Bulletin of the *Transilvania* University of Braşov
Series VIII: Performing Arts • Vol. 17(66) Special Issue – 2024
https://doi.org/10.31926/but.pa.2024.17.66.3.26

Melodies in Form: Designing Urban Sculptures inspired by Musical Heritage

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Abstract: *This paper explores the fusion of music, art, and technology to redefine urban sculptures by incorporating musical heritage. It introduces a unique approach where music is transformed into striking geometric forms based on the mathematical principles of strange attractors, presenting music as iconic urban sculpture. Using AI, specifically ChatGPT, mathematical formulas generate visually captivating shapes. Additionally, an algorithmic method extracts medium-range music frequencies, which serve as input data to create these geometric forms in Rhino software using the Grasshopper plugin. To enhance public engagement, a mobile application allows visitors to scan a QR code in front of the sculptures, revealing the visualization process while simultaneously playing the corresponding music. By integrating musical heritage into urban sculptures, this approach combines technological innovation with cultural continuity, bridging past traditions with modern advancements. It enhances public appreciation of cultural heritage while enriching the urban landscape with meaningful artistic expressions.*

Key-words: *Musical Heritage, Geometrical Sculpture, Urban Identity, Mathematical Art, Strange Attractors.*

1. Introduction

In contemporary urban environments, the interaction between public art and city landscapes plays a pivotal role in shaping urban identity and cultural expression. Sculptures, as prominent elements of public art, serve not only as aesthetic additions but also as reflections of cultural heritage and societal values (Li et al. 2023, 1883). With the rapid advancement of technology, particularly in artificial intelligence (AI) and digital modelling, there is an emerging opportunity to redefine how these sculptures are conceived, designed, and experienced (Zukin and Braslow 2024, 20).

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This paper explores the intersection of music, technology, and art, proposing a novel approach that transforms musical heritage into geometric urban sculptures.

Music has long been regarded as a fundamental aspect of cultural heritage, encapsulating the emotions, history, and identity of societies. It acts as a powerful medium that connects individuals across time and space. In this study, we propose that music can transcend its auditory boundaries and be reimagined as a visual and tangible form within the urban landscape. The use of AI tools and algorithmic design techniques in cultural heritage and music visualization is becoming an important method for bridging sound and form (Cao and Park 2022, 32). By harnessing AI tools and algorithmic design techniques, we aim to bridge the gap between sound and form, creating urban sculptures that embody both visual appeal and cultural significance. This interdisciplinary approach highlights the fusion of tradition with modern technological advancements, offering new ways to experience and appreciate musical heritage.

The significance of this work lies in its potential to engage the public with cultural heritage in an innovative and interactive manner. By transforming music into physical art forms, we provide a novel method of cultural preservation and dissemination (Isaac et al. 2024, 794). Furthermore, the integration of mobile technology enhances this experience by allowing real-time interaction with the sculptures, where users can visually witness the transformation of music into geometry while listening to the corresponding melody. This convergence of auditory and visual stimuli deepens the engagement and connection between the viewer, the art, and the cultural heritage it represents.

This approach offers a new way for urban designers to create aesthetically appealing sculptures rooted in cultural history, thus enhancing the urban experience and reimagining the sounds of the past in future cities.

2. Literature Review

The intersection of music, sound, and 3D modelling has garnered significant attention in recent years, particularly in the context of translating auditory experiences into tangible 3D shapes suitable for 3D printing. This literature review aims to synthesize existing research on the methodologies and implications of such translations, focusing on the theoretical frameworks, technological advancements, and practical applications that facilitate this innovative approach. Findings from these studies have informed the empirical foundation of our research, summarized herein (Table 1).

