analogue processes. Figure 4a shows an uncoloured line art design produced by Symsdraw: radial patterns are constructed from strokes on a single segment and then replicated according to the value of n, with the line thickness deliberately increased so that the boundaries of the fields are clear when printed. This unfilled design serves as a colouring template; all the closed areas formed by the repetition of curves provide visual 'cells' ready to be filled with colour. Figure 4b shows the results of manual colouring using crayons on the same template. A comparison of the two confirms the workflow: the design is created quickly and consistently in Symsdraw, then the colours are freely explored on paper without changing the geometric structure.

From a compositional point of view, radial templates provide a repetitive rhythm that facilitates colour mapping strategies. Colours can be arranged per concentric ring (e.g. value gradations from centre to edge to emphasise depth) or per sector (e.g. warm–cool alternations to emphasise rotation). Because the shapes are identical across sectors, small variations in intensity,

temperature, or saturation will immediately affect the balance and focus; ease it for the viewer to understand the relationship between colour decisions and changes in pattern perception. In practice, the thick Symsdraw lines act as a medium (crayon) barrier, preventing colours from bleeding over the edges and keeping the contours clean after colouring.

(a)   (b)
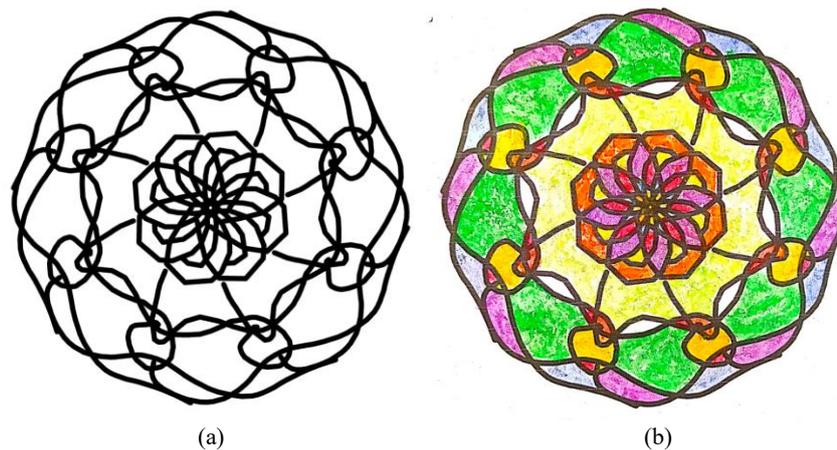
Fig. 4. Sketches using Symsdraw: (a) uncoloured, (b) manually coloured.

Technically, the template in Figure 4 is prepared by adjusting the line thickness and canvas size in the top bar, disabling the fill, and then exporting the PNG for printing. Once colouring is complete (Figure 4b), the results can be documented via scan or photograph; both can be displayed side by side to show the transition from structure to colour. This arrangement is relevant for classes or workshops: one Symsdraw template can be replicated for multiple participants, then each participant explores different colour schemes without having to redraw the pattern; thus, the comparison of results focuses on colour decisions, not on differences in line drawing skills. In the context of the article, the two images show that Symsdraw is not only a pattern-forming tool, but also a container for measured colour experimentation: the structure remains constant, while the play of colours becomes a creative variable that is evaluated.

4 Conclusion

Symsdraw demonstrated that the principle of radial symmetry, which empirically forms a unity with ease of visual processing, can be operationalised in a lightweight, easy-to-install desktop application with sufficient features. With geometric primitives, pens, stable closed-area colouring, and rotational replication up to high orders, users can consistently build layered motifs without manual duplication procedures. The implementation based on direct rotation transformation ($k\Delta\theta$) maintains geometric precision; antialiasing aids contour readability as the number of sectors increases; and project storage/export ensures workflow interoperability. Field tests showed that adjusting core parameters, such as the number of sectors, line thickness, canvas size, and colour, was sufficient to produce decorative outputs, graphic identities, and activity sheets. In addition to being a pattern construction tool, the generated line templates proved effective as a medium for colour play that was geometrically constant. Room for development

remained in advanced geometry constraints and layer organisation, but the current design met practical and precision goals, had a gentle learning curve, and produced consistent results across platforms.

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