Mapping Aesthetics in Competitions: Applying a computational aesthetics framework for historical comparison of architectural competitions

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Abstract. This study applies a computational aesthetics framework to analyze and compare architectural competition submissions for the Brazilian pavilion at five World Expositions (1970–2025). Unlike previous studies focusing on winning entries, this research includes a broader range of submitted proposals, enabling historical analysis of formal tendencies over five decades. A dataset of perspective images was compiled from academic sources and official archives. Six aesthetic metrics—compression complexity, brightness, fractal dimension, depth composition, aesthetic measure, and predicted hedonic response—were extracted using image processing, segmentation, and a trained neural network model. The results reveal evolving design trends, including increasing visual complexity, stabilization of brightness, and a return to spatial contextualization in recent renderings. Surprisingly, aesthetic efficiency and predicted pleasure remain loosely correlated, suggesting designers balance compositional order with emotional resonance. This research demonstrates how computational methods can enhance our understanding of historical aesthetic shifts in architectural representation and competition culture.

Keywords: Computational Aesthetics, Architectural Competitions, Visual Complexity, Design Analysis, Pavilion Architecture.

1 Introduction

Architectural competitions serve as a critical lens for analyzing the evolution of design aesthetics, jury preferences, and the impact of technological advancements in architecture. While previous studies have focused mainly on winning entries, this research extends the analysis to non-winning submitted proposals in pavilion competitions from the 1970s to today. By examining competitions for the Brazilian pavilion for the world expos, this study aims to use computational aesthetics to identify historical aesthetic trends, detect recurring formal strategies in winning and non-winning designs, and evaluate the role of digital tools in shaping museum proposals. The findings will contribute to using quantitative aesthetic methods to understand how aesthetic trends have evolved.

Brazil's involvement in international expositions began with the International Exhibition of 1862, held in London at the Crystal Palac. Under the reign of Emperor Dom Pedro II, Brazil presented itself as a modern and economically promising nation, exhibiting agricultural products alongside mineral resources and artisanal crafts. This inaugural participation started a sustained presence at World's Fairs. By 1889, Brazil had constructed its national pavilion, reflecting an investment in architectural representation. A milestone came in 1939, at the New York World's Fair, when Brazil commissioned a pavilion through a national competition. The winning project was submitted by Lúcio Costa, with Oscar Niemeyer—who placed second—later invited to collaborate on the final design. This building marked Brazil's alignment with the emerging ideals of modern architecture.

This study compiles and analyzes five pavilion competitions, each representative of its time: Osaka (1970), Sevilla (1992), Milano (2015), Dubai (2020), and Osaka (2025). This research did not consider the New York pavilion because of the lack of public documents on the non-winning designs.

1.1 Osaka Pavillion (1970)

Although this competition was organized in 1969 and completed in just 25 days, it received an impressive 83 submissions, reflecting the significant interest it generated among Brazilian architects (Fialho, 2007). Considered the most important architectural competition in Brazil since the design of Brasília, it marked a key moment in the country's architectural culture for the high quality of proposals submitted. The image database used in this study was constructed based on the documentation compiled in Fialho's thesis, which draws from *Revista Acrópole* (1969, 1970). The winning proposal by Paulo Mendes da Rocha was built and praised for its elegant structural composition.

1.2 Sevilla Pavillion (1992)

The competition for the Brazilian Pavilion at Expo 92 in Sevilla occurred between 1990 and 1991 when 165 designs were submitted. The competition received significant attention in architectural media, with critical reviews published in *Revista Projeto* (1991) highlighting both the strengths and controversies of the final result. Unfortunately, the winning project by Angelo Bucci, Alvaro Puntoni, and José Oswaldo Vilela was never built.

1.3 Milano Expo (2015)

In 2014, Brazil's national design competition to select the pavilion for Expo Milano 2015 drew 46 submissions, and the jury awarded three top prizes and seven honorable mentions in a single-stage process. The winning proposal by Studio Arthur Casas and Atelier Marko Brajovic resulted in a pavilion with a tensile network resembling a public square.

