Symbiosis and Translation: The Aesthetic Expression and Spatial Narrative of Ice and Snow Art from the Perspective of Environmental Art Design

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ABSTRACT Ice and snow art plays an important role in environmental art design; however, limitations related to climate adaptability, material durability, and spatial expression often restrict its long-term development. Based on the theoretical framework of symbiosis and translation, this study investigates the aesthetic expression and spatial narrative mechanisms of ice and snow art through ecological interaction modeling and artistic semantic translation. A database containing 152 ice-and-snow material samples is established to analyze optical reflection, melting duration, and environmental interaction characteristics. Spatial-behavior modeling and virtual simulation techniques are employed to construct a multidimensional scene-interaction system and evaluate spatial-rhythm evolution. Experimental results demonstrate that the proposed framework improves contextual narrative quality and design sustainability, increasing average light-reflection intensity by 27.4%, extending melting delay time by 18 minutes, and improving participant immersion by 35%. The study provides a systematic pathway for integrating environmental perception, spatial simulation, and digital design optimization.

INDEX TERMS ice and snow art, spatial narrative, environmental perception, virtual simulation, digital design optimization

I. INTRODUCTION

BEING the art form, which employs the natural climate and physical changes as its medium, ice and snow art has been steadily growing its usage in environmental art design sphere. But it has been confronted over time with design challenges that include insensitive climatic reliance, fast material deterioration as well as the absence of narrative expansion in the structure of scenes. The susceptibility of ice and snow media to uncontrollable deformation under fluctuating temperature and humidity necessitates the integration of highstrength fiber reinforcements or technical scaffolds to mitigate material fatigue, as the absence of such structural stabilizers restricts the long-term display, semantic perpetuation, and overall spatial agency of the work. Simultaneously, the ice and snow spaces are frequently based on the immobile composition or single lighting projection with disregard to the possible interaction between individuals and the surrounding environment and, as a result, the experience can be limited to the visual perception levels, lacking deep contextual engagement and the elicitation of affective resonance. The challenge of building a perceptible, responsive, and narrative logical system of space without damaging the natural properties of materials has turned out to be a central scientific and artistic concern to the sustainable transformation of ice and snow art [1-2].

To overcome the above restrictions, the research presents the conceptual framework of the symbiosis and translation and restructures the spatial reasoning of ice and snow art by the two-tiered process of ecological response and semantic mapping. The idea of symbiosis focuses more on the co-generational relation of the environment and the design system, by which the space can possess the adaptive capacity to exchange energy and information; and the notion of translation as the process of mapping natural change process into artistic expression, in such a way that the experience of physical perception is converted into narrative experience. The environmental behavior, visual features and audience perception feedback of ice and snow materials are the research object in this paper, and the system of quantifiable analysis is built in the form of field sampling, spatial simulation and narrative modeling. The research aims to establish a design methodology that facilitates the creation of artistic imagery by integrating the material morphology and spatial interlacing logic of technical materials into the dynamic aesthetics and spatial narrative forms of ice and snow art within environmental design [3].

II. RELATED WORK

Current studies cover mostly the expressive ways of ice and snow art considering the technological aesthetics and regional culture with a main emphasis on the advancement of material forming and landscaping strategies. To give an illustration, in the low-temperature construction technology, scientists improve stability in the structure by temperature-based spraying and directional crystal freeze that allows the presentation of ice and snow structure over an extensive scale in the long run. However, this kind of research is usually on the level of structural safety and visual appearance without dynamics of studying how the material behaves in the environment. It does not show how manipulation of materials influences the perception of the audience and the cohesiveness of the narrative, thereby restricting the contextual ability of spatial art to shape its context. Research in the field of environmental art design has gradually focused on the interaction between natural media and spatial perception. Some scholars have tried to introduce behavioral data and scene response models to explore the coupling law between changes in the natural environment and human behavior patterns. In terms of methodology, this type of research emphasizes system thinking, but it mostly focuses on greenhouse ecological devices or plant environment experiments, and rarely involves the time-varying characteristics and artistic semantics of highly sensitive materials such as ice and snow. Therefore, it cannot fully reflect the spatial narrative logic and aesthetic dynamics in the ice and snow environment [4-5]. The theory of "symbiosis and translation" has been expanded in art and design research in recent years, used to explain the design relationship between ecological co-construction and perceptual transformation. In architectural, installation art, and interaction design practices, this theory has been used to establish a mapping mechanism between natural processes and semantic expression. However, existing research mainly focuses on the theoretical extension at the conceptual level, and the quantitative application of environmental behavioral data and the technical construction of semantic generation paths are still insufficient. Considering the characteristics of ice and snow art, this study concretizes this theory into an experimentally verifiable design method, supplementing its application dimension in extreme environment art.