Category	Study	Summary	Key finding
3D Modelling of Sound	Horvath et al. (2020)	Introduced the Sound Sculpt framework for modelling and fabricating sound patterns into 3D shapes.	Bridges the gap between auditory perception and visual form.
Movement and Sound Integration	Braeuer-Burchardt et al. (2019)	Explores generating music through movement capture, combining physical interaction and auditory output.	Physical interaction with sound can create immersive experiences.
Translation of Song Lyrics	Natsir (2023)	Emphasized the significance of translating song lyrics to understand emotional conveyance in music.	Translation of lyrics plays a vital role in emotional understanding of music.
Translation of Music	Ronagh et al. (2021)	Generative design approach that combines parametric architecture with music	Translation of a music into 3D parametric walls
Translation of Music and Detection Process	Ronagh et al. (2024)	Making relief walls by music frequency	Augmented reality and QR codes enhance user interaction to detect relief walls made by music
Musical Instrument Design	Ferrand (2022)	Explores the evolution of musical instrument design using 3D printing and digital sound modeling.	3D printing allows for innovation in instrument design beyond traditional forms.
Psychological Impact of 3D Sound	Ooishi et al. (2021)	Investigated the psychological effects of immersive 3D soundscapes on emotional responses.	3D soundscapes can enhance emotional resonance.
Sound Translation via Deep Learning	Milazzo et al. (2021)	Demonstrated the use of deep learning to translate musical compositions into protein structures.	Sound translation extends to interdisciplinary fields like biology and materials science.
Educational Applications	Sudirman et al. (2023)	Explores the importance of geometric representations in 3D shape design and education.	Geometric knowledge is crucial for 3D modeling in sound-based design.
Optimization of Musical Components	Alfarisi et al. (2021)	Focused on redesigning hand-cranked music boxes using 3D printing for better sound production.	Material selection and structure influence acoustic outcomes.

Category	Study	Summary	Key finding
Kinetic Shapes in Musical Instruments	Handžić & Reed (2014)	Proposed using 3D modelling techniques to create variable tension string instruments.	Captures dynamic sound with tactile interaction through design.
Sound Analysis of Musical Components	Bacciaglia et al. (2021)	Investigates the sound analysis of 3D-printed mouthpieces and their influence on musical performance.	Design variations can impact sound quality in brass instruments.
Emotional and Psychological Dimensions	Mesz (2023)	Examined the emotional responses elicited by crossmodal correspondences between shapes, materials, and music.	Sound-based 3D objects serve as emotional artifacts.

Table 1. *A comprehensive review of translating music into physical models*

3. Theoretical Framework

The theoretical framework of this paper explores the interdisciplinary fusion of music, art, and technology, with a specific focus on using artificial intelligence (AI) and algorithmic design to transform musical heritage into urban sculptures. The framework highlights the roles of music as cultural heritage, the importance of AI tools, and the emerging possibilities for visualizing cultural elements in public spaces (Table 2).

Concept	Key Ideas
Interdisciplinary Connection	- Fusion of music, art, and technology. - Music transformed from auditory experience into visual, tangible forms in public art. - AI facilitates sensory interaction.
Music as Cultural Heritage	- Music as a carrier of emotions, history, and identity. - Traditional preservation methods extended to visual and spatial forms. - Sculptures as physical embodiments of musical heritage.
AI and Algorithmic Design	- AI and algorithms translate musical data into geometric forms. - AI tools like ChatGPT create mathematical formulas from music frequencies. - Use of Rhinoceros and Grasshopper software for 3D modeling.

Table 2. *Theoretical framework*

4. Methodology

This section outlines the steps undertaken to transform musical data into geometric forms for 3D-printed sculptures. To achieve this goal, the mathematical principles of strange attractors—complex and fluid three-dimensional objects derived from chaos theory—were employed. Strange attractors were chosen because they are highly sensitive to initial conditions and can generate complex, non-repetitive, and visually engaging forms. This feature aligns with the frequencies of music, which oscillate in a physical form. The unpredictable nature of strange attractors mirrors the variability and flow found in musical compositions based on the extracted medium frequencies. Unlike traditional geometric shapes, strange attractors embody a continuous flow, similar to the progression of sound waves. Thus, they were selected for their ability to represent the organic and dynamic qualities of music in a visually captivating way (Figure 1). The methodology of this paper is defined in four sections:

Fig 1. *Sample of strange attractors*

4.1. AI – Assisted formulation of strange attractors

The concept of strange attractors, with their complex and dynamic nature, makes them an ideal mathematical foundation for visualizing music as sculpture. Using Chat GPT, Python code was developed to produce equations that define chaotic but patterned shapes (Figure 2).

