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# The East Asian transmission of Southern Song Zen Buddhist painting base on compositional perspective

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The Southern Song aesthetics of simplicity, detachment, and reverence for nature exerted a profound influence on East Asian ink painting. Yet existing scholarship has limited adoption of systematic quantitative approaches. This study applies a machine learning – based image block entropy model to quantitatively examine compositional patterns in figure paintings by Liang Kai, Muqi, and Sesshū Tōyō. The analysis reveals shared technical and iconographic tendencies, including consistently lower-central placement of the primary subject, prominent upper inscriptions, and deliberately sparse backgrounds – features that together establish a “lowered center of gravity” composition distinct from the conventions of court painting. Sesshū adapted these traditions, utilizing bold lines and intricate detail, which resonated with Japanese aesthetic sensibilities. Compared to academic rigidity, Sesshū’s compositions emphasize spontaneity, reflecting Zen improvisation. By integrating computational modeling with art-historical inquiry, this study advances a replicable quantitative framework for analyzing the cross-cultural transmission and transformation of Zen painting styles.

Zen Buddhism flourished during the Tang dynasty and reached its zenith in the Song period, where its widespread influence ignited a deep enthusiasm for meditative practice among the intellectual elite. A defining feature of Zen Buddhism lies in its relative disregard for canonical scriptures and doctrinal exposition, privileging instead a direct mode of transmission encapsulated in its four foundational tenets: “not relying on words or texts,” “a special transmission outside the teachings,” “directly pointing to the human mind,” and “realizing one’s own nature to attain Buddhahood.” Zen thought foregrounds intuitive wisdom cultivated through meditative insight and embodied practice in the context of everyday life, rather than through discursive reasoning or scholastic study<sup>1</sup>.

Religious leaders and literati of the Zen sect sought to convey the concept of *Euigyeong* (意境)—a state of aesthetic and spiritual resonance arising from the fusion of objective correlative elements with the inner imagery perceived and internalized by the practitioner—through the medium of painting. The articulation of *Euigyeong* in individualized artistic language gave rise to what came to be known as Zen sect painting<sup>2</sup>. Indeed, the first decades of the twentieth century suggest the emergence of Zen painting as a separate category of Buddhist and Asian art<sup>3</sup>.

The spontaneity and simplicity of the 300 shades of gray between black and white created by the dilution of black ink on paper reflect the impermanence of reality and the importance of emptiness, fundamental concepts

of Zen Buddhism. Simplicity (簡素) and emptiness (空, *kū*) are central values in Zen doctrine, and they are also the aesthetic characteristics of its style<sup>2</sup>.

The Southern Song period (1127–1279) represents the pinnacle of Zen painting’s evolution, characterized by stylistic consolidation, the establishment of canonical imagery, and an unprecedented surge of creative expression. Following the institutionalization of the Five Mountains and Ten Temples system (五山十刹制度), Zen painter-monks began to congregate in cultural and religious centers such as Lin’an (present-day Hangzhou). The center of thirteenth-century Zen painting was in monasteries located in the hills of Hangzhou (杭州), especially in Liutong Temple (六通寺). Muqi was the abbot of this temple, and Liang Kai also used it as a “haven for a fugitive from the Imperial Academy”<sup>4</sup>.

Zen painting was functionally oriented toward ritual practice and devotional use; the largest proportion consisted of paintings depicting the characteristics or anecdotes of Zen figures<sup>5</sup>, while landscapes and depictions of flora and fauna were typically relegated to the realm of informal or playful sketches.

Zen monastic records classify figure paintings into two principal genres:

Buddha-Patriarch Portraits, which depict religious figures such as Śākyamuni, bodhisattvas, arhats, Zen patriarchs, and culturally affiliated

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subjects like Tang poets (e.g., Li Bai, Du Fu) and Daoist immortals (e.g., Laozi); Zen Encounter Scenes, which illustrate kōan dialogues between masters and disciples, are often set within sparse, minimalist landscapes.

Stylistically, Southern Song Zen painting coalesced around three major approaches: refined line drawing, economical brushwork, and ink-splashing (破墨). Of these, the latter two rose to dominance over time—emerging in rudimentary form during the early to mid-Southern Song, and reaching full codification and expressive maturity by the late period. In terms of composition, these works consistently exhibit a reductive background, central-lower placement of figures rendered with subtle contouring, and prominently positioned inscriptions in the upper register, forming a visual syntax emblematic of the Zen pictorial tradition.

The artistic innovations of Liang Kai (c. 1140–1210) and Muqi (c. 1210–1269) exemplify the fusion of Zen doctrine and pictorial abstraction.

Originally a court painter renowned for his meticulous baimiao (白描, fine-line drawing), Liang Kai later broke with convention to develop a radically abbreviated mode of brushwork known as jianbi (减笔, “reduced brush”)<sup>6</sup>. In *Li Bai Reciting Poetry While Walking* (李白行吟图) is distilled into a few dynamic strokes that capture an unrestrained, spontaneous spirit. In contrast, *Immortal in Splashed Ink Style* (泼墨仙人图) utilizes bold washes and amorphous forms to visually articulate the Zen concept of emptiness (śūnyatā) and transcendence.

Muqi was the most eminent of the Zen monk painters at the end of Southern Song. He studied under the Zen master Wuzhun Shifan (无准师范, 1179–1249)<sup>8</sup>, developed a distinctive synthesis of Sichuanese figural realism and Jiangnan ink aesthetics—a hybrid visual language shaped in part by his displacement from Sichuan to Hangzhou during wartime. In his iconic *Hotei* (布袋图), Muqi conveys the “form is emptiness” (色即是空) teaching through a combination of economical contouring and textured ink splashes, creating a figure both humorous and metaphysically charged. Elements of the grotesque—such as the infamous depiction of the “nose-hair Laozi” in *Portrait of Laozi* (老子图)—drew criticism in China for their lack of decorum but found strong resonance in medieval Japanese Zen, where such anti-classical, subversive aesthetics were embraced as authentic expressions of spiritual truth.

The dissemination of Southern Song Zen Buddhism across East Asia was mediated through multiple channels, including textual transmission<sup>7</sup>, poetry and visual art<sup>8</sup>, monastic institutions<sup>9</sup>, the Maritime Silk Road<sup>10</sup>, and direct interpersonal exchange. This multidimensional network of communication collectively advanced the diffusion and localization of Zen thought throughout the region. The spread of Southern Song Zen Buddhism was characterized by both interdisciplinary influence and religious syncretism, reshaping the East Asian cultural landscape through the convergence of the Three Teachings<sup>11</sup>, while simultaneously fostering new developments in literature<sup>12</sup>, visual and performing arts<sup>1</sup>, architecture<sup>13,14</sup>, and related fields. Taking Zen painting as an example, its concise visual language, ethereal spatial structures, and symbolic rendering of enlightenment not only stand out uniquely in Chinese artistic classics but also exert a lasting influence on the development of Chinese literati painting and Japanese ink painting traditions.

These Southern Song innovations—which translated Zen Buddhism’s doctrine of “direct pointing to the mind” (直指人心) into a powerful visual idiom—were transmitted to Japan through transnational monastic networks, even as they remained marginalized within Chinese imperial court circles. Once introduced, these visual strategies became foundational to Muromachi-period (1336–1573) ink painting, where Zen consciousness was creatively reinterpreted through the lens of indigenous Japanese aesthetics, including the principles of wabi-sabi (austere beauty and impermanence) and the spiritual ethos of bushidō (the way of the warrior).

In Japanese art history, ink painting (suibokuga, 水墨画) constitutes a culturally hybrid genre—Chinese in origin, yet profoundly localized through its integration with Zen Buddhism. As Zen thought permeated Japanese cultural life, ink painting flourished by aligning itself with spiritual and meditative needs, leading to the emergence of the painter-monk (gasō, 画僧) tradition.

Among these, Sesshū Tōyō (1420–1506) was of the most importance to Japanese art history, because he explored a new way of representation in ink painting. By incorporating Japanese elements into Chinese ink painting, he developed a uniquely Japanese style, which had a significant impact on Japanese art<sup>2</sup>.

Sesshū trained under the Rinzaï Zen master Tenshō Shūbun (周文). Sesshū journeyed to China in 1467, where he studied at Tiantong Temple (天童寺) and engaged directly with the artistic legacy of Southern Song painters. His exposure to the works of Liang Kai and Muqi facilitated a creative synthesis—integrating Liang’s spontaneous brushwork and Muqi’s evocation of void with distinctly Japanese aesthetic sensibilities.

Zen paintings were located firstly within East Asian art, rather than the art historical study of Buddhist schools and sites. Works of Zen art tend to be placed within developmental narratives of genre and style. In recent years, the most potent inquiry and debate have centered on portraiture and historiographical appraisal of portrait visuality. Furthermore, research on the interpretation of imagery and symbols across various domains of Zen art (such as painting, poetry, gardening, and the tea ceremony) holds significant value.

