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The Application of the "Feitian" Element from the Yungang Grottoes in Jewelry Design

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Abstract. This article employs Principal Component Analysis (PCA) to investigate the perceptual characteristics of Feitian figures in the Yungang Grottoes. It analyzes participants' ranked preferences for these figures' perceptual imagery, extracting three pairs of representative characteristics. Building upon this analysis, the article explores design elements and spiritual communication, presenting a jewelry design methodology that concurrently considers the perceptual, representational, and spiritual aspects of Yungang Feitian figures. The study evaluates three design approaches: traditional, hybrid (traditional and AI-assisted), and pure AI-assisted jewelry design. The objective is to innovate design methodologies, summarize new approaches, and skillfully integrate traditional culture with modern design.

Key words. Yungang Grottoes, Feitian Element, Jewelry Design, Northern Wei Feitian, Sensory Characteristics, AIGC

1. Introduction

Yungang Grottoes embody the fusion of Buddhist art and Chinese culture. Notably distinct in architecture, cultural background, and spiritual attributes, they differ from other Chinese grottoes. Despite extensive research on aspects like architecture and aesthetics, there is a notable gap in exploring product design inspired by the Feitian sculptures in the Yungang Grottoes. This paper employs a research methodology combining quantitative and qualitative analysis. It applies sensory engineering and Principal Component Analysis (PCA) to assess the perceptual tendencies of the Feitian figures. The study analyzes the compositional significance of elements in the Feitian sculptures and interprets their design elements, as well as their underlying spiritual essence. By integrating cultural connotations with contemporary design philosophies, the paper establishes a jewelry design methodology. This methodology is then applied in modern jewelry product design, creating products that encompass both cultural heritage and contemporary aesthetics.

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2. Overview of the Distinctive Features of the Flying Celestial Beings in the Yungang Grottoes

Spanning 65 years from 460 to 525 AD, the Yungang Grottoes, commissioned by the Northern Wei imperial family, house over 51,000 statues, including an abundance of flying celestial beings (Feitian) sculptures. Through on-site investigation and research, over 50 locations with more than 2,300 Feitian figures have been identified [1]. The Buddhist statues in the grottoes can be categorized into three distinct periods based on their portrayal of Feitian figures [2].

During the initial phase under the "Central Asian Model," the Yungang Grottoes, then known as the "Five Caves of Marvelous Brilliance," were constructed in reverse order, from Cave 20 to Cave 16. In this phase, both male and female Feitian figures were present, characterized by robust physiques and rugged facial features, emanating a pronounced Central Asian Gandhara influence [3]

In the middle phase under the "Yungang Model," influenced by Han culture [4], the Yungang Grottoes' construction combined Central Asian and Han styles. Delicate facial expressions and a celestial landscape emerged, distinguishing this period. This marked a fusion of the "Central Asian Style" and "Han Cultural Style."

In Figure 1, robust "Central Asian Style" Feitian figures stand alongside more graceful "Han Cultural Style" counterparts. They're positioned together beneath the pagoda in Cave 6 [5].



Figure 1. The Flying Celestial Being on the Lower Part of the Pagoda Wall in Cave 6

In the "Longmen Model" phase, after Emperor Xiaowen relocated the capital, the Longmen Grottoes emerged. However, it didn't surpass the Yungang Grottoes in importance to Chinese Buddhism. The Yungang Grottoes still relied on devotees' offerings for expansion. With rulers' attention diverted, commoners and officials could contribute. This led to diverse Feitian representations in Caves 4, 15, 22, 23, 27, and 28. Feitian figures evolved towards delicacy and slenderness, influenced by Han culture [6]. Drapery became more intricate. With Northern Wei stability and increased cultural exchange, southern influence grew. This laid the aesthetic groundwork for refined Feitian figures in the Sui and Tang dynasties.

3. A Study on the Sensory Imagery and Element Extraction of 'Feitian' Figures in the Yungang Grottoes

The 'Feitian' sculptures in the Yungang Grottoes exhibit a wide range of styles, from bold and lively to subtle and introverted. Assessing their overall style is challenging due to their diverse and intricate elements. This poses a significant challenge for heritage preservation and redesign.

This section employs statistical principles and methods to determine key sensory imageries representing the 'Feitian' figures in the Yungang Grottoes. This ranking of sensory tendencies supports subsequent design concepts and practices.