1.4 Dubai Expo (2020)

Brazil's pavilion for Expo 2020 (Dubai) was selected through a competitive design process in 2018 in preparation for the fair initially scheduled for 2020 (but held in 2021–2022). The contest attracted 42 architecture firms, including MMBB Arquitetos, Ben-Avid, and JPG.Arq, who was chosen to build. Their winning design featured an immersive "Amazon basin" with a shallow reflecting pool and a tensile steel-and-fabric canopy.

1.5 Osaka Expo (2025)

In October 2022, an open national design competition for Brazil's pavilion was launched, received 40 submissions, and was awarded first place for the collaborative proposal by Studio MK27 and Magnetoscope. Their design was based on a suspended, modular canopy that enclosed a three-level, multisensory experience. However, in April 2024, the Brazilian government announced that the pavilion would not be constructed.

2 Methodology

The methodology of this research consists of (1) dataset building, (2) computational aesthetics analysis, and (3) data visualization.

2.1 Dataset building

Initially, we implemented an automated image-harvesting pipeline for each competition that issues paginated Google Images queries via the SerpAPI client, restricting results to full-resolution images. Each batch passed through a CLIP-based classifier to remove photos of the built pavilion and retain only perspectives made by various techniques from renderings, hand-drew perspectives, collages, and physical model photos.
However, the dataset built via image-harvesting consisted mainly of various representations of the winning proposal, demising the goals of this research by focusing on non-winning submissions. Therefore, a more traditional method was applied by building a dataset based on available documentation from

academic sources (Fialho, 2007; Torggler, 2023), specialized magazines such as *Revista Acrópole* (1969, 1970) and *Revista Projeto* (1991), and websites such as concursodeprojetos.org and ArchDaily. Websites for the 2015, 2020, and 2025 exhibitions used to contain all submissions. However, they are offline. Unfortunately, not all submissions could be found and included in the dataset, as presented in Table 1. The dataset consisted only of perspective images submitted to the competitions because the computational aesthetics framework focused only on this kind of image because they more closely resemble how a subject experiences an object.

Table 1. Number of submissions to the competition and projects and images belonging to the dataset.

Competition	Submissions received	Projects in the dataset	Number of images
Osaka 1970	83	9	21
Sevilla 1992	165	61	102
Milano 2015	46	10	111
Dubai 2020	42	7	54
Osaka 2025	40	5	61

2.2 Computational Aesthetics Analysis

Our computational aesthetic framework builds on a previous publicly available framework (Sardenberg, 2024; Sardenberg et al., 2024) and analyzes each architectural perspective in six metrics that together characterize its formal complexity, pictorial structure, and inferred user appeal:

Compression Complexity: We calculate the compression ratio by saving the image as a lossless PNG and comparing its compressed file size to it (Birkin, 2010). Higher values indicate more visual information, while lower values reflect greater uniformity or repetition.

Mean Brightness: We compute the average luminance across all pixels to capture the image's overall lightness or darkness. This global brightness measure captures perceived clarity and mood.

Fractal Dimension: We estimate how detail fills space across scales by applying a box-counting algorithm to a binary edge map (Kulcke & Lorenz, 2023). The fractal dimension (between 1.0 and 2.0) quantifies textural complexity: values closer to 2 indicate richly detailed surfaces, whereas values near 1 denote simpler, sparser forms.

Depth Segmentation: Using a pre-trained ZoeDepth segmentation of the scene into the foreground, midground, and background regions, we measure the proportional area of each zone. The relative zone percentages serve as a proxy for compositional depth—how tightly or expansively the design is.