Zen painting has traditionally been situated within the broader framework of East Asian art, rather than approached primarily through the art-historical study of specific Buddhist schools or sacred sites. Scholarly discourse has often contextualized works of Zen art within developmental narratives of genre and style<sup>3</sup>. In recent years, however, critical inquiry has increasingly concentrated on issues of portraiture and on historiographical reassessments of portrait visuality<sup>15,16</sup>. Moreover, investigations into the interpretation of imagery and symbolism across diverse cultural expressions of Zen—including painting, poetry, garden design, and the tea ceremony—have proven to be of considerable scholarly significance<sup>17</sup>.

This study employs a machine learning – based block entropy algorithm to analyze compositional patterns in hanging scroll figure paintings by Sesshū, Liang Kai, and Muqi. By quantifying the spatial positioning of subjects and the distribution of visual information, the analysis reveals how core compositional principles from the Southern Song tradition – notably economy of means, use of negative space, and an improvisational spatial logic – provided the structural foundation for Sesshū’s cross-cultural transformation of Zen aesthetics within a Japanese artistic context.

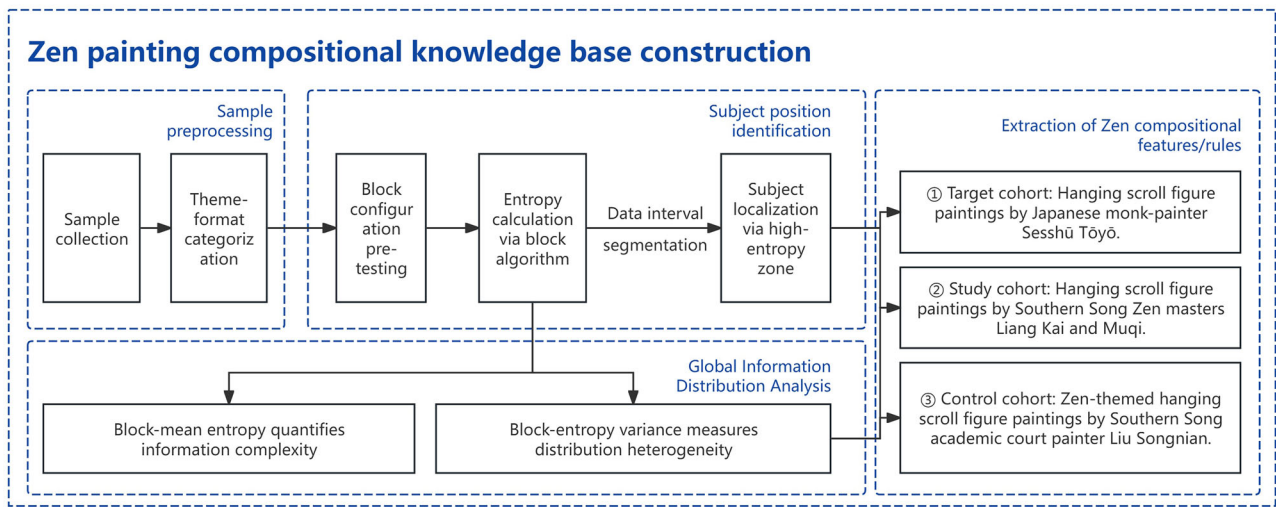
## Methods

This study proposes a machine learning-based methodology for constructing a compositional dataset of Zen paintings. As illustrated in Fig. 1, the technical workflow encompasses three sequential analytical stages shown in Fig. 2: (1) sample set preprocessing, (2) subject position identification, and (3) global information distribution analysis. Through this framework, we conduct comparative compositional examinations of:

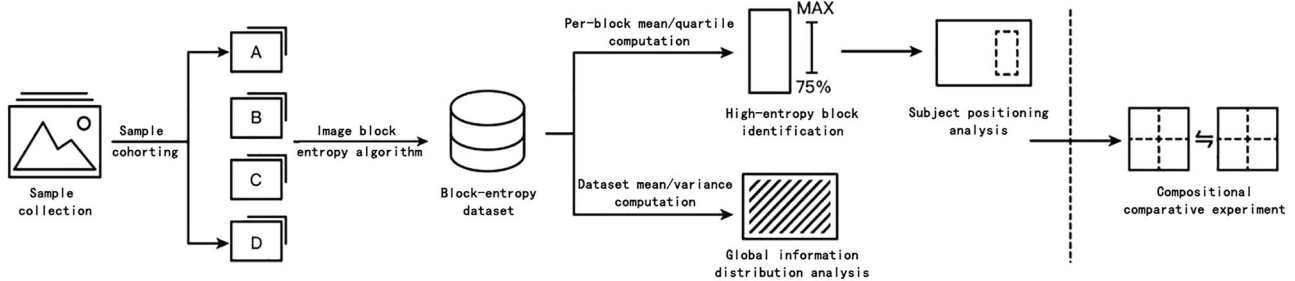
- (1) **Target cohort:** Hanging scroll figure paintings by Japanese monk-painter Sesshū Tōyō.
- (2) **Study cohort:** Hanging scroll figure paintings by Southern Song Zen masters Liang Kai and Muqi.
- (3) **Control cohort:** Zen-themed hanging scroll figure paintings by Southern Song academic court painter Liu Songnian.

The analysis systematically identifies compositional similarities and divergences among these groups, investigating their correlations and variations to quantitatively decipher the influence of Southern Song Zen aesthetics on Sesshū’s artistic practice.

In the sample pretreatment stage, the research samples utilized in this experiment were primarily sourced from digitized painting collections and verified high-resolution online image repositories. Given the historical age of original artworks, direct rescanning or rephotographing was unfeasible. Existing reproductions in published catalogues often exhibit suboptimal quality—particularly pronounced overall darkness—due to technological limitations and environmental constraints at the time of digitization. To optimize samples for compositional analysis, we implemented



**Fig. 1 | Overall technical workflow of the compositional analysis framework.** This figure outlines the three-stage analytical pipeline developed in this study. The workflow includes (i) sample preprocessing, (ii) subject position identification via block entropy analysis, and (iii) global information distribution analysis. Arrows indicate the sequential progression.



**Fig. 2 | Experimental procedure for entropy-based compositional analysis.** The diagram details the operational steps of the experimental design. Stage 1 involves image preprocessing and categorical filtering, where A,B,C,D denotes the classification categories. Stage 2 implements entropy computation for subject localization. Stage 3 calculates mean and variance of block entropy to evaluate global information distribution patterns.

preprocessing enhancements including Luminance and saturation augmentation, Noise reduction, and Reconstruction of brushstroke textural details.

Concurrently, acknowledging that compositional effects are influenced by both subject matter and physical dimensions, samples underwent dual-categorization by painting theme and scroll format during preprocessing. Subsequent analysis focused exclusively on figure paintings in vertical hanging scroll format for comparative compositional examination.

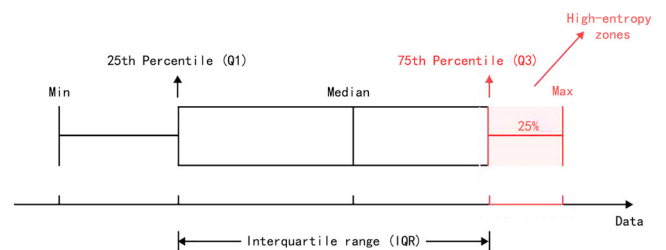
In the subject position identification stage, preliminary experiments were conducted to determine optimal partitioning strategies, as the block segmentation approach directly impacts experimental outcomes and subsequent analysis. These pre-tests involved comparative evaluation of different block configurations informed by pictorial content, enabling selection of appropriate block size and segmentation methodology.

Painting composition manifests spatially heterogeneous information distribution. Regions with complex color variations and intricate brushwork details exhibit heightened pixel-value fluctuations, corresponding to elevated information entropy<sup>18</sup>. We therefore implemented an entropy-based image block segmentation algorithm to calculate per-block entropy values (Eq. 1):

$$H(X) = - \sum_{x \in X} P(x) \log_b P(x) \tag{1}$$

Where  $X$  is a discrete random variable,  $P("x")$  denotes the probability that  $X$  takes the value "x", and the expected information measure of  $X$  is defined as the information entropy  $H(X)$ .

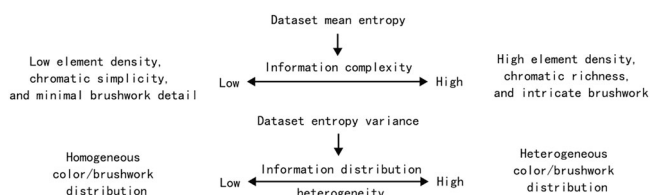
cation categories. Stage 2 implements entropy computation for subject localization. Stage 3 calculates mean and variance of block entropy to evaluate global information distribution patterns.



