

Motion Shaper:

A cross-platform sound synthesis and visual parameter control system rooted in Morphological Synchresis theory

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ABSTRACT

This paper introduces Motion Shaper, a cross-platform sound synthesis and visual parameter control system designed to achieve Morphological Synchresis—a sustained structural relationship between sound and visuals grounded in Spectro-Morphology theory. Moving beyond conventional parameter mapping or momentary synchronisation, the system employs hierarchical motion envelopes to shape co-evolving transformations across both modalities. Motion Shaper comprises two core components: the Audio Motion Shaper (AMS), which controls sound synthesis and processing through dynamic envelopes, and the Visual Motion Shaper (VMS), which synchronises visual transformations via shared motion logic. The system is implemented in Max/MSP, leveraging Open Sound Control (OSC) for real-time interoperability with visual engines such as Unreal Engine. An interactive audiovisual installation, Undercurrent, demonstrates the framework’s application, utilising Leap Motion gestures to trigger morphologically linked sound and visual changes. By prioritising relational congruence over superficial alignment, Motion Shaper offers a systematic framework for generative audiovisual composition, addressing imbalances in existing practices. Future directions include expanding synthesis methods, integrating spatial audio, and hardware prototyping. This work contributes a theoretically grounded toolset for achieving profound perceptual coherence in audiovisual media. A demonstration video of Undercurrent and the Motion Shaper system can be viewed at: <https://www.blackoutstudio.org/undercurrent>

1. INTRODUCTION

Traditional audiovisual practices often relies on simplistic parameter mapping for audiovisual synchronisation. For instance, in Ryoji Ikeda’s works, the transformation of minimalist black-and-white visual blocks is synchronised with high-frequency tones or clicking sounds. In composer Konx’s works [5], visual elements can be observed responding to audio envelopes. While these practices provide a certain level of synchresis, as proposed by Chion (1994) [1], they lack structured theoretical support and a design framework.

Harris(2021)[6]argues that audiovisual composition should adopt a balanced approach, one that does not privilege either the visual or sonic elements. This paper proposes a solution by designing the Motion Shaper software in Max/MSP. The system establishes a deeper structural mapping rela-

tionship by using motion envelopes to shape transitions between sound and visuals.

2. THEORETICAL FOUNDATIONS

2.1 Spectro-Morphology and Its Relevance for Audiovisual Composition

Initially developed for electroacoustic music, Spectro-Morphology describes the evolution of sound through spectral and morphological transformations, with motion and transformation serving as fundamental structural elements.

In contemporary electroacoustic composition, timbre encompasses the inherent qualities of the whole sound rather than being merely the part of sound that is not pitch (Smalley, 1994, p. 40) [8]. Timbral composition is closely linked to sound processing and spatial playback techniques within the electroacoustic domain. The tools used for spectral and spatial processing typically provide multiple adjustable parameters, which directly contribute to the multidimensional nature of timbre in electronic music. In other words, timbre in electroacoustic music is not determined by a single parameter but rather by the synergy of multiple parameters. Motion is one of the emergent properties of timbral transformation.

Spectro-morphology defines various motion and growth processes based on temporal shaping. These are categorised into four main types: unidirectional, bi/multidirectional, reciprocal, and cyclic/centric. Within each category, Smalley (1986) [9] identifies different types of motion. While these classifications were initially designed to analyse spectral evolution in sound, they also offer compositional strategies for electroacoustic music (Smalley, 1986) [9].

Smalley’s theory also inspired further research beyond sound analysis and composition, including Stuart James’s investigation of Spatiomorphology (2015) [7], Tiernan Cross’s exploration of Spectro-Morphology in spatial audio composition (2024) [3], and Daniel Fallon’s examination of Spectro-Morphology in audiovisual media (2019) [4]. These studies highlight the broader relevance of Smalley’s theory beyond electroacoustic composition and inform the use of Spectro-Morphology as a structural mapping framework in audiovisual composition. Incorporating these principles, this research develops a structured software system that fa-

cilitates motion-based control of both sound and visuals, thereby reinforcing the perception of audiovisual synchrony.