Adapted Aesthetic Measure (AM): From two segmentation outputs—MSER parts and SAM for larger architectural elements—we construct (A) A Diagram of Scaled Parts, in which each detected region is uniformly resized and overlaid to reveal part count and distribution, and (B) A Connectivity Graph, linking centroids of overlapping parts to edge counts and average link lengths. We then compute:

$$\text{Aesthetic Measure} = \frac{\text{Order}}{\text{Complexity}} = \frac{\text{Connection edge length average} \times \text{Number of connections}}{\text{Number of parts} \times \sqrt{\text{Number of pixels}}}$$

This formula captures the density of compositional order relative to the viewer's perceptual effort.

Predicted Hedonic Response (PHR): All five preceding features are concatenated and fed into our trained artificial neural network, trained on thousands of crowdsourced scores from the AVA dataset (Murray et al., 2012). The PHR outputs a 0–10 hedonic score—an estimate of how an audience is likely to rate each perspective.

By applying these six metrics to every entry, we build a multi-dimensional profile of form, texture, illumination, spatial depth, structural order, and anticipated appeal—enabling quantitative comparison and historical trend-spotting across decades of competition submissions.

2.3 Mapping

Principal Component Analysis (PCA) is a dimensionality reduction technique that projects high-dimensional data—such as visual features extracted from architectural images—into a 2D space while preserving as much variance as possible. In architectural analysis, PCA maps help reveal patterns of similarity, clustering, and outliers among design proposals. Architects and researchers can identify dominant styles, trace formal evolutions over time, and compare how submissions relate visually within or across competitions by visualizing how projects group or diverge based on their aesthetic attributes.

3 Results

To validate the use of this aesthetic framework for studying competition trends, each aesthetic metric is compared by plotting charts demonstrating how they evolve across each competition.

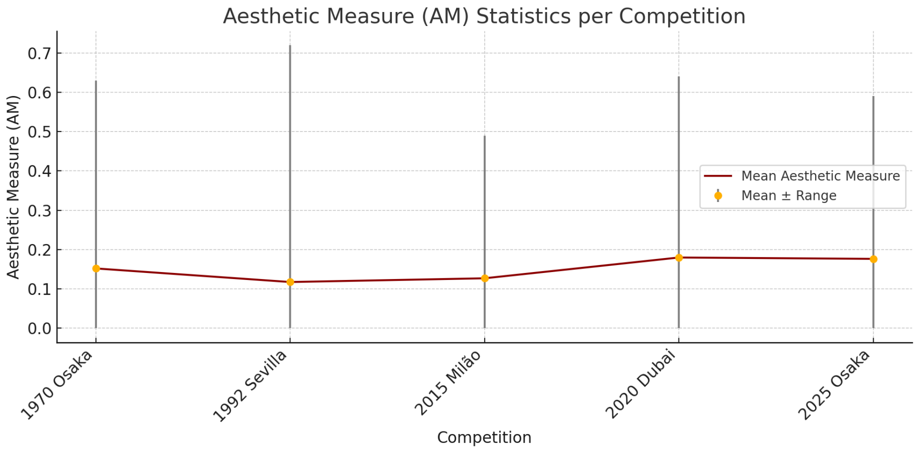


Figure 1. Aesthetic measure statistics per competition. Source: Authors, 2025.

The Aesthetic Measure (AM, figure 1) quantifies a design's visual order relative to its complexity—an "aesthetic efficiency" score reflecting structural coherence. Across competitions, AM values are generally low, indicating that few entries achieve high compositional balance. The temporal variation reflects stylistic shifts: early hand-drawn entries showed moderate AM, while postmodern periods declined due to visual eclecticism. Recent increases in AM suggest digital tools may aid in harmonizing complexity and order, though highly efficient designs remain rare. AM appears independent mainly of basic features like brightness, instead capturing deeper organizational qualities. Overall, the metric reveals a long-term evolution from clear ordering principles to complexity-driven expression, with contemporary designs aiming to reconcile intricacy with visual clarity.