**Fig. 3 | Quartile-based thresholding for high-entropy block identification.** Blocks were ranked by entropy value and segmented into quartiles (Q1–Q4). Blocks within the upper quartile (Q4) were designated as high-entropy regions and interpreted as probable subject-dominant zones. Color intensity corresponds to entropy magnitude, with warmer tones indicating higher information density.

This quantifies information density within each block. Data segmentation via quartiles established distribution parameters, with blocks in the upper quartile (Q4) identified as subject position regions (Fig. 3).

In the global information distribution analysis stage, this study employs block-based information entropy to characterize spatial distribution features in Zen painting imagery. When calculating image information entropy, the mean and variance of block entropy values<sup>19</sup>—quantify information complexity and distributional heterogeneity, respectively, as illustrated in Fig. 4.



**Fig. 4 | Conceptual interpretation of mean and variance in block entropy analysis.** The schematic illustrates how mean entropy reflects overall information density, while entropy variance captures spatial heterogeneity. Higher variance indicates stronger contrast between subject and background regions.

The variance of block entropy values indicates the salience of information distribution heterogeneity within the image, as formalized in Eq. 2.

$$V = \frac{1}{n} \sum_{i=1}^n (H_i - H_m)^2 \quad (2)$$

Where  $H_i$  denotes the block entropy,  $H_m$  represents the mean block entropy, and  $V$  signifies the entropy variance.

We elaborate on our selection of software, the computational environment, and other pertinent tools: The experimental platform for the algorithms in this study was implemented on the Ubuntu system, utilizing an AMD Ryzen 7 3700X CPU. The proposed block-based information entropy method was developed in Python 3.7, leveraging key libraries including NumPy, OpenCV-Python, and Matplotlib. Furthermore, the image calibration step within the sample preprocessing phase was performed on the Windows 10 system using Adobe Photoshop CC 2023 as the tool.

## Results

### Preliminary Zen painting feature analysis

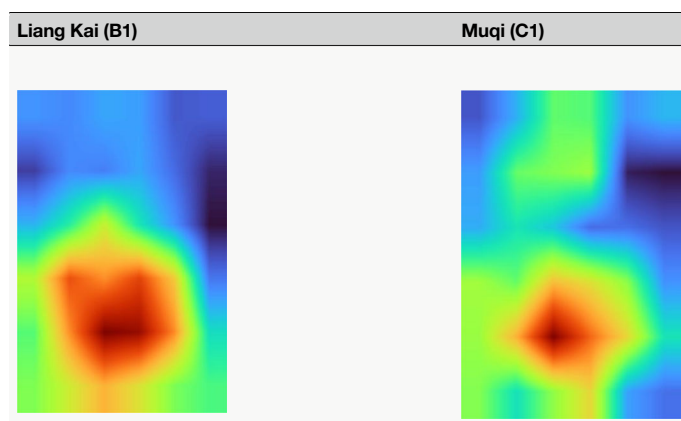
As established in the Research Background and Literature Review sections, Sesshū Tōyō’s artistic production reveals clear compositional and philosophical affinities with Liang Kai and Muqi, both emblematic figures of Southern Song Zen painting. In recognition of Liang Kai’s dual trajectory—first as an academic court painter and later as a Zen practitioner—this study chronologically filters his works to include only those produced after his resignation as Painter-in-Attendance (post-1204 CE), marking his departure from courtly conventions and engagement with Zen-inflected abstraction. These late-period works, alongside Muqi’s representative oeuvre, form the basis for a preliminary analysis of Zen compositional features.

The mean entropy visualization results (see Table 1) quantitatively corroborate the compositional traits traditionally associated with Zen aesthetics. Entropy maps reveal a consistent visual structure across the dataset: sparse and atmospheric backgrounds, central-lower placement of subtly rendered subjects, and prominent inscriptions located in the upper register. These findings not only validate historical interpretations of Southern Song Zen painting but also establish a measurable framework for identifying its stylistic transmission.

### Sample preprocessing

Zen painting primarily features figure subjects, relegating landscapes, flora, and fauna to “playful sketches”. As Southern Song Zen figure painting predominantly comprises single-patriarch portraits and multi-figure kōan scenes—typically executed in hanging scroll format for ritual veneration—For this study, we analyzed a corpus of forty-nine hanging-scroll figure paintings—fourteen attributed to Sesshū Tōyō, twenty-one to Liang Kai, and fourteen to Muqi. The sample was determined through evaluations conducted by a specialist panel comprising three painting and calligraphy artists, three art historians, and one literary theorist. Using a five-point Likert scale, the panel anonymously assessed each work in terms of stylistic

**Table 1 | Block-mean visualization**



typicality, artistic value, and source reliability. Only paintings receiving mean scores above 4.7 across all three dimensions were included in the final dataset. The evaluation scales appear in Supplementary Information A. Detailed metadata for each image—covering date, attribution, collection history, and the size and resolution of the corresponding digital files—are provided in Supplementary Information B. The images exhibit short-side pixel counts ranging from 408 to 6166 pixels and long-side counts from 636 to 12,406 pixels. Sample groupings and representative examples are documented in Table 2.

Subsequent luminance (+45) and saturation (+28) calibrations were applied uniformly using Adobe Photoshop. Following denoising pre-processing, the refined experimental sample images enabled enhanced reconstruction of authentic compositional structures and brushstroke details.

During sample set preprocessing, systematic examination of the corpus revealed notable similarities in painting techniques and figural representation among Sesshū, Liang Kai, and Muqi:

- (1) Technical Dimensions
  - (a) Dotted-Line Drooping Branch Technique
 

Employed by Liang Kai in *The Sixth Patriarch Tearing a Sutra* (六祖撕经图) and Muqi in *Arhat Paintings* (罗汉图), *Painting of Bodhidharma* (达摩图), and *Fenggan the Monk* (羊干图). Characterized by swift, light-ink U-shaped strokes for tree branches, overlaid with vertical streaks and accentuated by heavy ink dots. Absent in Sesshū’s works, where branches exhibit rigid angularity.
  - (b) Dry Brush Side-Stroke Technique
 

Liang Kai’s application for drapery (*Hotei*, 布袋图), Muqi’s for fur (*The Fifth Patriarch with a Hoe*, 五祖荷锄图), and monastic robes (*Hotei*, 布袋图). Sesshū adopted this for hair rendering in *Sakyamuni Leaving the Mountains* (出山释迦图).
  - (c) Wet-Light Reduced Brushwork
 


Exemplified in Liang Kai’s *Li Bai Reciting Poetry While Walking* (李白行吟图), Sesshū’s *Sakyamuni Leaving the Mountains* (出山释迦图), and Muqi’s *Hotei* (布袋图) and *Portrait of Laozi* (老子图).
  - (d) Dense-Light Splashed Ink Technique
 

Manifested in Liang Kai’s *Immortal in Splashed Ink Style* (泼墨仙人图) and *The Immortal Puhua Ringing a Bell* (普化振铃图), alongside Sesshū’s *Portrait of Du Fu* (杜子美图) and *Portrait of Pan Shuang* (潘双图).
  - (e) Broken-Reed Line Drawing

Liang Kai’s signature technique in *The Sixth Patriarch Tearing a Sutra* (六祖撕经图) and *The Sixth Patriarch Cutting Bamboo* (六祖截竹图) features abrupt robe-fold strokes. Sesshū emulated this in *Sakyamuni Leaving the Mountains* (出山释迦图), achieving dynamic movement through calligraphic abruptness despite restrained figural postures.

- (2) Iconographic Dimensions

**Table 2 | Research samples**

No.	Artist	Primary Pictorial Elements	Representative Exemplars of Hanging Scroll Figure Paintings
A1	Sesshū Tōyō (14)	Figure	
B1	Liang Kai (21)	Figure	
C1	Muqi (14)	Tree, Figure	

Southern Song Zen painting developed vernacular expressiveness infused with whimsical humor, particularly in patriarch portraits. Recurring motifs included: Laughing figures (Hanshan, Shide, Fenggan, Budai) depicted clapping, guffawing, or belly-holding; Exaggerated bellies (Hotei, Arhat); Narrative humor: Sixth Patriarch gleefully tearing sutras, monks amused by cockfights (*Chicken-Bone Immortal*, 鸡骨图), Shennong chewing grass blades (*Painting of Shennong*, 神农图), elongated foreheads (*The God of Longevity*, 寿星图), Muqi’s Laozi with exposed nasal hair.

Despite this playful vernacular, Zen paintings maintained austere dignity through: a Restrained monochrome palette, Centralized compositions, Ritual solemnity transcending trivial gestures (nose-picking, tooth-gaping, rope-twisting)

This unique synthesis—where reverence coexists with approachability—contrasts with orthodox Buddhist art’s formality, embodying Zen’s integration of spiritual practice and lived experience.