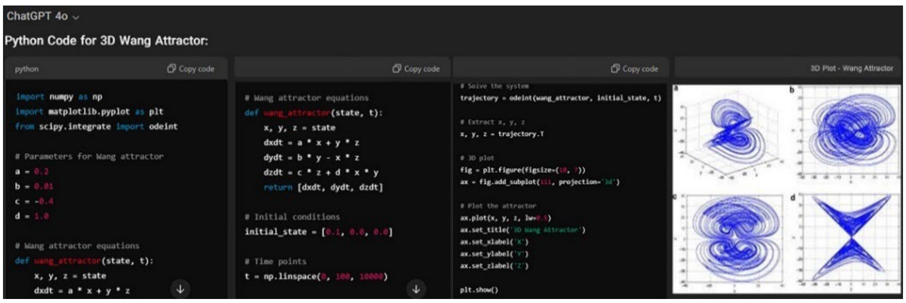

Fig 2. *Creating Python script of a strange attractor using Chat GPT*

These equations, well-suited for representing the fluid and unpredictable qualities of music, were then imported into the Grasshopper plugin in Rhino, a parametric design tool for creating 3D models. These mathematical formulas were depicted based on numerical variables as input.

4.2. Music Medium Frequency Extraction and Form Creation

To establish a direct link between the input data (music) and the output form (sculpture), an algorithmic approach was employed to extract medium frequencies from selected music compositions. Medium frequencies were chosen as they are central to most musical experiences, carrying melodic and harmonic content, which we aimed to visualize. The corresponding algorithm was developed by AI to process the music file, identifying, and isolating the medium frequency range (Figure 3).

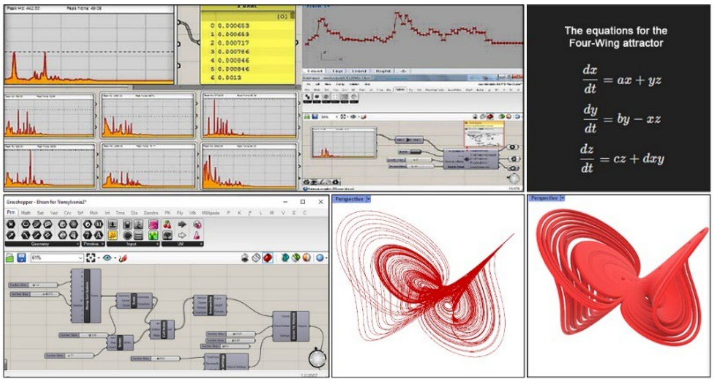

Fig 3. *Music medium frequency extraction and creation of a strange attractor using Grasshopper in Rhino program*

These data were then used as input parameters for the strange attractor equations in the Grasshopper plugin, directly influencing the geometrical forms created. This process generated a wide variety of unique 3D forms that directly corresponded to the frequency characteristics of each musical piece. These forms were exported for 3D printing, resulting in small-scale physical sculptures that represent the music in tangible form.

4.3. Fabrication of 3D Sculptures

The 3D models generated in Grasshopper were optimized for 3D printing, ensuring structural integrity and detail at a small scale. The printing process was carried out using a high-resolution 3D printer to capture the intricate details produced by the strange attractor equations. These printed sculptures serve as physical manifestations of the corresponding musical compositions, with each form uniquely shaped by the medium frequencies of its musical input (Figure 4).