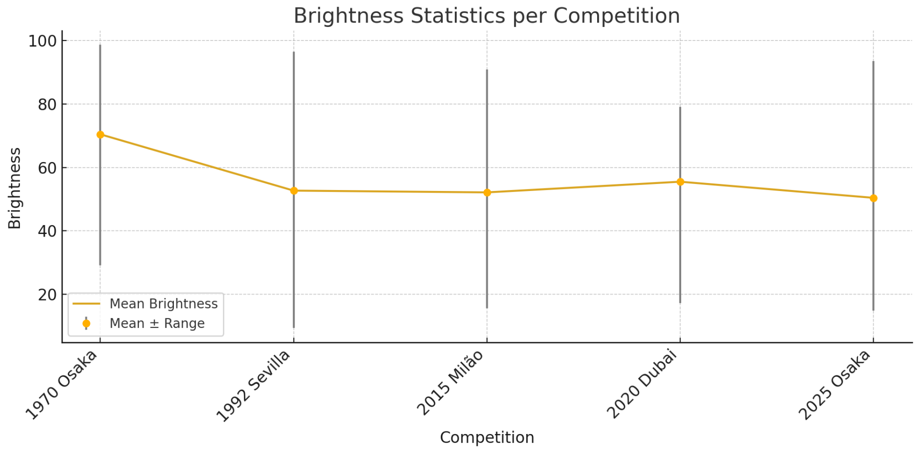


Figure 2. Brightness statistics per competition. Source: Authors, 2025.

Brightness (Figure 2) in competition entries has shifted from high-key, white-background drawings to more balanced lighting. Early renderings were brighter, while recent ones used moderate brightness, reflecting photorealistic and atmospheric visualization advances. Moreover, recently, it has become common to see night renders. Most contemporary images now cluster in a mid-range, suggesting better light control to enhance readability without overexposure. Notably, brightness correlates strongly with visual complexity (r ≈ 0.75): brighter images often feature more intricate textures, while dimmer ones tend to simplify detail. This convergence toward optimal brightness reflects evolving representational strategies that balance clarity and visual richness.

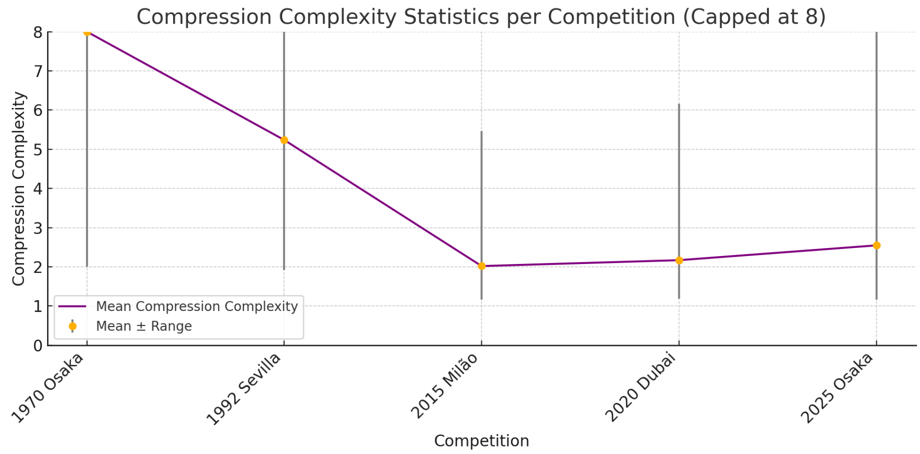


Figure 3. Compression complexity statistics per competition. Source: Authors, 2025.

Compression complexity (Figure 3) reflects visual complexity by measuring how well an image compresses: simple graphics yield high ratios, while detailed ones do not. Older competitions, with sparse drawings on blank backgrounds, are highly compressible. Compression ratios dropped as digital renderings with rich textures and context became standard—indicating greater visual density. By the 2010s, most entries showed low compressibility, marking a clear shift from minimalist graphics to information-rich imagery. Overall, the trajectory points to increasingly detailed competition entries that resist compression highlighting a broader move toward complexity in architectural representation.