Beyond these visually discernible features, compositional patterns resist verbal generalization across individual artworks. This study therefore

employs statistical quantification of compositional data to: First, objectively identify similarities/differences among Sesshū, Liang Kai, and Muqi. Second, correlate similarities with the Southern Song Zen painting’s influence on Japanese Zen art. Third, interpret differences as evidence of Sesshū’s culturally-grounded translation of Chinese traditions.

**Subject position identification—Experiment 1: image block entropy analysis**

Experiment 1 applies unit entropy principles to partition sample images into blocks, calculating entropy values per block via information entropy algorithms. This transforms object locations into entropy-based spatial ranges, quantifying positional data through block coordinates. The primary objectives are:

- (1) **Providing data validation for high-entropy subject regions**
- (2) **Mapping information distribution patterns across all pictorial elements in four thematic categories**

During entropy analysis, subject areas typically exhibit elevated entropy values due to concentrated brushwork complexity and chromatic variation. Conversely, background and secondary elements demonstrate lower entropy through reduced detail density. As subjects constitute the core pictorial elements—interacting dynamically with other components to define compositional characteristics—this experiment focuses on subject positioning and information distribution.

**Partitioning strategy.** Image segmentation methodology critically influences experimental outcomes. We evaluated two approaches:

**Fixed block dimensions:** Resulted in inconsistent block counts across samples due to compositional/scalar variations, impeding unified analysis of theme- or format-based groups.

**Fixed block count:** Produced variable block sizes but minimally impacted positional descriptions for consistent themes/formats, aligning with classical compositional frameworks like the Rule of Thirds.

The fixed-block-count approach was consequently adopted.

**Grid configuration testing.** Comparative analysis of grid configurations (3 × 3, 4 × 4, 5 × 5, 6 × 6, 7 × 7, 8 × 8) revealed (Table 3):

Excessive granularity (e.g., 8 × 8): Dispersed high-entropy blocks (red), obscuring subject boundaries

Insufficient granularity (e.g., 3 × 3): Overly expansive high-entropy zones (blue), conflating subjects with peripheral elements


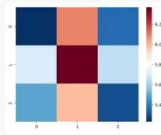
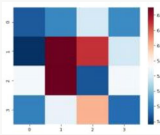
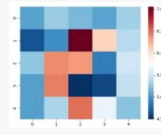
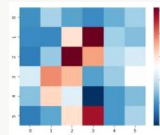
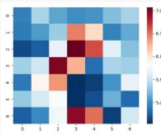
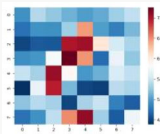
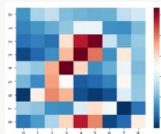
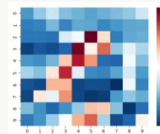
Artists typically abstract key elements through holistic observation before detailing—a cognitive process mirrored computationally. The 6 × 6 grid optimally balanced precision and holistic coherence, preserving subject integrity while minimizing interference from ancillary components.

Therefore, this study ultimately adopted a 6 × 6 block configuration for the image block entropy analysis. The entropy heatmaps for samples across the four thematic categories are presented in Table 4.


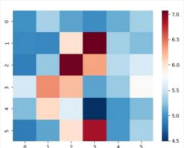




To establish correspondence between block entropy values and spatial positions, this study implements a coordinate-based localization system for sample blocks. A coordinate system constitutes a specific spatial reference framework that defines the position of points or targets within a two-dimensional plane. The Cartesian coordinate system comprises the origin point, X-axis, and Y-axis. With the top-left vertex of the image designated as the origin (0, 0), the X-axis extends left-to-right, the Y-axis extends top-to-bottom. As illustrated in Fig. 5, hanging scrolls (vertical scrolls) are denoted by “V”. Consequently, each sample block is uniquely identified as “V(x-coordinate, y-coordinate)”. For example, the top-left block in a horizontal scroll sample is designated “V(1, 1)”.

First, all 49 samples were uniformly processed 6 × 6 block segmentation, and block entropy values were calculated—yielding 36 entropy data points per sample. Second, to identify subject distribution zones: block means and quartiles were computed for six format groups across four thematic categories; block heatmaps were generated for analytical visualization, with blocks in the top 25% of mean values

**Table 3 | Grid configuration testing**

Sample	3 × 3	4 × 4	5 × 5	6 × 6
				
	7 × 7	8 × 8	9 × 9	10 × 10
				

**Table 4 | Block-entropy heatmap**

Sesshū Tōyō’s Hanging Scroll Exemplar	Heatmap	Liang Kai’s Hanging Scroll Exemplar	Heatmap	Muqi’s Hanging Scroll Exemplar	Heatmap
					

designated as high-entropy regions (yielding 9 high-entropy blocks per sample). Finally, enhanced thermal distribution maps were created for auxiliary analysis, using a red-to-blue gradient to represent high-to-low entropy transitions.

Compositional metrics for Sesshū Tōyō’s hanging scroll figure paintings (A1), Liang Kai’s hanging scroll figure paintings (B1), and Muqi’s hanging scroll figure paintings (C1)—including block means, quartiles, and block-mean visualizations—are presented in Tables 5–8.

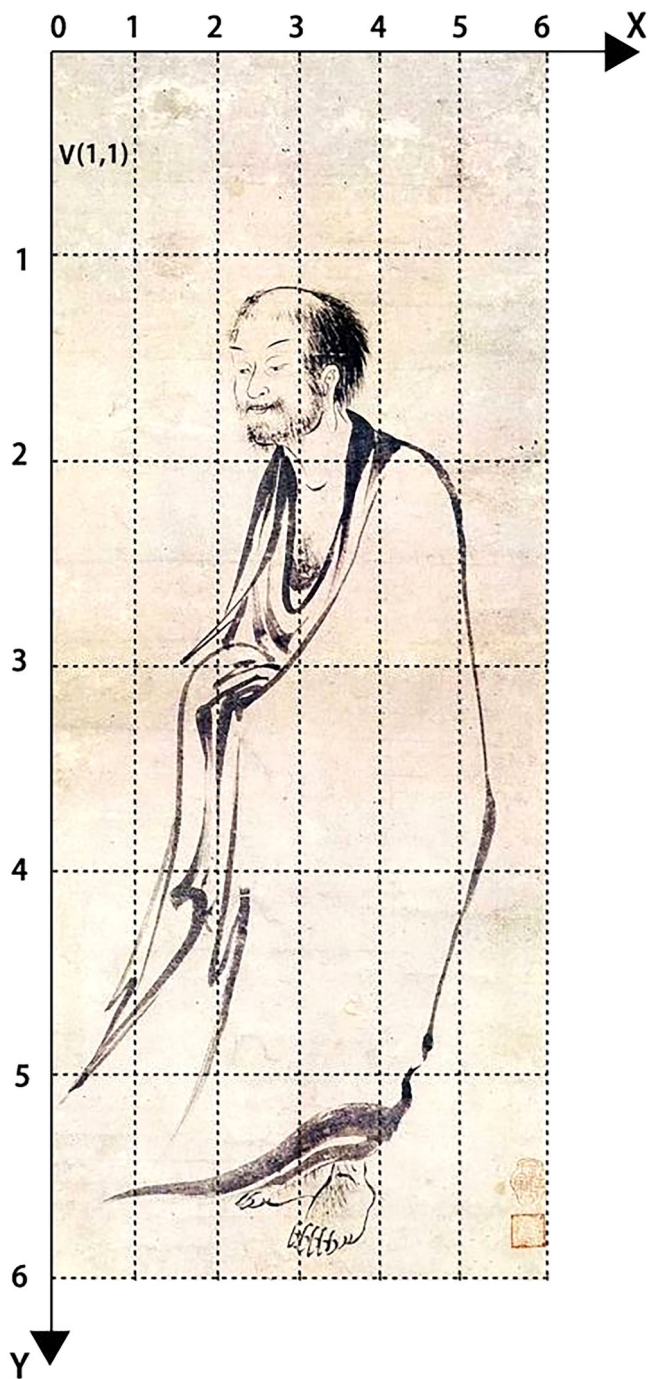
In summary, in terms of the distribution of the main subject, the three painters’ vertical hanging scroll paintings share the following similarities: the maximum value of the block mean is at V(3,5), high entropy values are mostly in the fifth row, and the main subject is mainly distributed near the bottom half and centred. The figures in the paintings are generally positioned at the centre or slightly below the centre of the composition. The upper or middle sections of the scrolls often feature inscriptions. Among these, portraits of Zen masters with distinct Zen attributes represent a unique painting style created by the Zen school, with most lacking a background. Works featuring Bodhisattva and Zen master portraits are significantly influenced by traditional painting patterns, with early works often employing panoramic compositions. As Zen painting matured, these works also tended toward simplicity. Zen assembly-themed works often incorporate narrative elements and are accompanied by simplified depictions of trees and rocks. The conventional layout of Zen vertical scroll figure paintings can be summarised as: figure (lower centre, light ink) + blank space (centre) + inscription (upper centre, dark ink). Central composition and large areas of blank space are the most distinctive features of Zen painting figure layouts, complemented by prominent square or rectangular inscriptions, creating a simple

yet dignified composition. Examples of three figures are shown in Table 9.