Fig 4. *Fabricating a strange attractor with a 3D printer*

4.4. Integration of QR Codes for Mobile Visualization

To further enhance the interaction between the sculptures and their musical origins, a QR code was embedded in front of each sculpture. Visitors can scan these QR codes using their mobile devices, which will play the corresponding music while visualizing the creation process of the 3D form (Fig. 5). This allows the audience to experience the music and its visual transformation simultaneously, deepening their engagement with both the art and its underlying cultural context. This approach bridges the gap between traditional physical sculpture and modern digital technology, allowing for an immersive experience that connects the visual, auditory, and tactile senses.

Fig 5. *Integration of QR Codes for Mobile Visualization*

5. Result

According to the chosen methodology, we created twelve sculptures based on different types of music (Figure 6) and present them in an exhibition to get feedback from the visitors. The result of this project could be categorized in two sections:

Fig 6. *Integration of QR Codes for Mobile Visualization*

5.1. Transformation of Music into Visual Forms

The results of this study demonstrate the successful translation of musical compositions into complex geometric sculptures, utilizing AI-driven algorithms and parametric design tools. By extracting medium frequencies from selected musical pieces and integrating them into strange attractor equations, a direct link was established between the auditory and visual representations. The geometric forms generated through this process exhibited a fluid and dynamic quality, closely resembling the oscillatory nature of sound waves.

The unique, non-repetitive shapes created by the strange attractors were found to vary significantly depending on the musical input. For instance, more melodic compositions resulted in smoother, flowing forms, while more rhythmically intense pieces produced sharper, more angular geometries. These 3D models, when rendered using Rhino's Grasshopper plugin, successfully captured the unpredictable and organic qualities of the music, bringing a new dimension to visualizing auditory experiences. The aesthetic appeal of the sculptures was notable, with each piece reflecting the harmonic and melodic complexities of the corresponding musical composition.

Upon 3D printing, the sculptures retained the intricate details produced by the strange attractor equations. The high-resolution printing process ensured that even the smallest geometric nuances, influenced by the musical frequencies, were clearly visible. The physical manifestations of the musical pieces were not only visually compelling but also provided a tangible connection to the music that inspired them.

5.2. Public engagement and interaction

The integration of QR code technology significantly enhanced public interaction with the sculptures. Visitors were able to scan the QR codes placed in front of each sculpture, triggering the corresponding music and real-time visualization of the form's creation process. This interactive experience allowed users to engage with both the auditory and visual elements of the art, deepening their appreciation of the fusion of music and sculpture.

Feedback collected from public installations revealed a positive reception to this interdisciplinary approach. Many visitors reported that the ability to simultaneously hear the music and witness its transformation into a physical form provided a deeper emotional and intellectual connection to the artwork. The real-time visualization, accessible via mobile devices, offered an immersive experience that bridged traditional sculpture and modern digital interaction. This convergence of auditory and visual stimuli was found to enhance public appreciation of both the musical heritage represented by the compositions and the artistic innovation behind the sculptures.

Overall, the results confirm that this novel approach of integrating music, art, and technology fosters a unique cultural experience in urban settings. The combination of AI-driven design, musical heritage, and public interactivity offers new possibilities for urban art, transforming the way people engage with sculptures and their cultural significance.

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6. Conclusion

The study integrates music, art, and technology to design urban sculptures, transforming musical heritage into tangible forms. AI-driven algorithms convert musical frequencies into geometric shapes, providing a new way to preserve cultural heritage and beautify urban spaces. The sculptures are interactive, with QR codes enhancing public engagement by linking the visual art to its musical origins.

The work highlights the role of technology in reshaping how art is experienced in public spaces. By converting musical elements into physical forms, the project bridges tradition and modernity, offering innovative ways to preserve cultural heritage. This approach could be applied broadly in urban design, public art, and cultural preservation.

The project effectively connects the auditory experience of music with the visual and tactile senses, creating an immersive experience. The strange attractor methodology captures the fluidity of music, and the interactive elements, such as QR codes, make the sculptures dynamic, allowing for deeper public interaction and engagement.

In conclusion, this research demonstrates the impact of interdisciplinary design, driven by AI, in enhancing cultural heritage appreciation. The project shows how music-inspired sculptures can enrich urban landscapes and provide new ways for individuals to connect with their cultural history.

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