2.2 Morphological Synchrony as a Structural Mapping Framework

Morphological Synchrony extends Denis Smalley’s (1986) Spectro-Morphology [9] and Michel Chion’s (1994) Synchrony theory [1], redefining synchrony as a sustained structural property rather than a momentary perceptual effect. Spectro-morphology describes sound structures through dynamic transformations, with core concepts such as motion, growth, gesture-framing, and texture-setting. Traditional synchrony, as Chion describes, emerges from the temporal coincidence of sound and image. However, Morphological Synchrony embeds synchrony within the compositional process itself, ensuring that sound and visuals co-evolve through shared transformation principles (Figure 1).

In Morphological Synchrony, Spectro-Morphology serves as the foundation for a framework governing both sound and visual creation. Rather than relying on momentary synchronisation or direct parameter mapping, this framework emphasises dynamic morphological transformations as the core mechanism for establishing synchrony. Motion Shaper, as an implementation of this concept, employs hierarchical motion structures to synchronise audiovisual evolution over time, ensuring that synchrony emerges not only at discrete points but throughout the entire transformation process (Figure 2).

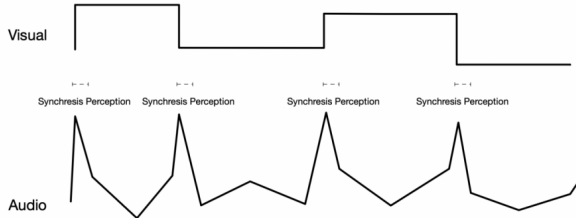


Figure 1: Conventional Synchrony Perception

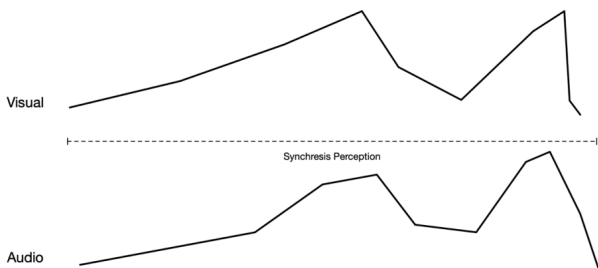


Figure 2: Morphological Synchrony Perception

2.3 Motion as the Connecting Factor

Conventional audiovisual mapping methods often depend on direct parameter correspondence, such as linking volume to brightness or frequency to colour. While effective in generating basic synchronisation, these methods tend to overlook the larger-scale structural evolution that sustains perceptual coherence over time. Morphological Synchrony addresses this limitation by using motion envelopes as the structural link between sound and visuals.

By centring audiovisual relationships around motion patterns, such as contraction and expansion, this approach ensures that synchrony is perceived not only in certain moments, but dynamically throughout the transformation process. For example, a sound that has an increasing spectral richness might be mirrored by a visual that grows in scale and brightness, with both adhering to a shared motion rather than simple one-to-one parameter mappings. This structural integration fosters a balanced interplay between sound and visuals, reinforcing synchrony as an emergent property of their co-evolution rather than a reactive alignment of discrete events.

3. SYSTEM DESIGN

3.1 Architecture Overview

3.1.1 Motion Envelope as a Core Mechanism

The core of Motion Shaper is motion envelopes, which are used to control the transformation of both sound and visual elements. Drawing on Cipriani and Giri’s (2019) [2] classification of motion processes, simple motion can be created with a single motion envelope. For example, an simple ascending motion envelope can be used to increase both sound volume and visual brightness, gradually raising parameter values to achieve the desired effect.

In other cases, complex motion requires the combination of multiple simple motions. The number and types of motion envelopes used to shape sound and visual elements do not need to be uniform. For instance, vortex motion in sound requires an ascent motion envelope and an oscillation motion envelope to control different parameters to achieve the desired effect. In the visual domain (using the Niagara system in Unreal Engine as an example), two ascent motion envelopes are employed to control vortex force strength and noise force strength, while a descent motion envelope is used to control spring force strength, thereby achieving the desired effect.

Table 1 illustrates the simple motions selected from the motion and growth processes in Spectro-Morphology. Based on this, it analyses the necessary conditions for constructing complex motions.