**Sesshū Tōyō** masterfully synthesized the abbreviated brushwork (减笔) of the Southern Song with the decorative linearity characteristic of Japanese Yamato-e, producing strokes that are both vigorous and rhythmically fractured. This stylistic hybridization is evident in several of his representative works. In *Painting of Shennong* (神农图), leaf-patterned drapery articulates the contours of Shennong’s body, while zones of peak entropy—notably at V(3,4) and the cluster V(2,5) to V(5,5)—correspond to the intricately rendered herbal elements held in his hands.

In *Portrait of Du Fu* (杜甫美图), heightened entropy appears at V(2,4), V(3,4–3,5), and V(5,5), capturing the dynamic flow of the poet’s sleeves and the facial and bodily features of the accompanying horse. In *The God of Longevity* (寿星图), peak entropy is located at V(3,5), emphasizing both the pronounced jawline and the expressive rendering of robe folds. These visual data points reinforce Sesshū’s compositional focus on gesture, figural vitality, and localized density—hallmarks of Zen painting interpreted through a Japanese aesthetic lens.

**Liang Kai** constructed dynamic visual axes through calligraphic brushwork, concentrating visual information along implied trajectories of movement. In *Hotei* (布袋图), a series of drooping arc lines counterbalances the figure’s left-leaning posture, while densely inked garment folds generate zones of high entropy across V(2,4)–V(3,5). In *Painting of Liu Hai the Immortal* (刘海仙人图), entropy peaks at V(3,5), within a broader zone spanning V(1,5)–V(5,5). The right sleeve, articulated in three successive ink gradients, exemplifies the rhythmic alternation of “dry–wet ink interaction”, while the X-shaped composition—formed by the intersection of the head–foot diagonal and the right arm arc—establishes a kinetic equilibrium.



**Fig. 5 | Block coordinate system for spatial localization in vertical hanging scrolls.** A Cartesian coordinate system is superimposed on a 6 × 6 grid. The top-left corner is defined as the origin (V(1,1)). The x-axis extends horizontally (left to right), and the y-axis vertically (top to bottom). Each block is uniquely identified as V(x,y), enabling quantitative localization of entropy regions.

This intersecting axis system is later echoed in *The Sixth Patriarch Cutting Bamboo* (六祖截竹图), where the gesture is amplified by vertical coin strings, anchoring the figure’s posture. Here, entropy peaks at V(3,5), while the angular bamboo branches extend sightlines beyond the frame, producing a sense of psychological expansion and spatial openness.

In contrast, *Muqi* employed ink tonalities to stratify space and evoke atmosphere, foregrounding diffusion, void, and negative space as compositional agents. In *The Fifth Patriarch with a Hoe* (五祖荷锄图),

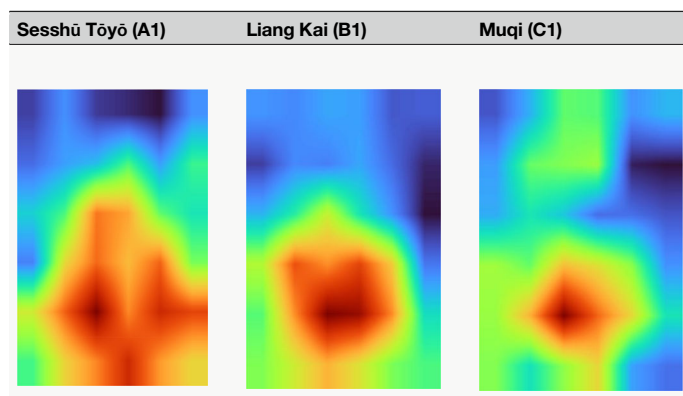
**Table 5 | Block-mean values by sample**

Sesshū Tōyō: Hanging Scroll Figure Painting (Cohort A1)						
V	1	2	3	4	5	6
1	5.331	5.491	5.319	5.288	5.243	5.498
2	5.415	5.523	5.587	5.788	5.523	5.762
3	5.634	5.786	6.266	6.184	5.815	5.693
4	5.459	6.056	6.290	6.135	6.301	5.845
5	6.004	6.303	6.582	6.233	6.437	6.365
6	5.776	6.074	6.239	6.436	6.203	6.068
Liang Kai: Hanging Scroll Figure Painting (Cohort B1)						
V	1	2	3	4	5	6
1	5.739	5.688	5.643	5.680	5.666	5.693
2	5.513	5.600	5.602	5.614	5.602	5.527
3	5.669	5.760	6.006	5.787	5.620	5.482
4	5.896	6.187	6.116	6.222	6.038	5.595
5	5.823	6.146	6.310	6.277	6.094	5.744
6	5.862	5.953	6.093	6.011	5.950	5.858
Muqi: Hanging Scroll Figure Painting (Cohort C1)						
V	1	2	3	4	5	6
1	5.682	5.818	5.973	5.973	5.779	5.818
2	5.777	5.991	5.997	6.037	5.636	5.624
3	5.821	5.879	5.837	5.694	5.764	5.698
4	6.085	6.052	6.214	6.152	6.076	5.878
5	6.096	6.224	6.499	6.293	6.150	5.981
6	6.083	5.974	6.110	6.219	5.919	5.845

**Table 6 | Quartile distribution of block means**

Cohort	Min	Q1 (25th Percentile)	Median (Q2)	Q3 (75th Percentile)	Max
A1	5.243	5.523	5.815	6.233	6.582
B1	5.482	5.620	5.760	6.011	6.310
C1	5.624	5.818	5.973	6.085	6.499

**Table 7 | Block-mean visualizations**



the hoe functions as a “visual black hole”, its tonal saturation guiding the viewer’s gaze centripetally. In *The Monk Called “Clam-Monk”* (蜆和尚图), peak entropy emerges at V(3,5), within the broader region of V(2,5)–V(3,5); the stark contrast between the dark robe and light-toned face directs focus toward the clam-holding gesture, while the vacant

**Table 8 | Comparative entropy analysis: Sesshū Tōyō, Liang Kai, and Muqi**

	Sesshū Tōyō (A1) Analysis	Liang Kai (B1) Analysis	Muqi (C1) Analysis
Max block mean	6.582 at V(3,5)	6.310 at V(3,5)	6.499 at V(3,5)
75th percentile	6.233	6.011	6.085
High-entropy range	6.582–6.233	6.310–6.011	6.499–6.085
High-entropy blocks	V(2,5), V(3,3)–V(3,6), V(4,5)–V(4,6), V(5,4)–V(5,5), V(6,5)	V(2,4)–V(2,5), V(3,4)–V(3,6), V(4,4)–V(4,6), V(5,4)–V(5,5)	V(1,4)–V(1,5), V(2,5), V(3,4)–V(3,6), V(4,4)–V(4,6), V(5,5)
Distribution pattern	<ul style="list-style-type: none"> <li>★ 50% high-entropy blocks in Row 5</li> <li>★ Central concentration &gt; lateral zones</li> <li>★ Primary subjects cluster near bottom 1/3 region with central emphasis</li> </ul>	<ul style="list-style-type: none"> <li>★ 80% high-entropy blocks in Rows 4–5</li> <li>★ Central dominance &gt; lateral areas</li> <li>★ Subject concentration in bottom 1/2 region with central alignment</li> </ul>	<ul style="list-style-type: none"> <li>★ 50% high-entropy blocks in Row 5</li> <li>★ Left-central prevalence &gt; right zones</li> <li>★ Subject focus in bottom 1/2 region with left-central bias</li> </ul>

background embodies the Zen principle of “originally nothing exists” (本来无一物).

In *Portrait of Laozi* (老子图), entropy concentrates at V(3,5), within the clusters V(1,4), V(2,5)–V(4,5), V(4,4), and V(2,6)–V(3,6). With minimal yet deliberate strokes, Muqi conjures spatial depth through concentrated ink in drapery folds, achieving an impression of immaterial vastness. In *Fenggan the Monk* (丰干图), economic contours combined with tonal gradation define the subject’s textural qualities. Subject prominence emerges at V(3,5) and V(4,6), while the void background heightens the figure’s presence through stark visual isolation.

All of the above examples conform to the prominent characteristics of Zen painting composition, with a simple background, a light-coloured subject located in the lower centre, and a striking inscription at the top. The differences lie in the fact that Sesshū prefers to place the subject in the lower right-hand corner, Liang Kai prefers to place it in the centre, and Muqi prefers to place it in the lower left-hand corner.