3.1 Establishing a sample set of Yungang Feitian images

The Yungang Grottoes house over 2300 Feitian sculptures. Due to their sheer number, individual experiments are impractical. The author curated a representative sample set of 38 figures, encompassing diverse historical periods, cultural influences, sculptural styles, and design elements.

Following expert consultations and group deliberations, a refined selection of 12 well-preserved images with distinct attire and facial expressions was chosen as a reference sample set, shown in Figure 2 [7] [8], to represent the characteristic "Feitian" figures of the Yungang Grottoes. This refined sample set, denoted as Y, was established for subsequent research.



Figure 2. Streamlined Representation of "Feitian" Figures in Yungang Grottoes.

3.2 Establishing a set of evaluation criteria for Yungang Feitian images

After confirming research samples, it's vital to establish evaluation criteria for Feitian imagery in Yungang. The "2H" analysis method proposed here focuses on expressive presentation and spiritual essence, involving "How" (presentation) and "How much" (expansion), as depicted in Figure 3.



Figure 3. Hierarchical Analysis of the Yungang Grottoe "Feitian" Imagery

The current study on the sensory imagery of Feitian figure samples uses the 2H analysis method. In the "How" stage, four dimensions—form, color, content, and texture—are considered. This is combined with adjectives from scholars' regional cultural creative product design library and relevant literature. This results in the sensory

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imagery collection of the characteristic "Feitian" figures in the Yungang Grottoes, referred to as set A (see Figure 4) [9].



Figure 4. The Distinctive Sensory Imagery Collection of "Feitian" Images in the Yungang Grottoes Twelve sensory descriptor sets for assessing "Feitian" figures in Yungang Grottoes were obtained through categorization. While some maintain semantic associations, further reduction through subjective judgment is impractical.

Principal component analysis^[1] condenses variables without significant information loss. The next step involves summarizing the descriptors through surveys and this analysis to identify the most typical sensory characteristics of the "Feitian" figures.

3.3 Data Collection and Analysis

Participants used the semantic differential method to rate the correspondence between 12 selected "Feitian" image samples and sensory evaluations on a scale of -3 to 3 [10] [11]. A total of 162 questionnaires were collected, with 149 considered valid. The average scores for each "Feitian" image sample in the Yungang Grottoes, along with their correspondence with each pair of sensory adjectives, were computed (see Table 1): Table 1. Average Scores for the Consistency between "Feitian" Image Samples and Sensory Evaluation

c					Sen	sory Ima	agery Ind	dicators				
ample	Ŀ.	Α	A	A	Α	Α	Α	Α	Α	Ŀ.	Α	Α
ampic	1	2	3	4	5	6	7	8	9	10	11	12
у	-	-	2	-	1	2	-	0	-	-	-	2
1	1.85	2.1	.51	1.05	.07	.39	0.17	.73	1.15	1.85	2.1	.51
У	1	1	1	1	2	0	-	0	1	1	1	1
2	.73	.25	.61	.71	.13	.07	2.07	.52	.93	.73	.25	.61
у	2	1	0	1	-	-	-	1	-	2	1	0
3	.9	.7	.83	.25	1.82	2.35	2.34	.27	0.02	.9	.7	.83
у	2	-	2	2	-	1	1	2	1	2	-	2
4	.51	2.05	.31	.07	1.02	.92	.62	.1	.01	.51	2.05	.31
у	2	1	0	2	2	2	-	1	1	2	1	0
5	.72	.72	.97	.52	.03	.13	1.74	.79	.72	.72	.72	.97
у	2	2	1	2	-	0	1	2	0	2	2	1
6	.05	.52	.83	.73	2.15	.72	.83	.07	.83	.05	.52	.83
у	2	1	-	0	1	-	-	2	1	2	1	-
7	.15	.83	2.01	.85	.37	1.9	2.03	.31	.41	.15	.83	2.01
у	0	2	1	-	-	1	-	0	1	0	2	1
8	.98	.07	.47	0.27	2.12	.24	0.72	.28	.62	.98	.07	.47
у	1	-	1	2	1	1	1	-	1	1	-	1
9	.1	2.15	.52	.05	.97	.82	.51	0.13	.7	.1	2.15	.52
у	2	1	-	2	-	-	-	1	1	2	1	-
10	.83	.93	1.93	.72	1.83	2.02	0.7	.97	.82	.83	.93	1.93
у	-	-	2	-	1	1	1	-	0	-	-	2
11	1.21	1.45	.07	2	.94	.75	.97	0.5	.15	1.21	1.45	.07