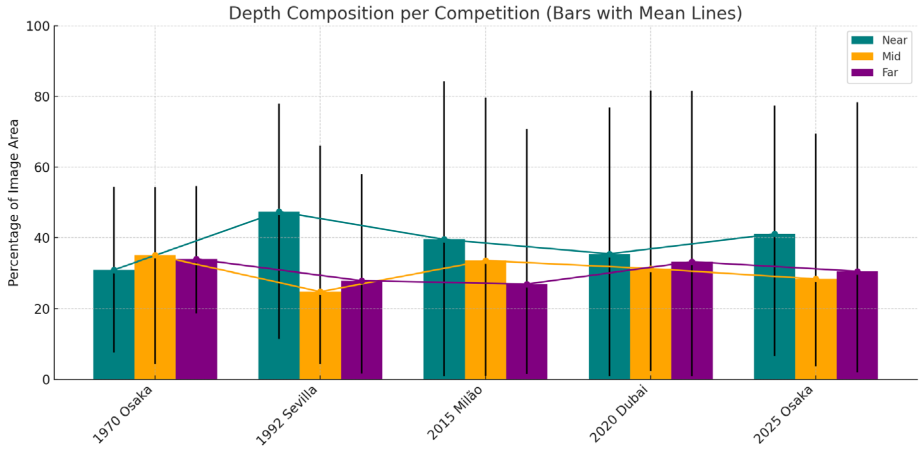


Figure 4. Depth composition per competition. Source: Authors, 2025.

The depth metric (Figure 4) analyzes each image's distribution across foreground, middle-ground, and background, revealing how architects frame spatial focus. Early competition entries showed balanced depth, with equal attention to building and context. By the 1990s, images became foreground-heavy, emphasizing close-up views and minimizing background—a shift driven by dramatic perspectives and hero shots. In the 2010s, renderings began reintroducing more contextual depth, showing sky, surroundings, and layered scenes. Recent entries vary: Some still focus on foreground details, while others restore deep background for immersive compositions. This evolution reflects an oscillation between object-centric and context-rich visual strategies. The metric highlights how architectural representation has shifted between isolating the building and embedding it in a broader spatial narrative. The depth metric's trends underscore the interpretative value of depth: it reveals how presentation techniques have shifted to either isolate the building for impact or embed it within its larger spatial story.

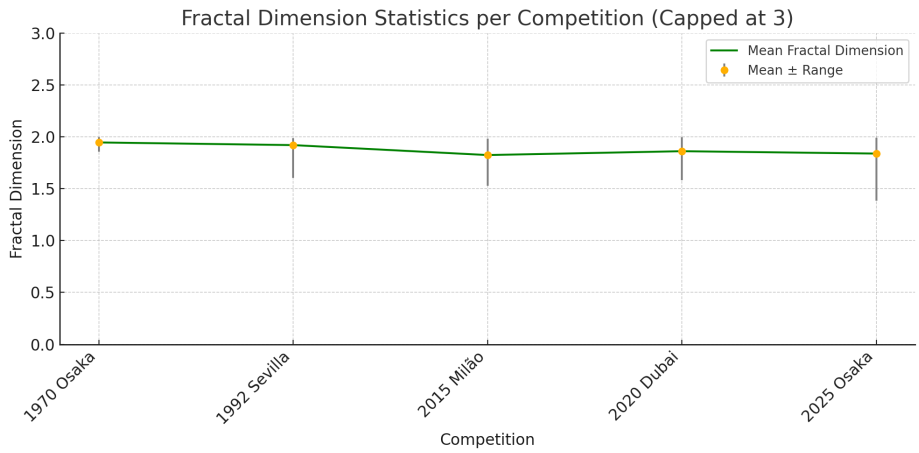


Figure 5. Fractal dimension statistics per competition. Source: Authors, 2025.