Table 1: Motion Categories and Types

Category	Type	Key Features / Conditions
Unidirectional	Ascent	Upward motion; rising pitch, energy. Simple envelope.
	Descent	Downward motion; falling pitch, energy. Simple envelope.
	Plane	Linear motion; even spread. Simple envelope.
Bidirectional	Divergence	Expanding distance. Envelope combo.
	Convergence	Contracting distance. Envelope combo.
	Dilation	Expanding range/intensity. Envelope combo.
	Contraction	Compressing range. Envelope combo.
Curvilinear	Parabola	Arch shape; rise-peak-fall. Simple envelope.
	Inverted Parabola	Inverse arc. Simple envelope.
	Oscillation	Back-and-forth swing. Simple envelope.
	Undulation	Wavelike motion. Simple envelope.
Reciprocal	Convolution	Interwoven paths. Envelope combo.
Centric/Cyclic	Centrifugal/Centripetal	Circular motion; tension/release. Envelope combo.
	Pericentricity	Local loops near center. Envelope combo.
	Vortex	Spiral rotation. Envelope combo.
	Helix	3D spiral path. Envelope combo.
Eccentric/Complex	Refraction	Direction shift via medium. Envelope combo.
	Accumulation	Increasing density. Visuals + source.
	Dissipation	Fading elements. Visuals + source.
	Exogeny	External trigger. Visuals.
	Endogeny	Internal origin. Visuals.
	Confraction	Alternate expand/contract. Visuals + source.
	Diffraction	Bending/scattering. Visuals + source.
	Conglomeration	Elements merging. Visuals + source.



Figure 3: Audio Motion Shaper

3.1.2 System Components

Motion Shaper consists of two main parts: the Audio Motion Shaper (AMS) and Visual Motion Shaper (VMS) (Figure 4) uses .

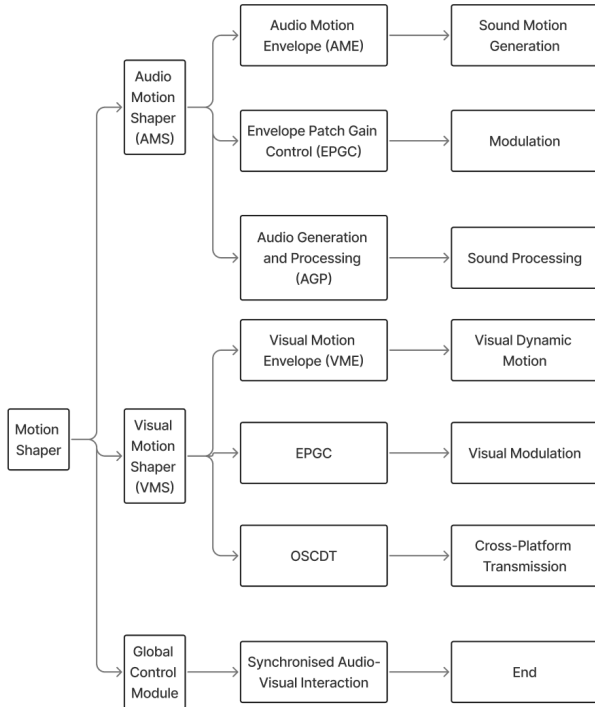


Figure 4: Architecture Overview

3.2 Audio Motion Shaper (AMS)

The AMS section is composed of three modules: the Audio Motion Envelope (AME) Module (Figures 5 and 6) uses , the Envelope Patch Gain Control (EPGC) Module, and the Audio Generation and Processing (AGP) Module.

3.2.1 Audio Motion Envelope (AME) Module

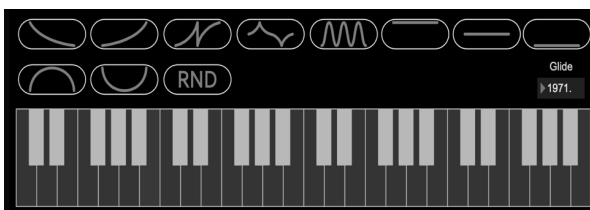


Figure 5: Audio Motion Envelope Module 1

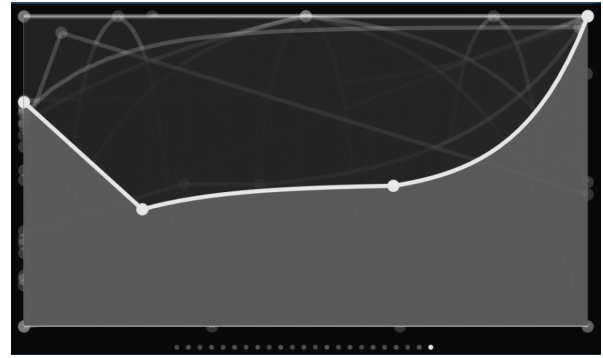


Figure 6: Audio Motion Envelope Module 2

The Audio Motion Envelope (AME) Module offers a range of pre-made envelope types for creating simple motions, and allows users to adjust or redraw the envelopes themselves.