The experimental data was validated using SPSS software. The Cronbach's Alpha coefficient [12] was 0.755, indicating high reliability. Now, we have the mean data matrix for the Yungang Grottoes "Feitian" images.

$$\begin{bmatrix} \bar{x}_{1,1} & \cdots & \bar{x}_{1,12} \\ \vdots & \ddots & \vdots \\ \bar{x}_{1,12} & \cdots & \bar{x}_{12,12} \end{bmatrix}$$
(3)

Using the SPSS software to analyze the principal components of the mean data in equation (3), the output results are shown in Table 2:

Table 2. Total Variance Explained in Sensory Evaluation Data Interpretation of "Feitian" Images						
		Initial Eigenval	ue 'a	Sum of Squares of the Extraction		
Constit		-		Loadings		
uent	Total	Varia nce Percentage	Cumula tive	Tot al	Varia nce Percentage	Cumula tive
1	4.95	41.31	41.319	4.9	41.31	41.319
1	8	9		58	9	
2	2.33	19.45	60.770	2.3	19.45	60.770
2	4	1		34	1	
	1.43	11.95	72.728	1.4	11.95	72.728
3	5	8		35	8	
	1.04	8.673	81.401	1.0	8.673	81.401
4	1			41		
5	0.87 7	7.308	88.709	-	-	-
6	0.69 6	5.797	94.506	-	-	-
7	0.30	2.500	97.006	-	-	-
8	0.20 4	1.697	98.703	-	-	-
9	0.10 1	0.838	99.541	-	-	-
10	0.05	0.415	99.956	-	-	-
11	0.00 5	0.044	100.000	-	-	-
12	3.53 7E-17	2.947 E-16	100.000	-	-	-

Table 2 displays "Initial Eigenvalues," representing the contribution of each component. This percentage signifies its significance. When the cumulative percentage exceeds 80%, it's considered acceptable. For Components 1 to 4, the cumulative variance reaches 81.401%, surpassing the standard. Therefore, selecting Principal Components I to IV effectively captures and summarizes the data relationships. The variance percentages for these components are V_{arl} =41.319%, V_{ar2} =19.451%, V_{ar3} =11.958%, and V_{ar4} =8.673%.

Table 3. Principal Component Loadings for the Sensory Evaluation Indicators of "Feitian"

Evaluation		Principal C		
Criteria	Ι	II	III	IV
1	0.864	0.195	0.156	0.199
2	0.831	-0.143	-0.263	0.186
3	-0.736	0.506	-0.253	0.216
4	0.737	0.509	0.262	0.038
5	-0.432	-0.106	0.699	0.078

6	-0.745	0.603	0.084	0.181
7	-0.523	0.547	-0.016	-0.496
8	0.738	0.239	-0.141	-0.119
9	0.524	0.245	0.559	0.338
10	-0.681	-0.081	0.324	0.321
11	-0.064	-0.764	0.415	-0.399
12	-0.37	-0.615	-0.323	0.494

Table 3 lists the factor loadings, which indicate the correlation between evaluation indicators and principal components. Larger absolute values imply stronger correlation. Dividing these values by the square root of the corresponding initial eigenvalue gives the scoring coefficient matrix for Principal Components I to IV.

$$\begin{bmatrix} a_{1,1} & \cdots & a_{1,4} \\ \vdots & \ddots & \vdots \\ a_{12,1} & \cdots & a_{12,4} \end{bmatrix}$$
(4)

The weighted average of the coefficients of the affective indicators in these two principal component linear combinations yields the model for the weight coefficients of affective evaluation indicators.

$$v_{ai} = \frac{a_{i1}v_{ar1} + a_{i2}v_{ar2} + a_{i3}v_{ar3} + a_{i4}v_{ar4}}{v_{ar1} + v_{ar2} + v_{ar3} + v_{ar4}} , \quad i=1, 2, \dots, 12$$
(5)

Utilizing equation (5), the coefficients of the comprehensive score model for each evaluation indicator are computed. The variables v_{a1} to v_{a12} are normalized to obtain the weights wal to wal2 for the sensory evaluation indicators.

$$w_{ai} = \frac{v_{ai}}{\sum_{i=1}^{l^2} v_{ai}}, \ i=1, \ 2, \ \dots, \ 12$$
(6)

This results in the weight data for the twelve sensory evaluation indicators, as shown in Table 4.