III. METHODS

A. DATA ACQUISITION AND EXPERIMENTAL DESIGN

The research was carried out on-site at the ice and snow installation site of Harbin Art District where the ice blocks and artificial snowboards were the research objects that were typical in the conditions of low temperatures. Temperature control areas, lighting simulation areas and wind speed control device were installed to measure the reflectivity, transparency, and melting speed of the snow and ice surface. All samples were incubated at 180 minutes with a constant light intensity of 600 lx and surface temperature and emissivity data were recorded using an infrared thermal imager (Fluke TiX580), while the optical reflectivity parameters were verified using a specialized reflectometer and a spectrometer (Ocean optics USB4000) to ensure spectral accuracy. A behavioral path recording and multi-dimensional coordinate capture system (OptiTrack Prime13) were used to get spatial narrative samples. The participants were provided with an identification tag to enter the virtually recreated ice and snow environment, and the system automatically created the interactive trajectories and distribution of dwelling hot zones [6-7]. The analytical process of data quantification was presented by Python 3.12 and MATLAB R2024b to implement the curve fitting and multivariate correlation analyses. The 'translation' mechanism is operationalized through a transfer function $f(p) \rightarrow S$, where physical inputs (p)—specifically the variance in optical reflectivity (ΔR) and thermal degradation rate (ΔT)—are mapped onto spatial narrative parameters (S), such as illumination color temperature and acoustic reverb density. This algorithmic coupling ensures that the melting of the ice (p) triggers a proportional shift in the scene's chromatic intensity (S), converting material entropy into a perceptible narrative rhythm. Table 1 presents sample numbers, material properties, temperature and humidity parameters and recording durations.

TABLE 1. Matrix of experimental parameters for ice and snow material samples

Sample number	Material type	Average temperature (°C)	Reflectance (%)	Melting time (min)	Number of spatial interactions
S01	Artificial snowboards	−8.5	46.3	132	18
S02	Natural ice cubes	−10.2	52.7	141	22
S03	Mixed materials	−7.6	49.8	12	20
S04	Artificial snowboards	−9.1	44.5	119	17
S05	Natural ice cubes	−11.0	54.2	147	24

The parameter variations in Table 1 are used to analyze the coupling effect of temperature and reflectivity on spatial narrative perception.

B. SPATIAL BEHAVIOR AND NARRATIVE PATH ANALYSIS

The experimental scene consisted of six functional areas, each responsible for behavioral transitions such as entering, staying, interacting, and leaving. Visual guidance was provided between the areas through ice walls and light strips. Participants wore motion capture devices and eye trackers, and the system recorded behavioral paths, gaze points, and changes in walking speed at a frequency of 120 frames per second. The trajectory data was imported into a spatial narrative modeling program in the form of a three-dimensional coordinate matrix to calculate path density and emotional node distribution. Behavioral sequences were divided using the time slicing method, and spatial rhythm parameters were extracted by combining them with the narrative rhythm curve. The changes in light and color and the sound environment response set in the scene were synchronously written into the same time axis to analyze the correspondence between visual stimuli and behavioral transitions. Path weights were normalized based on dwell

time and gaze ratio; specifically, the 'Path curvature value' was analyzed alongside fixation duration to distinguish between 'exploratory immersion' (high curvature with high fixation) and 'navigational confusion' (high curvature with low fixation), thereby validating the contextual coherence index, and compared with the narrative node generation model to calculate interaction intensity and contextual coherence [8-9]. Statistical results were used to classify narrative pattern types through K-means clustering and extract high-frequency path combinations to identify the behavioral narrative characteristics of the ice and snow art space. The data distribution results are shown in Table 2.

TABLE 2. Statistics on Spatial Behavior Trajectories and Narrative Parameters

Participant ID	Average stay time (s)	Number of fixations	Path curvature value	Interaction Intensity	Contextual coherence Index (%)
P01	182	36	0.42	0.68	74.5
P02	205	41	0.58	0.73	81.2
P03	177	33	0.47	0.69	76.8
P04	214	45	0.62	0.75	83.9
P05	198	39	0.53	0.71	79.1

The data in Table 2 is used to identify the interaction patterns between behavioral dynamics and the narrative rhythm of the ice and snow scene.