The AME Module is built upon the `mc.function` object for envelope editing and management, and is integrated with `buffer~` for storage and scanning, allowing efficient real-time control. The overall workflow is as follows:

1. The envelope shape drawn by the user is written into the `buffer~` as data storage. This method enables greater editability and playback precision of the envelope, supporting the creation of complex custom curves.
2. The `buffer~` is scanned using normalised control parameters (0.0 – 1.0) to obtain the envelope values at the current time point. This ensures that the envelope can adapt to different time lengths and supports advanced features such as variable-speed playback and reverse scanning.
3. The `mc.function` object allows for the simultaneous processing of multiple envelope signals, enabling the AME module to control multiple target parameters or perform multidimensional modulation. This feature is particularly valuable in scenarios such as polyphonic synthesis, spatial audio motion control, and multi-parameter synchronised modulation.

3.2.2 Envelope Patch Gain Control (EPGC) Module

The Envelope Patch Gain Control (EPGC) module (Figure 7) dynamically routes the envelope signals generated by the AME module to different sound parameters and provides independent gain control to adjust the intensity of the envelope effect. This module is based on Max/MSP's crosspatch mechanism, allowing users to flexibly route multiple envelope signals and apply varying modulation strengths to different target parameters, thereby creating rich, dynamic variations.

Table 2: Audio Motion Envelope (AME) Module Functions

Main Function	Details
Motion Envelope Preset	Provide preset motion envelopes such as exponential, logarithmic, and linear. Users can adjust these presets or manually draw custom envelopes.
Motion Envelope Editing	Use the <code>mc.function</code> object for motion envelope editing, combined with <code>buffer~</code> storage and scanning, allowing real-time modification and playback.
Data Storage	The envelope drawn by the user is stored in the <code>buffer~</code> object, supporting playback, variable-speed scanning, reverse playback, and other functions, enhancing dynamic control capabilities.
Multi-Target Modulation	The <code>mc.function</code> object can be used to edit multiple envelopes, supporting independent modulation of multiple parameters, thereby enhancing control flexibility.

Table 3: Envelop Patch Gain Control Module Functions

Main Function	Details
Motion Envelope Data Routing	Use <code>matrix~</code> for dynamic routing of motion envelope signals, allowing flexible adjustment of the envelope’s influence on various target parameters.
Gain Adjustment	The <code>crosspatch</code> mechanism allows applying different gain levels to each envelope, supporting precise control of modulation depth.
Target Parameters	It can affect core audio parameters such as factor, filter cut-off frequency, reverb amount, delay time, and feedback amount.

Table 4: Audio Generation and Processing Module Functions

Sections	Main Function	Details
Audio Generation	Phase Modulation Synthesis	It uses a Carrier and Modulator structure to generate note-like sounds.
	Feedback Phase Modulation Synthesis	It enhances the noise characteristics through a feedback mechanism, creating complex noise-like timbres.
	Modulation Parameters (Modulated by AME Module)	Factor (Modulation Ratio), Amp (Modulation Amplitude), Feedback Amount (Feedback Level), Modulation Index (Modulation Depth), Volume
	Carrier Frequency Control	Manual control through <code>keyslider</code> object
Audio Processing	Filter	Uses low-pass (LPF), high-pass (HPF), and band-pass (BPF) filters, with control over Cut-off Frequency and Resonance.
	Delay	Includes controls for Delay Time and Feedback Amount, which can be used for rhythmic echoes and spatial expansion.
	Reverb	Uses algorithmic reverb processing, with controls for Reverb Mix.