### Global information distribution analysis

Sample means and variances were computed for the three artist cohorts—Sesshū Tōyō, Liang Kai, and Muqi—to analyze holistic information characteristics in their hanging scroll figure paintings. Results are presented in Figs. 6 and 7.

The mean entropy plot (Fig. 6) reveals: Muqi (C1) > Sesshū (A1) > Liang Kai (B1). The variance plot (Fig. 7) shows: Sesshū (A1) > Liang Kai (B1) > Muqi (C1). Detailed analysis follows:

The Sesshū Tōyō cohort (A1) exhibits intermediate mean entropy and maximal variance, indicating moderate information density with pronounced distributional heterogeneity. Works such as *Sakyamuni Leaving the Mountains* (出山释迦图) and *The God of Longevity* (寿星图) demonstrate economical brushwork, while *Huike’s Severed Arm* (慧可断臂求法图) and *The Portrait of Vimalakirti* (维摩诘像) feature detailed depictions of narrative scenes and environmental elements—amplifying informational disparities.

The Liang Kai cohort (B1) exhibits minimal mean entropy and intermediate variance, indicating reduced overall information density with controlled distributional equilibrium. The lowest entropy value occurs in *Li Bai Reciting Poetry While Walking* (李白行吟图)—where the full figure is rendered in merely twelve brushstrokes—exemplifying Liang’s signature approach of simplicity mastering complexity. Representative works like *Immortal in Splashed Ink Style* (泼墨仙人图) and *The Sixth Patriarch Cutting Bamboo* (六祖截竹图) demonstrate compositional principles characterized by instantaneous capture of kinetic figural dynamics and strategic void treatment in backgrounds, generating potent visual tension. For instance, in *Immortal in Splashed Ink Style* (泼墨仙人图), the torso expands horizontally through pomo ink application, and the head is delineated with fine-line brushwork. This creates sparse upper vs. dense lower textural contrast; the upper void embodies Zen emptiness.

The Muqi cohort (C1) exhibits maximal mean entropy and minimal variance, indicating elevated information density with homogeneous distribution. This richness stems from detailed environmental depictions—

beyond figural elements—in works like *White-Robed Guanyin* (观音图), *Arhat Paintings* (罗汉图), and *Painting of Hanshan and Shide* (寒山拾得图), where rocks and flora are meticulously rendered. In *White-Robed Guanyin* (观音图): Central axial placement of the deity, Light-ink washes modeling mountainous backgrounds, Yin-yang spatial dynamics emerging from void-solid interplay.

Sesshū Tōyō’s Landscape with Figures inherits this compositional logic: Figures offset to one side, Expansive void implying infinite nature, Asymmetrical void-occupation disrupting panoramic equilibrium, Emphasis on psychic imagery over formal balance.

In summary, Sesshū Tōyō’s compositions exhibit a moderate overall information density, marked by pronounced distributional heterogeneity. Works such as *Sakyamuni Leaving the Mountains* (出山释迦图) and *The God of Longevity* (寿星图) showcase brushwork techniques that resonate with Liang Kai’s dynamic, abbreviated figural style, emphasizing expressive immediacy and rhythmic vitality. In contrast, paintings like *Huike’s Severed Arm* (慧可断臂求法图) and *The Portrait of Vimalakirti* (维摩诘像) reveal spatial strategies aligned with Muqi’s void-infused aesthetics, deploying detailed environmental narratives to achieve atmospheric depth and visual embodiment of emptiness. Together, these affinities reflect Sesshū’s ability to synthesize Southern Song compositional logics within a distinctly Japanese Zen visual idiom.

During its Sinicization, Zen Buddhism underwent a process of syncretic assimilation, notably integrating Daoist principles such as the unity of heaven and humanity into its doctrinal and aesthetic frameworks. This conceptual evolution highlights a fundamental truth: Zen aesthetics are not a peripheral phenomenon but an intrinsic component of China’s traditional aesthetic system. To exclude them is to leave any account of Chinese artistic heritage critically incomplete.

Zen-infused painting embodies this aesthetic philosophy by stripping away the distractions of the external, chaotic world, allowing spiritual clarity to emerge through visual form. In the creative process, the artist internalizes Zen discipline, organizing thought and manifesting inner states of mind through brushwork and compositional structure. The result is a body of work characterized by innovative spatial logic and transcendental imagery, which together established enduring paradigms in East Asian art history and continue to inform the visual language of Zen aesthetics today.

### Comparative analysis: compositional differences between Sesshū Tōyō and Liu Songnian’s Hanging scroll figure paintings

To ensure thematic consistency in comparative analysis, Zen-themed figure paintings from Southern Song academic painters were evaluated. Given Liang Kai’s court affiliation and his established influence on contemporaries (Jia Shigu, Yu Qi, Li Quan, Liu Pu, etc.), comparative study within this lineage offered limited analytical value. Therefore, Liu Songnian’s Zen figure paintings were selected based on temporal proximity and artistic milieu.

#### (1) Sample Preprocessing

This study collected: 9 Zen-themed hanging scroll figure paintings by Liu Songnian and 14 hanging scroll figure paintings by Sesshū Tōyō. Sample groupings and representative exemplars are documented in Table 10.

Table 9 | Representative artworks: Sesshū Tōyō, Liang Kai, and Muqi

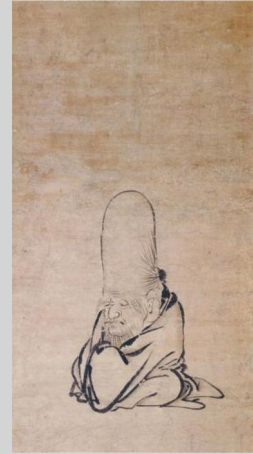
A1  
Sesshū Tōyō  
Exemplars



Painting of Shennong  
《神农图》 (Cultural Note: Shennong, mythical inventor of agriculture)



Portrait of Du Fu  
《杜子美图》 (Historical Context: Du Fu (712-770), Tang dynasty poet)



The God of Longevity 《寿星图》 (Iconography: Star God of Southern Polar Constellation)

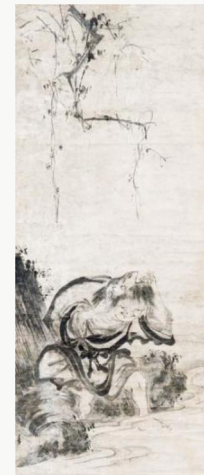
B1  
Liang Kai  
Exemplars



Hotei  
《布袋图》 (Zen Significance: Laughing Buddha prototype)



The Sixth Patriarch Cutting Bamboo  
《六祖截竹图》 (Key Scene: Huineng demonstrating sudden enlightenment)



Painting of Lihai the Immortal  
《刘海仙人图》 (Daoist Tradition: Coin-dancing toad tamer)

C1  
Muqi Exemplars



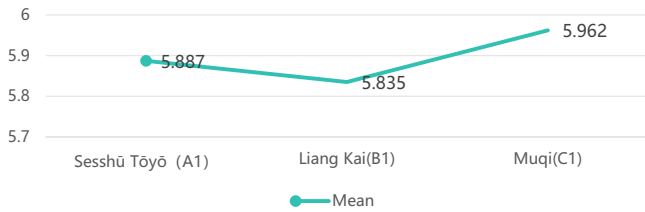
The Monk Called "Clam-Monk"  
《蜆子和尚图》 (Zen Folklore: Tang dynasty eccentric monk)



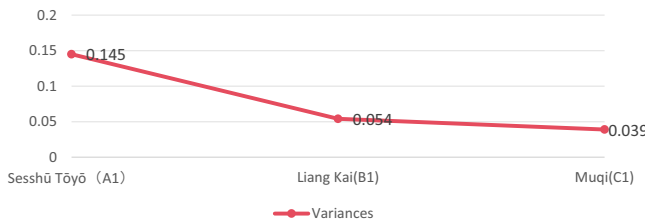
Portrait of Laozi  
《老子图》 (Philosophical Icon: Founder of Daoism)



Fenggan the Monk 《丰干图》 (Zen Triad: Companion to Hanshan and Shide)





**Fig. 6 | Comparison of mean entropy across artists.** The plot presents the average entropy values for Sesshū Tōyō (A1), Liang Kai (B1), and Muqi (C1). Higher mean entropy indicates greater overall information density within the composition.



**Fig. 7 | Comparison of entropy variance across artists.** The graph displays the entropy variance for Sesshū Tōyō (A1), Liang Kai (B1), and Muqi (C1). Greater variance reflects increased spatial heterogeneity in information distribution, indicating stronger contrast between subject and background zones.

**Table 10 | Comparative cohort sample**

No.	Artist	Primary Pictorial Elements	Representative Exemplars of Hanging Scroll Figure Paintings
A1	Sesshū Tōyō (14)	Figure	
D1	Liu Songnian (9)	Trees, Tables and chairs, Believers, Railings	

Uniform luminance (+45) and saturation (+28) calibrations were applied using Adobe Photoshop CC 2023. Post-denoising pre-processing enhanced the reconstruction of authentic compositional structures and brushstroke details.