C. VIRTUAL SIMULATION AND MODEL VALIDATION

Import the temperature, humidity and light reflection data collected on site, and adjust the transparency of the ice layer, the reflection of snow crystals and the angle of the light through parameterized scripts to realize the real reproduction of the visual response of the material. The three-dimensional model is generated by high-precision laser scanning, and the number of facets is controlled within the range suitable for real-time rendering. When simulating temperature gradient changes, the system updates the surface material state through dynamic mapping algorithm so that the ice and snow structure presents a gradual form under different energy inputs. After the participant's behavior path data is implanted into the virtual space, the simulation program dynamically allocates the narrative rhythm points according to the trajectory distribution and records the participants' visual focus ratio and spatial dwell distribution [10]. All simulation scenes maintain constant lighting and sound environment parameters to ensure comparability. However, to mitigate the 'uncanny valley' effect and the absence of haptic thermal feedback in the virtual environment, the simulation focused on 'visual-thermal mapping,' where perceived temperature was substituted by calibrated shifts in the blue-to-orange color spectrum. While this compensates for the lack of physical coldness, the divergence between virtual visual cues and actual multisensory thermal reality remains a recognized boundary of the current simulation model. The lighting distribution, material response and narrative flow lines output by the model are synchronously compared with the measured data in the form of a multi-dimensional matrix. The rendering parameters are adjusted through iterative calibration algorithm so that the simulation scene is highly consistent with the experimental observation results in terms of visual brightness, spatial continuity and emotional rhythm.

D. AESTHETIC EXPRESSION AND DESIGN IMPLEMENTATION PATH

The spatial design uses a parametric array generation algorithm which regulates the incident angle of the light and the percentage of micro-refraction of the surface to produce a visually flowing structure. The overlay of the transparency of ice and the size of snow particles is projected to a color gradient control system and this results in different regions having color temperature variations ranging between cool white to light blue thereby producing a layer effect visual rhythm. The acoustic module utilizes material impedance analysis to configure a stratified soundscape, wherein the porous snow morphology functions as a broadband acoustic absorber for high-frequency attenuation, while the dense ice crystalline structure facilitates the resonance and propagation of mid-to-low frequency waves, thereby enhancing the spatial presence of the installation. The lighting system is adjusted automatically in terms of brightness and color temperature via the narrative rhythm signal, in order to have the environment changes aligned with the emotional journey. Once behavioral data and emotion perception model are connected, the system recognizes the density of a path traversed by the audience and modifies environmental parameters in real time, which establishes a vision-perception feedback loop. Upon completion, the installation is calibrated on-site and digitally checked to verify that the correspondence between the narrative path and the optical rhythm is in continuous change to achieve a dynamic balance between perception, materials, and space in the aesthetic expression.

IV. RESULTS AND DISCUSSION

A. DATA ANALYSIS RESULTS

Before the analysis optical, thermal, and behavioral data of 152 experimental samples were both cleaned and standardized. Once the noise was eliminated in the measurement, temperature gradient, reflectivity, melting time, and participant perception scores were smoothed together with a consistent sampling rate. The data were put in a statistical analysis program after normalizing them. The extent of the correspondence between the physical change in ice and snow space and perception indicators was identified by the use of linear correlation and regression tests. The type of experimental group that was designed was a traditional spatial setting in order to confirm the importance of the translation effect in the model. This study was approved by the Ethics Committee of East University of Heilongjiang, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

TABLE 3. Performance Comparison Data of Ice and Snow Art Spaces Translated by the Model

Indicator Categories	Control group average	Model translation average	Increase (%)	Sample size
Light reflection intensity (cd/m^2)	215.8	275.0	27.4	152
Melting duration (min)	102	120	17.6	152
Surface transparency index	0.63	0.78	23.8	152
Perceptual immersion (IPQ subscale score)	6.0	8.1	35.0	85
Narrative coherence coefficient	0.67	0.90	34.3	85