The fractal dimension (Figure 5) measures visual complexity by assessing the density of patterns in an image. In architectural competitions, values typically range from 1.5 to 2.0, indicating a consistent preference for moderately to richly detailed visuals. Early entries (1970s) had high value due to dense hatching and line work. This complexity dipped slightly in the late 20th century as styles favored bold massing and open space but rose again in the 2010s with the return of intricate digital renderings and parametric designs. Brightness strongly correlates with fractal dimension—brighter images tend to be more detailed, while darker ones often simplify. Despite stylistic shifts, architectural presentations have maintained elevated levels of visual complexity, with recent works enhancing this through digital means.

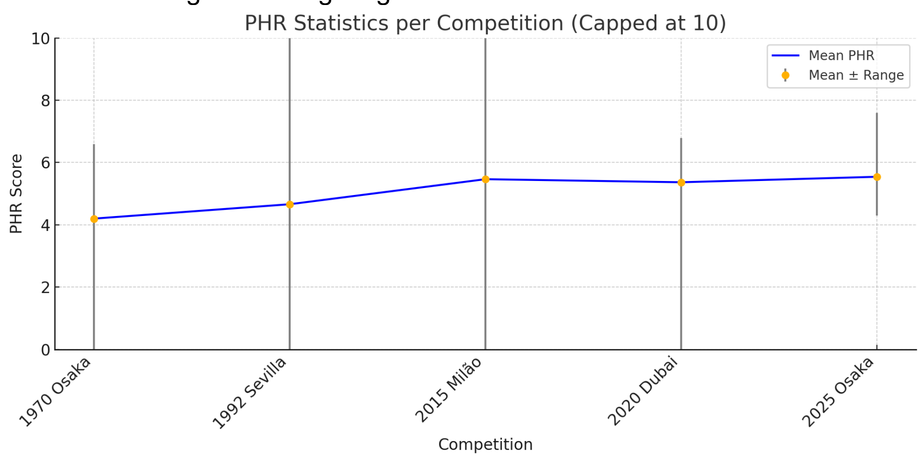
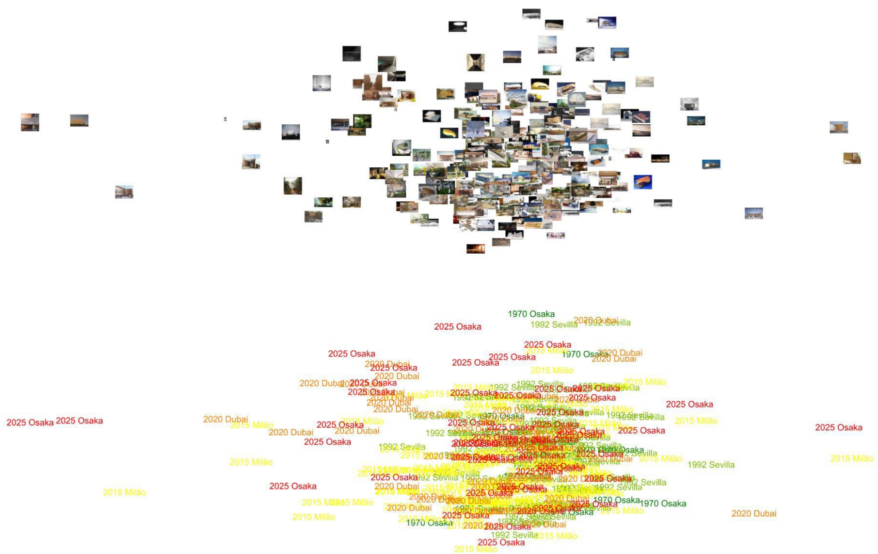


Figure 6. PHR statistics per competition. Source: Authors, 2025.