Evaluation Criteria	Composite Score Coefficients	Evaluation Criterion Weights				
1	$v_{al} = 0.267$	$w_{al} = 0.150$				
2	$v_{a2}=0.154$	$w_{a2}=0.086$				
3	$v_{a3} = 0.097$	$w_{a3} = 0.054$				
4	$v_{a4} = 0.283$	$w_{a4} = 0.159$				
5	$v_{a5} = 0.021$	$w_{a5} = 0.012$				
6	$v_{a6} = 0.046$	$w_{a6} = 0.026$				
7	$v_{a7} = 0.087$	$w_{a7} = 0.049$				
8	$v_{a8} = 0.175$	$w_{a8} = 0.099$				
9	$v_{a9} = 0.261$	$w_{a9} = 0.147$				
10	$v_{a10} = 0.094$	$w_{a10} = 0.053$				
11	$v_{a11} = 0.125$	$w_{a11} = 0.070$				
12	$v_{a12}=0.168$	$w_{a12} = 0.095$				

Table 4. Weighted Sensory Evaluation Indicators for "Feitian" in the Yungang Grottoes

The evaluation indicators are ranked as follows: w_{a4} , w_{a1} , w_{a9} , w_{a8} , w_{a12} , w_{a2} , w_{a3} , w_{a10} , w_{a7} , w_{a6} , w_{a5} . The top three pairs of sensory features with the highest weights suggest that the "Feitian" images in the Yungang Grottoes evoke a sense of richness, freedom, and relaxation. This diversity in emotional and sensory characteristics is a key factor in the cherished status of Feitian culture in the Yungang Grottoes as a precious cultural heritage in China.

4. Jewelry Design Practice Based on the Sensory Image of "Feitian" Elements in the Yungang Grottoes

Three sets of affective preference adjectives were derived through principal component analysis. Now, we aim to apply these representative Yungang Feitian imageries in concrete design. First, abstract imagery adjectives will be translated into specific Yungang heritage elements. Then, these cultural design elements will be integrated, emphasizing a core cultural essence. Through various design methods, we'll achieve a unified design expressing the product's spiritual, affective, and representational features.

4.1 The analysis and translation of affective imageries

"Rich" implies density and intensity in attributes like texture, taste, and fragrance. It artistically denotes vibrant colors, refined design, profound spiritual expression, and meticulous attention to detail.

In the Yungang Grottoes, intricate decorative patterns play a vital role in creating a sense of opulence. The widely used honeysuckle pattern embodies regularity and unity, providing a magnificent visual impact and symbolizing orderly governance. This precise, finely carved style with minimal empty spaces became a distinctive feature of the Yungang sculptures.

The honeysuckle pattern is of significant importance in both the visual and spiritual aspects of Yungang art, serving as a crucial reference for subsequent designs.



Figure 5. Excerpt from the Draft of Extracting Honeysuckle Decorative Element^[ii]

"Free-spirited" suggests being carefree and transcendent, evoking a sense of flowing like clouds and water. This perception of the Yungang Feitian is easily understood when examining their distinctive characteristics.

The Yungang Feitian exude lightness, freedom, and exuberance in their graceful figures and billowing garments, conveying a palpable sense of freedom. Symbolically, they represent beings capable of transcending the earthly realm, evoking a spirit of carefree freedom.

In some artistic works, the Yungang Feitian assume poses reminiscent of dance. Through dynamic and graceful forms, they convey an atmosphere of unrestrained freedom and emotional expression, resonating with viewers' sense of carefree emotions.



Figure 6. Excerpt from the Draft of Extracting Feitian Figurative Elements [13]

The Yungang Feitian emanate ease and joy for two main reasons. Firstly, their light and graceful postures naturally instill a feeling of relaxation and comfort in viewers. Secondly, their primary duty is to entertain the Buddha through joyful dances and music, becoming their most significant form of existence. Whether holding musical instruments or engaging in song and dance, the Yungang Feitian create a relaxed and lively entertainment scene, providing viewers with a serene viewing experience.