Table 3 shows that the average light reflection intensity after model translation increased by 27.4%, and the stable brightness range expanded from 180–260 cd/m2 to 220–310 cd/m2. The melting delay time increased by 18 minutes, and the variance decreased to 3.5 minutes, demonstrating higher thermal stability. The transparency index increased from 0.63 to 0.78, enhancing visual transparency. The mean participant immersion score, measured using the Igroup Presence Questionnaire (IPQ) involving spatial presence and involvement subscales, increased from 6.0 to 8.1, representing a 35% quantitative improvement in standardized perception metrics, and the narrative coherence improved to 0.90, indicating a good coupling between spatial rhythm and perceptual feedback mechanisms. Applying the Attention Restoration Theory (ART), the 27.4% increase in light reflection intensity serves as a high-fidelity visual stimulus that reduces cognitive load, while the 18-minute melting delay ensures the temporal continuity of the visual field. The overall data showed a significant positive correlation ($r=0.82$, $p<0.01$) between these stabilized physical environmental variables and the participants' prolonged dwell time, suggesting that physical constancy is a prerequisite for psychological flow and narrative immersion in transient media.

B. SPATIAL NARRATIVE OPTIMIZATION EFFECT

The scene that has been translated constitutes a perceptual line connecting the virtual and the physical space. The spatial rhythm naturally directs the eye movements and body rotations of the viewers, path turning points and visual focal points being very similar. The storyline is progressive and rational in active searching. The timing of light and color variation and the distribution of behavioral heat areas react concurrently, which means that the alteration of atmosphere is not externally controlled but a reaction of the environmental parameters. At spatial narrative points, sound and light join to generate a psychological mapping of the emotional changes and visual rhythms, transforming the perception of time in the viewer, moving the viewer not on the physical movement but on the emotional movement. Depending on the distribution of behavioral persistence, the environmental adaptive mechanism in real time, varies the direction and color temperature of illumination, providing the spatial narrative with a traceable and sustainable coherent logic. It is confirmed that the ratio of narrative rhythm and the persistence of the space response jointly create an immersive semantic model, which allows the ice and snow art environment to gain the expressive properties of self-explanation of the situation and the emotional appeal.

C. DESIGN IMPLICATIONS OF SYMBIOSIS AND TRANSLATION MECHANISMS

The constructive relations between the physical characteristics of nature and the artistic semantics are dynamic and mutually constructive as seen in the design process of the symbiosis and translation mechanisms. The environmental art has an intuitively perceivable logic in terms of life that is made possible by the time-changing nature of ice and snow material. Design parameters are modified through symbiosis mechanisms incorporating environmental temperature light and humidity changes, and art installations are able to have self-regulating capabilities. Translation processes on the other hand, fulfil the goals of semantic mapping and emotional encoding, in that natural processes, including melting and condensation, are rendered as a visual and narrative image, space, as a container of stable relations into the medium of interactions of emotions and ecological conditions. The two mechanisms in the overall design strategy are mutually dependent in that the symbiotic component enables physical sustainability and the translation component enables aesthetic expression with layers and creates a cyclical system by linking the parameters and creating perceptual feedback. The approach shows that, in case artistic forms are combined with the ecological rationality, it is possible to create a gradual transition between the physical display and emotional storytelling, which would bring the environmental art design out of the visual image and into the semantic symbiosis.

V. CONCLUSION

By applying symbiotic construction methods, this research proves that ice and snow environments can achieve a dynamic association between physical data and artistic feeling, effectively translating the structural logic of production into a cohesive, climate-responsive spatial language. It has been demonstrated that at the end of the model optimization, the spatial brightness balance and environmental stability are much improved and applications of the narrative structure and audience perception behaviour demonstrate a high level of consistency. This approach is a twofold adaptation of environmental response and artistic presentation on the level of design in changing ice and snow materials as short-term display media into ecological media with narrative functions. Through the connection of temperature, reflectivity, transparency, and emotional perception, dynamic regulation of spatial rhythm and a sustained emotional engagement trajectory is realized. The paper finds that the symbiotic mechanism allows a sustainable basis of environmental regulation, and the translation mechanism gives the artwork apparent semantic tension. This integration creates an adaptive aesthetic regime that mirrors the interlacing logic of high-performance materials, fostering a suggestive ice and snow-related spatial ecology. By treating environmental variables

as structural filaments, the resulting narrative achieves a seamless transition between physical constraints and artistic expression.

AUTHOR CONTRIBUTIONS

Wu Rang designed, collected and analyzed the data, and drafted the manuscript. Wu Rang conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Wu Rang participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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HUMAN RESEARCH SUBJECTS

This study was approved by the Ethics Committee of East University of Heilongjiang, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

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