The Predicted Hedonic Response (PHR, Figure 6) metric estimates the expected user enjoyment of an image, providing a quantitative gauge of how pleasurable an architectural image might be. Across competitions over several decades, PHR values show a gentle upward trend – earlier entries (e.g., mid-20th-century designs) tend to have slightly lower predicted enjoyment scores than more recent proposals, suggesting a gradual shift toward designs that the model deems more pleasurable. Notably, PHR appears independent mainly of other visual aesthetic metrics: studies find only negligible correlations between PHR and measures like brightness, fractal complexity, or even overall aesthetic score. In fact, a slight negative correlation exists between PHR and fractal complexity in competition data, indicating that extremely intricate visuals disfavor predicted pleasure. This data aligns with Berlyne's classic theory that people prefer moderate complexity – too little detail bores, but excessive complexity can overwhelm them (Berlyne, 1971). The implication is that architects may have balanced complexity for comfort over time, yielding designs that are increasingly expected to please without relying on extreme visual intricacy.



Figures 7 and 8. On top is the PCA map of the thumbnail of each image, and on the bottom is the distribution with the competition's label. Source: Authors, 2025.

The two PCA-based visualizations (Figures 7 and 8) offer complementary views of aesthetic similarity and temporal variation in architectural competition entries. The first image map spatially arranges thumbnails by visual features, revealing a dense central cluster of conventionally styled entries and several outliers that diverge in form or representation. The second, labeled by competition year, shows how submissions from different Expos occupy overlapping but distinct regions, with older entries (e.g., 1970 Osaka) appearing more compact and consistent, while recent ones (notably 2025 Osaka) are more dispersed—suggesting greater stylistic variation or experimentation. Together, these maps indicate that while a shared visual language persists throughout the decades, contemporary competitions exhibit both higher aesthetic diversity and a departure from earlier representational norms.

4 Discussion

Examining all six metrics in concert reveals a nuanced picture of evolving aesthetic priorities in architectural competitions over time. Broadly, there is evidence that competition entries have become more complex and visually information-rich as decades progress, yet designers strive to balance this complexity with clarity and user-oriented considerations. Visual complexity (as captured by fractal dimension and compression measures) peaked early in some respects and then resurged with digital design – contemporary entries pack detailed textures and elaborate forms, though tempered by lessons of over-complexity's diminishing returns on enjoyment. Lighting and brightness have stabilized to moderate, controlled levels in modern images, in tandem with complexity: brighter scenes with rich detail are favored, aligning lighting and texture to enhance aesthetic impact. Meanwhile, the predicted emotional response (PHR) to these designs has slightly improved over time, suggesting that newer competition proposals are, on average, crafted to be more intuitively pleasing or comfortable. Moreover, it is important to note that the PHR was trained with contemporary audiences, which means that the hedonic response captured in the AVA dataset reflects contemporary preferences. Importantly, however, PHR remains relatively orthogonal to formal aesthetic metrics – a beautifully composed image does not guarantee higher predicted enjoyment – implying that designers have progressively learned to marry visual appeal with human-centric subtlety rather than simply maximizing visual metrics.

The aesthetic measure (AM), reflecting order amidst complexity, shows that truly high-efficiency designs are rare in every era, but recent works inch closer to that ideal, possibly due to advanced tools allowing better orchestration of visual elements. Finally, changes in depth composition mirror the field's shifting representational ethos: from balanced contextual presentations to object-focused dramatization and back toward contextual integration. Together, these metric trends illustrate an overarching evolution: architectural competition visuals have grown in technical sophistication and complexity, yet the most successful designs orchestrate complexity into coherent, well-lit, and engaging compositions. This methodological insight – quantifiable through computational aesthetic metrics – provides valuable interpretative power: it enables us to chart how design communication has progressed and to understand the delicate balance designers strike between visual richness and experiential readability in conveying architectural visions over time. The findings suggest that while styles and tools have changed, the core challenge remains constant: achieving an aesthetically compelling yet engaging representation of architectural space. Each metric offers a lens on this evolution, and together, they confirm that architectural aesthetics in competition entries are dynamic, responding to technological, cultural, and artistic currents while gradually converging on designs that resonate visually and experientially.

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