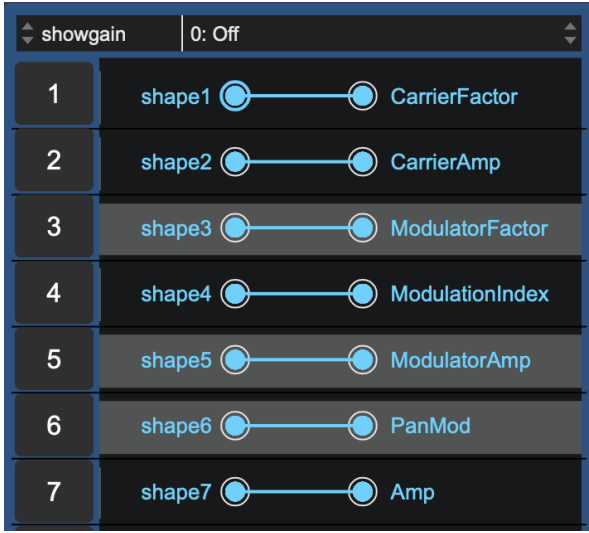


Figure 7: Envelop Patch Gain Control Module (Audio)

3.2.3 Audio Generation and Processing (AGP) Module

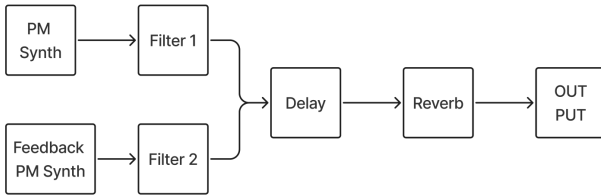


Figure 8: Signal Routing Diagram

The AGP module (Figure 9) is divided into two main sections: Audio Generation and Audio Processing, each controlled by specific parameters to achieve different tonal shaping methods.

The control mode switch enables switching between Global mode, where the parameter is controlled by the Global Control Module, Self mode, where LFO modulation is accepted, and Manual mode, where users can manually control the parameters. The “scale” function within this control is designed to map the normalised control values to the valid range of sound parameter values.

The sound generation section of the AGP module consists of two PM (Phase Modulation) synthesisers, which are based on the concept of the note-to-noise continuum from Spectromorphology. One synthesiser focuses on the sound that leans towards perceptible pitch quality components (note-like), while the other emphasises timbres that are more noise-oriented (noise-like).

The sound processing section of the AGP module includes independent filters, delay, and reverb units. All audio processing modules can independently affect the output of either the PM or Feedback PM synthesiser, providing further tonal shaping capabilities for the synthesisers.

The AGP module is based on Phase Modulation synthesis, combined with Feedback Modulation (Feedback PM),

providing continuous control over timbre from note-like to noise-like characteristics. It is further processed with filters, delay, and reverb. The design of this module carefully considers parameter adjustability, utilising the EPGC module to dynamically control key modulation and processing parameters while also retaining parameters suitable for manual adjustment, allowing for flexible operation during live performance and sound design.

3.3 Visual Motion Shaper (VMS)

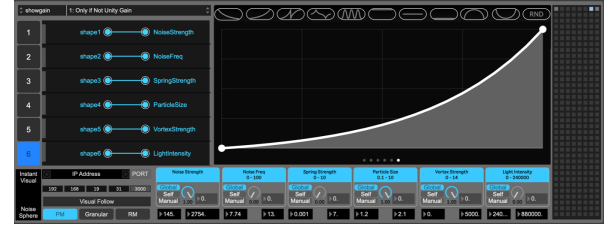


Figure 10: Visual Motion Shaper

3.3.1 Visual Motion Envelope (VME) Module

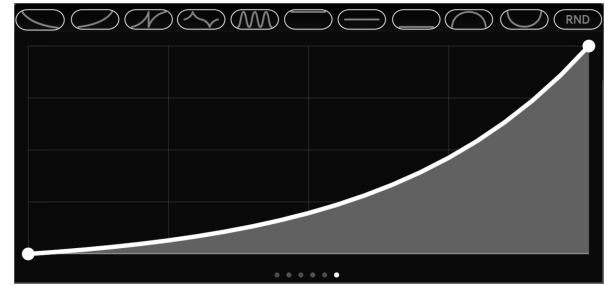


Figure 11: Visual Motion Envelope Module

In the case of VMS (Figure 10), similar to AMS the Visual Motion Envelope (VME) Module also provides a variety of preset envelope types and allows users to adjust or redraw the envelope as needed. The parameter scale function is designed to map the normalised control values to the valid range of visual parameters.