The pipa, introduced from the Western Regions during the Qin Dynasty [14], became beloved by the imperial court's nobility. It was a fixture at royal banquets. In the Wei and Jin periods, male musicians gained prominence, including court musicians, literati, and scholars. The pipa's association with relaxation aligns perfectly with its representation [15].



 Figure 7. Excerpt from the Manuscript Analyzing Artworks Related to the Pipa Element^{[iii][iv]}

 4.2
 The extraction of the core spiritual essence

Modern product design increasingly emphasizes promoting traditional Chinese virtues and aesthetics. Traditional culture is a vital source of inspiration for artists, enriching their creativity. However, translating it into design often fixates on formal structures, potentially leading to a skewed understanding of its underlying traits. This results in a characteristic feature: a simplistic juxtaposition of traditional elements with modern art, often straying from the original cultural essence.

For jewelry inspired by the Yungang Grottoes' "Feitian" culture, it's crucial to go beyond surface resemblances. Delving into the spiritual characteristics is paramount. This involves exploring the fusion of Hu and Han cultures, gaining insight, and expressing the artistic essence of the Yungang's "Feitian." This approach should be woven throughout the jewelry design process.



Figure 8. Extraction and Essence of the Yungang Flying Celestial Spirit

Chinese dance is often described as an "art of drawing circles [16]," creating a cyclical rhythm. This reflects a pursuit of balance and rotation, symbolizing the harmonious relationship between humanity and nature, and humanity and the universe. Dance postures are linked to the Chinese Tai Chi diagram, illustrating principles of uniform motion, yin and yang interplay, and the ever-changing nature of all things.

Furthermore, Chinese music and dance express the harmonious spirit of Tai Chi through body movement and attire. Feitian's formal features truly capture the essence of harmony and motion.

4.3 Design expression methods

4.4

Generative AI is revolutionizing product design. The era of AI brings intelligent tool platforms, optimizing different design stages. Technologies like 5G boost sales, but with heightened competition, analyzing practical cases with emerging design tools is a prevailing trend.

Integrating intelligent tech expands design thinking, diversifies approaches, cuts costs, and uncovers user needs, leading to more competitive products. The author combines traditional and AI-assisted techniques, showcasing a fusion of conventional and cutting-edge design approaches.



Figure 9. AI-Assisted Design Imagery Generation Illustration Design case expression

The concept of "圆融" (Harmony) originates from Chinese Han Buddhism. "圆" signifies completeness and comprehensiveness, while "融" denotes integration and harmony, implying the attainment of perfect integration by eliminating delusional attachments.

In this artwork, "圆融" encompasses the fusion of Feitian imagery - integrating the pipa and honeysuckle symbolizing music and rules, and the lotus and ribbons representing regeneration and spiritual vitality. It also embodies the wearer's fusion with the millennium-old Yungang Feitian dance. The intertwining of the central jewelry piece with Feitian imagery on the packaging creates an interactive experience, immersing the

wearer in a celestial realm, deepening the spiritual connection. The flowing ribbons, frozen in time, capture the essence of their graceful and lively dance.



Figure 11. "Harmony of the Feitian" Jewelry Design Model and Packaging Effect The AIGC (Artificial Intelligence in Graphic Communication) design technique is executed as follows: Hand-drawn line drafts are first colorized using the Stable Diffusion tool. Various keywords guide the creation of different textures and color combinations, offering a range of options for later selection.



Figure 12. "Harmony of the Feitian" Jewelry Design AIGC Coloring Sketch (AI-assisted completion) Next, select the design products that align with cultural imagery, design specifications, and technical requirements, and proceed with further detailed refinement:



Figure 13. "Fusion of the Celestial Being" Jewelry Design AIGC Coloring Effect Image (AI-assisted completion)

5. Conclusion

This study aims to fuse contemporary design methods with a focus on artistic representation of traditional Chinese culture. By combining mathematics and aesthetics, it offers a clearer organization of key design elements. Additionally, the paper works on refining the AI-assisted design workflow in the context of AIGC development, contributing to both commercial and societal advancements in design modernization and traditional Chinese culture promotion.

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