**(2) Subject Position Identification—Experiment 2: Comparative Analysis**

Experiment 2 similarly employed a 6 × 6 block configuration for image block entropy analysis. The resulting block-entropy heatmaps for all samples are presented in Table 11.

Liu Songnian (D1) block means and quartiles, as well as block mean visualisation, are shown in Tables 12–14. The maximum block mean is 6.786, located at V(2,5), and the 75th percentile value is 6.613. Therefore, the high entropy value coordinate range is defined as 6.786 to 6.613. Compared to other groups, this group has a higher entropy value, indicating more detailed painting elements. The high-entropy coordinate corresponds to the blocks V(1,4) to V(1,5), V(2,3) to V(2,5), V(3,4) to V(3,5), V(4,4) to V(4,5), and V(5,5). Overall, high-entropy data is predominantly found in rows 4 to 5. The vertical scroll figure paintings by Sesshū Tōyō, Liang Kai, and Muqi have a lower centre of gravity compared to others, indicating that Zen Buddhist aesthetics favour a ‘lower centre of gravity’ composition, with the upper blank space symbolising the Zen concept of ‘emptiness.’ The high-entropy value coordinates on the left side of the painting are more numerous than on the right, indicating that the main subject of Liu Songnian’s vertical scroll figure paintings is primarily distributed in the middle-left portion of the painting.

**(3) Global Information Distribution Analysis**

The sample mean and variance were calculated to analyse the overall information features, and the results are shown in Figs. 8 and 9.

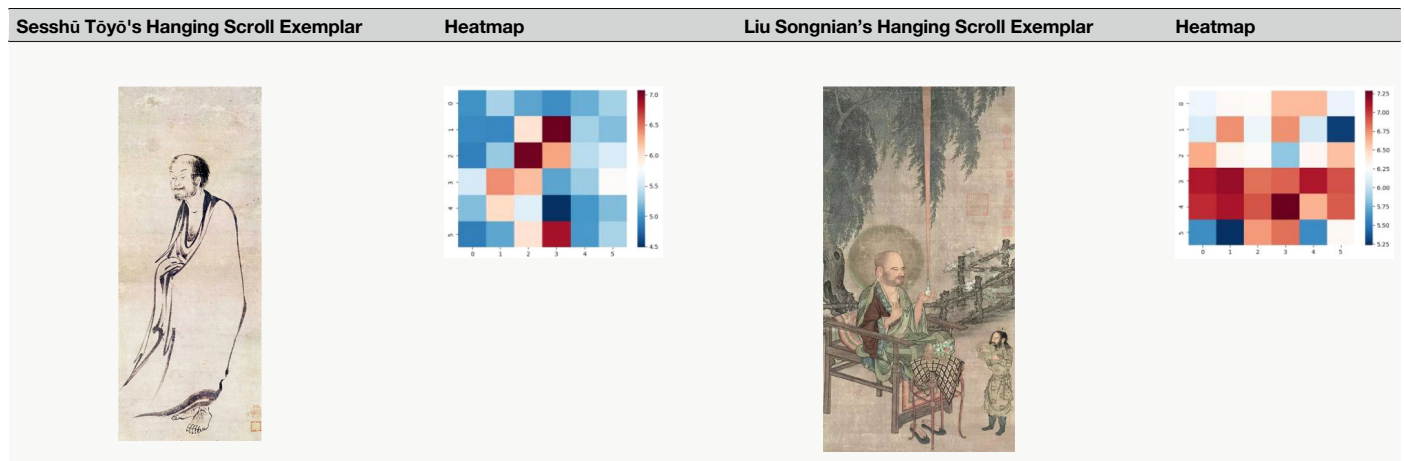
The mean entropy plot (Fig. 8) reveals: *Liu Songnian (D1)* > *Muqi (C1)* > *Sesshū (A1)* > *Liang Kai (B1)*. The variance plot (Fig. 9) shows: *Sesshū (A1)* > *Liu Songnian (D1)* > *Liang Kai (B1)* > *Muqi (C1)*. Detailed analysis reveals: Liu Songnian’s pictorial richness surpasses that of Sesshū Tōyō, Liang Kai, and Muqi, with pronounced distributional unevenness. His hanging scroll *Arhat Assembly* emphasizes comprehensive narrative presentation, employing Three Distances perspective to partition space through layered rocks and architecture, embedding figures within intricate environments saturated with detail - starkly contrasting the “void-centered compositions” of Sesshū, Liang Kai, and Muqi. This academic tradition prioritizes physical verisimilitude and symbolic scenography with explicit Confucian didactic purpose, fundamentally opposing Zen’s abstract “direct pointing to mind” expression. Liu Songnian adopted Li Tang’s axe-cut texture strokes for precisely contoured rocks, while delineating drapery with iron-wire lines; conversely, Sesshū deliberately compromised linear precision to pursue Muqi-inspired spontaneous ink dots, using frayed-brush strokes to emphasize textural rawness and manifest Zen painting’s “untrammeled class”. This dichotomy reflects the fundamental opposition between Southern Song academic painting’s worldliness and Zen painting’s transcendental spirituality.

Sesshū Tōyō’s compositional approach essentially constitutes a culturally-grafted transformation of Southern Song Zen painting: he synthesized Liang Kai’s dynamic abbreviated brushwork with Muqi’s void permeation, transmuting Zen’s “wordless enlightenment” into visual syntax while rejecting the realist tendencies of Southern Song academic painting. Conversely, the academic tradition epitomized by Liu Songnian—through its fixation on objective order—forms the antithetical framework to Zen-inspired composition.

**Discussion**

This study employs machine learning algorithms to investigate the cross-cultural reception of Southern Song Zen painting styles by analyzing the compositional structures of hanging scroll figure paintings by the Japanese monk-painter Sesshū Tōyō and Chinese Zen masters Liang Kai and Muqi. Utilizing an image block entropy model to quantify spatial distributions, the analysis reveals consistent compositional signatures across all three artists: primary subjects consistently cluster around coordinate V(3,5) in the lower-central region, with a marked concentration along Row 5, reflecting a lowered visual

**Table 11 | Block-entropy heatmap**



**Table 12 | Block-mean values by sample**

Sesshū Tōyō: Hanging Scroll Figure Painting (Cohort A1)						
V	1	2	3	4	5	6
1	5.331	5.491	5.319	5.288	5.243	5.498
2	5.415	5.523	5.587	5.788	5.523	5.762
3	5.634	5.786	6.266	6.184	5.815	5.693
4	5.459	6.056	6.290	6.135	6.301	5.845
5	6.004	6.303	6.582	6.233	6.437	6.365
6	5.776	6.074	6.239	6.436	6.203	6.068
Liu Songnian: Hanging Scroll Figure Painting (Cohort D1)						
V	1	2	3	4	5	6
1	6.103	6.110	6.128	6.090	6.047	6.013
2	6.364	6.409	6.478	6.256	6.055	5.982
3	6.535	6.613	6.536	6.294	6.235	6.414
4	6.633	6.729	6.692	6.700	6.605	6.524
5	6.660	6.786	6.707	6.656	6.724	6.367
6	6.213	6.235	6.351	6.289	6.273	6.144

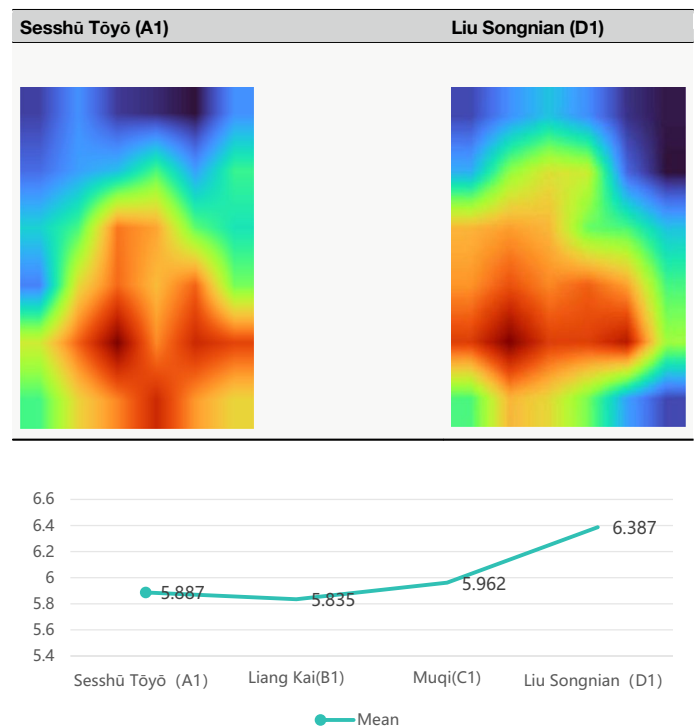
**Table 13 | Quartile Distribution of Block Means**

Cohort	Min	Q1 (25th Percentile)	Median (Q2)	Q3 (75th Percentile)	Max
A1	5.243	5.523	5.815	6.233	6.582
D1	5.982	6.144	6.364	6.613	6.786

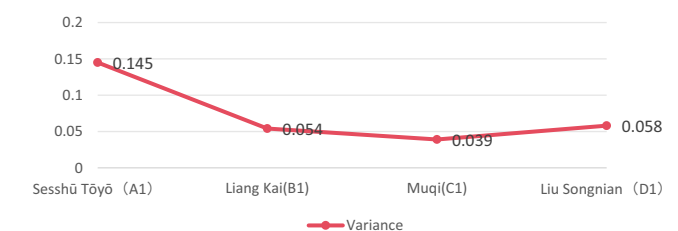
center of gravity. This spatial tendency sharply contrasts with the elevated focal points characteristic of Liu Songnian’s academic court paintings. Furthermore, Sesshū’s works exhibit moderate information density and deliberately asymmetrical distribution patterns, suggesting a synthesized compositional logic that both inherits and transforms Southern Song Zen paradigms within a Japanese context.