3.3.2 Envelop Patch Gain Control (EPGC) Module

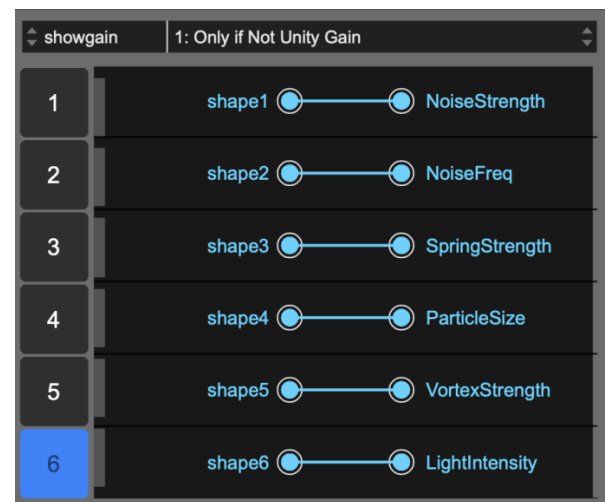


Figure 12: Envelop Patch Gain Control Module (Visual)



Figure 9: Audio Generation and Processing (AGP) Module

Table 5: OSC Data Transmission Module Functions

Main Function	Details
Real-Time Data Transmission	Uses the UDP protocol to send and receive OSC messages, enabling low-latency parameter synchronisation.
Parameter Mapping	Max/MSP serves as the OSC sender, controlling external visual engines (such as Touch Designer, Unreal Engine, and Unity) to ensure audiovisual synchronisation.
Expandability / Scalability	Supports multi-device communication for collaborative or cross-platform applications.

Table 6: Global Control Module Functions

Control Mode	Details
Function	Allows users to manually draw lines to define custom motion envelope curves. Uses LFO modulation, where two sine waves modulate each other to create complex motion curves.
Manual	Users can manually adjust the motion envelope, making it suitable for real-time control needs.

The Envelope Patch Gain Control (EPGC) module (Figure 12) in VMS, similar to that in AMS, dynamically distributes the envelope signals generated by the VME module to different visual parameters, while providing independent gain control to adjust the intensity of the envelope's effect. This module is based on Max/MSP's cross-patch mechanism, allowing users to flexibly route multiple envelope signals and apply varying levels of modulation to different target parameters, thereby creating rich, dynamic variations.

3.3.3 OSCDT (OSC Data Transmission) Module

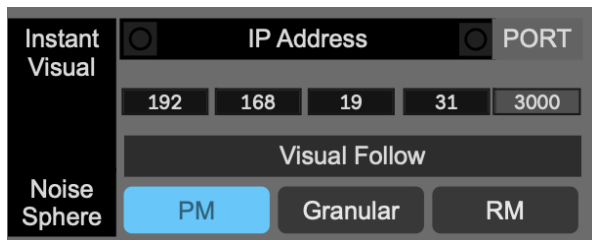


Figure 13: OSC Data Transmission Module

The OSCDT modul (Figure 13) facilitates realtime data transmission between Max/MSP and external visual platforms (such as ToucDesigner, Unreal Engine, Unity, etc.) through Open Sound Control (OSC), ensuring the synchronised interaction of audio and visual content.

3.4 Global Control



Figure 14: Global Control Module

The Global Control module (Figure 13) is used to synchronise the parameter changes of the Audio Motion Shaper (AMS) and Visual Motion Shaper (VMS). This module offers three different control modes, enabling all parameters affected by the motion envelope to undergo forward or reverse scanning, thereby achieving consistent dynamic changes.