The data reveal Sesshū’s strategic adaptation of Southern Song traditions. He synthesizes Liang Kai’s economical brushwork and Muqi’s void-centered spirituality through localization strategies. Technically, he replaces Liang’s gestural dynamism with vigorous angular strokes—exemplified by geometric drapery folds in *Huike’s Severed Arm* (慧可断臂求法图)—while counterbalancing Muqi’s emptiness with narrative elaboration, as seen in botanical details of *Painting of Shennong* (神农图). Aesthetically, he hybridizes Southern Song’s “sudden

**Table 14 | Block-Mean Visualizations**



**Fig. 8 | Comparison of mean entropy across artists.** The plot presents the average entropy values for Sesshū Tōyō (A1), Liang Kai (B1), Muqi (C1), and Liu Songnian (D1). Higher mean entropy indicates greater overall information density within the composition.



**Fig. 9 | Comparison of entropy variance across artists.** The graph displays the entropy variance for Sesshū Tōyō (A1), Liang Kai (B1), Muqi (C1), and Liu Songnian (D1). Greater variance reflects increased spatial heterogeneity in information distribution, indicating stronger contrast between subject and background zones.

enlightenment” ethos with Japanese wabi-sabi austerity and bushido resolve, manifested in the desolate snowscape and spiritual intensity of *Sakyamuni Leaving the Mountains* (出山釋迦圖). This transformative process highlights a fundamental transmission mechanism: Zen visual language undergoes tripartite reshaping through regional religious practices (e.g., Japanese Zen’s ascetic rigor), natural philosophy (e.g., seasonal setsugetsuka sensitivity), and cultural psyche (e.g., mono no aware consciousness).

Critically, Sesshū’s compositional approach rejects Liu Songnian’s rigorous formalism in favor of improvisational spontaneity rooted in Zen logic. His departure from representational order marks a functional evolution wherein Zen painting transitions from religious instrumentation to cultural identity vectors—a shift demonstrating that reception efficacy is ultimately dictated by political frameworks, social hierarchies, and period-specific demands within the adopting culture.

Methodologically, the block-entropy algorithm employed in this study reduces the subjective biases inherent in traditional stylistic interpretation, while its parameter-adjustable architecture allows for the mitigation of errors arising from partition variability and chromatic interference. Nevertheless, certain limitations persist—chiefly, the inconsistent quality of digital reproductions, which may suffer from resolution loss, aspect-ratio distortions, or color inaccuracies, as well as the restricted sample scope drawn from selected exemplars. Although we have sought to ensure the highest feasible image quality in our dataset, certain limitations remain. Given the heterogeneity of the source materials, the fidelity of the collected images is not fully consistent. To maintain the integrity of the originals, all analyses were conducted using the pixel data as acquired. Future work will prioritize obtaining higher-resolution images, establishing preprocessing protocols for lower-quality materials, expanding the dataset to encompass a wider range of East Asian Zen artworks, and refining entropy-based models to better accommodate polychromatic and multichannel visual data. Ultimately, this computational method contributes to comparative studies of cross-cultural reception of Zen painting styles by quantitatively tracing the transformation of aesthetic “genes” as they mutate across geopolitical boundaries, while preserving their underlying spiritual lineages.

## Data availability

The datasets used and analyzed during the current study are available from the corresponding author (R.r.F.) upon reasonable request.

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## References

- Jun, H. Y. A review of East Asian paintings reflecting Zen philosophy (선종사상이 반영된 동아시아 회화 고찰-산성도와 심우도를 중심으로). *Study Cult. Art.* (문화와예술연구) **23**, 223–249 (2023).
- Prieto, J. M. & Donas, J. B. Medieval Japanese Zen painting in the Muromachi period. Study of a hanging scroll attributed to Sesshū Tōyō (雪舟等楊): Hānshān (寒山) the poet, or Zhutou/Zhimeng (猪頭/志蒙), the boar’s head priest?. *Medio Aevo* **14**, 129–157 (2025).
- Levine, G. P. A. Critical Zen art history. *J. Art Historiography* **15**, 12–46 (2016).
- Cahill, J. *Chinese Painting* (95.98) (Rizzoli International, 1985).
- Shin, K. A Study on the Zen Paintings by Muqi in the Chinese Southern Song Dynasty (南宋代 牧谿 筆 禪宗 畫 에 대한 一 考察). *BULKYOMISULSAHAK* (불교미술사학) **35**, 53–79 (2023).
- Zhan, B. *Muqi: A Study of the Stylistic Transmission of Chan Painting from China to Japan* (Purdue University, 2015).
- Welter, A. Reimagining the Dharma: Yanshou, Daoyuan, and Zanning on the Three Pillars of Buddhism. *Int. J. Buddh. Thought Cult.* **32**, 21–50 (2022).
- Fraleigh, M. Approaching Classical Chinese Poetry in Early Modern Japan: Intralingual and Interlingual Translation Strategies in Rikunyo’s Remarks on Poetry. *Sungkyun J. East Asian Stud.* **23**, 137–162 (2023).
- Welter, A. The Hangzhou Region and the Spread of East Asian Buddhism. *Religions* **15**, 201 (2024).
- Min, T. & Zhang, T. Bidirectional transmission mapping of architectural styles of Tibetan Buddhist temples in China from the 7th to the 18th century. *Religions* **15**, 1120 (2024).
- Trần, T. D. Doctrine beyond borders: the sinographic cosmopolis and religious classics in Vietnam from the tenth to the fourteenth centuries. *Sungkyun. J. East Asian Stud.* **23**, 1–26 (2023).
- Fu, R. Chan Gong’an and the “flexible method”: a study on Xuedou Chongxian’s Classic Eulogies and its influence on poetics. *Religions* **14**, 1105 (2023).
- Cha, J. H. & Kim, Y. J. Rethinking the proportional design principles of timber-framed Buddhist buildings in the Goryeo era. *Religions* **12**, 985 (2021).
- Zeng, X. Constructing a sacred site overseas: the Japanese Reinvention of the Rujing Stūpa in Hangzhou. *Religions* **14**, 1542 (2023).
- Zhang, Y. The meaning of the Patriarch’s coming from the west: a study of Triptych of Three Zen Masters: Linji, Bodhidharma, and Deshan. *Religions* **15**, 1285 (2024).
- Fraser, S. E. & Chen, S. Encounters with Chan: Tales of the Eight Eminent Monks 八高僧故事圖卷 Attributed to Liang Kai 梁楷. *Arch. Asian Art.* **75**, 29–48 (2025).
- Malinina, E. E. Motif of the way and spiritual pilgrimage in Zen Art. (Мотив Пути и духовных странствий в искусстве буддизма дзэн.). *Vestn. Novosibirskogo Gosudarstvennogo Universiteta (Вестник Новосибирского государственного университета), Seriya: Istoriya, Filologiya* (Серия: История, филология) **23**, 70–78 (2024).
- Oliva, D., Hinojosa, S., Osuna-Enciso, V., Cuevas, E., Pérez-Cisneros, M. & Sanchez-Ante, G. Image segmentation by minimum cross entropy using evolutionary methods. *Soft Comput.* **23**, 431–450 (2019).
- Li, Y., Li, Z., Wei, K., Xiong, W., Yu, J. & Qi, B. Noise estimation for image sensor based on local entropy and median absolute deviation. *Sensors* **19**, 339 (2019).

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## Author contributions

R.r.F. and J.x.L. wrote the main manuscript text and R.y.F. was responsible for the algorithmic component. All authors reviewed the manuscript.

## Competing interests

The authors declare no competing interests.

## Additional information

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