4. APPLICATION: UNDERCURRENT INSTALLATION

4.1 Artistic Concept

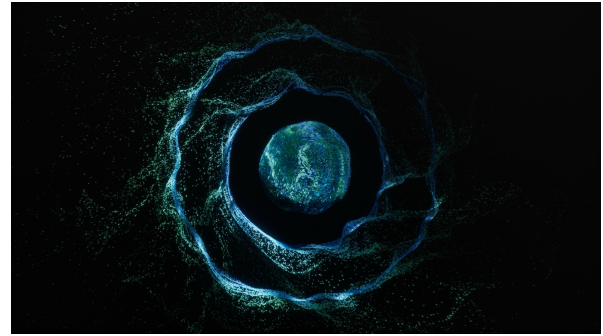


Figure 15: Undercurrent

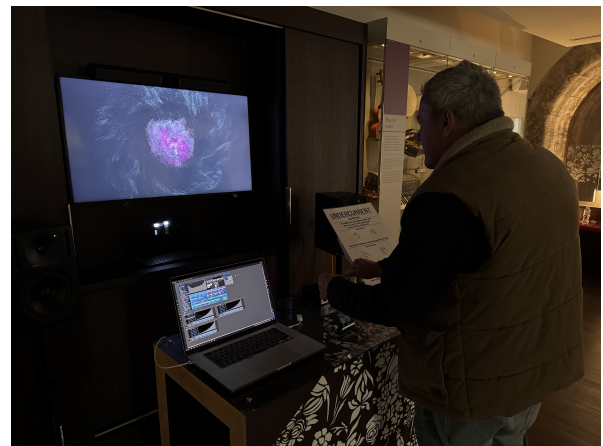


Figure 16: Installation Site

Undercurrent is an interactive audiovisual installation that explores morphological synchresis as a structural framework for real-time audiovisual composition. It also demonstrates the application of the Motion Shaper software system, which is designed to bring this framework to life in practice.

At its core, the work investigates morphological synchresis—the dynamic synchronisation of auditory and visual elements based on their shared motion and transformation. By responding to user interactions, *Undercurrent* creates a constantly evolving environment where gestures generate ripples of change, emphasising the interplay between control and unpredictability.

The installation is designed as an immersive space where participants influence an ever-shifting audiovisual object. Using the custom Motion Shaper software system, sound and visuals are not merely synchronised but share the same transformation process, shaping and reshaping each other through spectral transformations and particle-based visuals. Participants become both shapers and observers by engaging with gesture interaction, witnessing how their interactions reshape the audiovisual experience.

4.2 Gesture Interaction

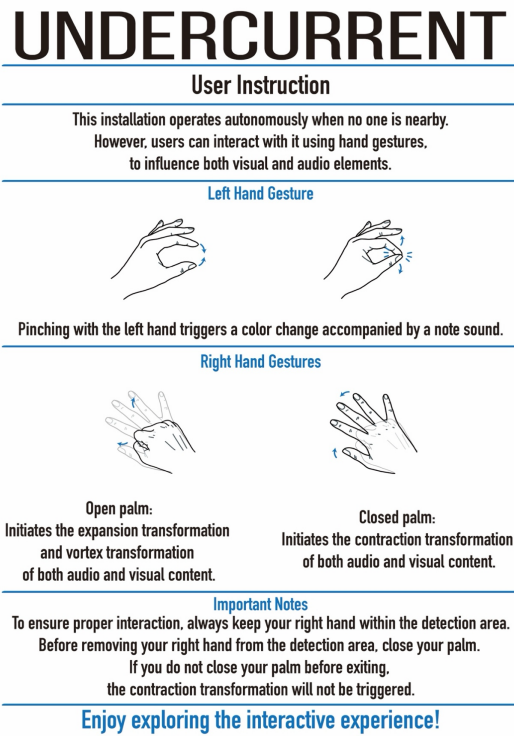


Figure 17: User Interaction Instruction

The interaction design is powered by Leap Motion, leveraging its infrared tracking technology to accurately capture audience hand movements and gestures, which in turn drive real-time audiovisual transformations. The Motion Shaper system features two distinct control modes:

4.2.1 ShapeOsc Mode (Idle State)

When no audience interaction is detected, the installation enters ShapeOsc Mode, where sound and visuals evolve autonomously, driven by low-frequency oscillators (LFOs). In this mode, audiovisual changes follow predefined motion envelopes, creating a rhythmic “undercurrent” that symbolises the natural flow of the world.

4.2.2 Function Mode (Interactive State)

Once an audience member engages with the installation using hand gestures, the system changes to Function Mode, allowing direct, real-time manipulation of audiovisual elements:

- **Right hand open (expansion):** Triggers an outward transformation in sound and visuals. The sound exhibits an increase in frequency and spatial depth, while the visuals respond with an expanding particle field and intensified vortex motion.

- **Right hand closed (contraction):** Induces a converging transformation, causing the vortex motion to dissipate. The sound becomes denser and more compact while the particle field visually contracts into a more concentrated form.
- **Left-hand pinch gesture:** Generates a pure tone with a distinct pitch, accompanied by changes in particle colour and lighting, adding an extra layer of interactive depth.

4.3 Implementation Details

The technical integration of *Undercurrent* is achieved through OSC data transmission, which enables communication between Max/MSP (for sound processing and parameter generation) and Unreal Engine (for visual rendering and interaction). Leap Motion captures gesture data, which is processed through Unreal Engine’s framework and mapped into the Motion Shaper system, directly influencing audio-visual transformations. Additionally, the design of interaction also reflects Harris’s (2021)[6] transperceptual attention concept, reinforcing both emotional engagement and intellectual resonance by positioning the audience as active co-creators of the experience.

5. FUTURE DEVELOPMENT & CONTRIBUTIONS

- Extend *Audio Motion Shaper*’s timbre design through systematic integration of multiple synthesis paradigms (granular, additive, and physical modeling)
- Implement spatial audio processing algorithms to enable dynamic sound localization in 3D space
- Prototype a dedicated hardware interface with FPGA/DSP co-processing architecture for real-time performance
- Develop a Max for Live plugin to facilitate interoperability with standard digital audio workstation workflows
- Investigate VR-based multimodal interaction frameworks combining binaural rendering and visual feedback systems

6. CONCLUSIONS

Motion Shaper introduces an innovative approach to sound-visual synchronisation, moving beyond simple parameter mapping to establish a profound audiovisual relationship grounded in morphological motion. By leveraging the control of motion envelopes, sound and visuals can evolve synchronously in structure, transcending the limitations of traditional synchronisation methods. This enables a true morphological synthesis, achieving a dynamic perceptual fusion that redefines the possibilities of audiovisual integration.

7. ACKNOWLEDGMENTS

In the paper “Motion Shaper: A Cross-Platform Sound Synthesis and Visual Parameter Control System Designed Based on Morphological Synchresis Theory” (Xu and Sun, 2025), Chenghao Xu, as the first author, was responsible for the conceptualisation and development of the Motion Shaper system. This includes designing the theoretical framework of Morphological Synchresis, implementing the Audio Motion Shaper (AMS) and Visual Motion Shaper (VMS) modules in Max/MSP, integrating Open Sound Control (OSC) for real-time audiovisual synchronisation, and leading the creation of the Undercurrent interactive installation. Chenghao Xu also conducted the primary literature review, developed the system architecture and drafted the manuscript. Yiming Sun, the second author, provided valuable support by assisting with the testing of the Undercurrent installation’s gesture-based interaction using Leap Motion, contributing to the documentation of experimental results, and offering feedback on the manuscript. All aspects of the research were conducted collaboratively, with Xu’s role focusing on the leadership and execution of the core technical and theoretical components.

- [9] Denis Smalley. *Spectro-morphology and Structuring Processes*. Ed. by Simon Emmerson. Palgrave Macmillan UK, 1986, pp. 61–93. DOI: 10.1007/978-1-349-18492-7_5.

References

- [1] Michel Chion. *Audio-vision: Sound on Screen*. Columbia University Press, 2019.
- [2] A. Cipriani and M. Giri. *Electronic Music and Sound Design: Theory and Practice with Max and MSP - Volume 2*. 2nd. Virtual Sound, 2019.
- [3] T. Cross. “Reframing Sound Shapes in Spectromorphological Composition: Notating perspectival space through spherical, Euclidean and Cartesian-coordinate systems”. In: *Organised Sound* 29.2 (2024), pp. 228–238.
- [4] D. J. Fallon. “Source bonding, ”music” and sound in electroacoustic composition and the audiovisual sound canvas”. PhD thesis. PhD thesis. University of Liverpool, 2019. URL: <https://core.ac.uk/download/pdf/227453288.pdf>.
- [5] Konx-Om-Pax Riccardo Giovinetto. *Uaxuctum//FEM-INA - Sonica*. <https://sonic-a.co.uk/events/uaxuctum-femina>. 2024.
- [6] Louise Harris. *Composing Audiovisually: Perspectives on Audiovisual Practices and Relationships*. CRC Press, 2021.
- [7] S. James. “Spectromorphology and Spatiomorphology of Sound Shapes: Audio-rate AEP and DBAP panning of spectra”. In: *Proceedings of the 41st International Computer Music Conference 2015*. International Computer Music Association, 2015. URL: <https://ro.ecu.edu.au/ecuworkspost2013/7084/>.
- [8] D. Smalley. “Defining timbre—Refining timbre”. In: *Contemporary Music Review* 10.2 (1994), pp. 35–48. DOI: <https://doi.org/10.1080/07494469400640281>.