Fuzzy Creativity: Composing with Uncertainty in *Incerta*

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Abstract

Incerta is an electroacoustic composition that explores the artistic potential of fuzzy logic as a tool for creative decision-making in music. Rather than relying on data-driven generative models, the piece is structured around a rule-based fuzzy inference system designed by the composer, allowing for nuanced, interpretable control over spatial and temporal processes. The system governs the activation and diffusion of 21 sound sources across an eight-channel setup, using dynamic Gaussian functions whose parameters evolve according to fuzzy logic rules. By adjusting the behavior of these functions, the composer can shape multiple distinct performances of the piece, each emergent, yet bounded by aesthetic intent. This paper situates *Incerta* within the broader discourse on algorithmic composition and creativity, highlighting how fuzzy systems offer a compelling alternative to black-box AI approaches. Through an "artist-in-the-loop" methodology, *Incerta* foregrounds uncertainty as a compositional force, enabling complexity, variation, and control to coexist within a human-guided creative process.

1 Introduction to Fuzzy Logic

Fuzzy logic, a branch of artificial intelligence developed by Zadeh (1965), offers a mathematical framework for reasoning under uncertainty. Unlike traditional binary logic, which imposes strict true/false values, fuzzy logic allows for degrees of truth, making it ideal for interpreting ambiguous, gradual, or imprecise data. In the context of music, fuzzy systems can translate vague musical concepts—such as motion, density, or articulation—into concrete compositional parameters.

1.1 Fuzzy Logic and Creativity in Music Composition

Fuzzy logic contributes to creativity in music by enabling composers to formalize uncertainty and subjectivity—qualities central to artistic expression. Instead of relying on rigid rules or pure randomness, fuzzy systems allow nuanced modeling of vague musical concepts such as "slightly fast," "somewhat dissonant," or "moderately dense" (Suiter, 2010a,b; Guliyev and Memmedova, 2020). In music, fuzzy logic enhances musical expressivity by enabling computational models to interpret qualitative descriptions like "slightly fast" or "moderately loud." (Cádiz, 2020). These characteristics make fuzzy logic particularly suitable for tasks like harmonization, phrase shaping, spatial design, or rule-based constraints that incorporate chance events (Garrett, 2017).

In composition, fuzzy logic supports preference-based decisions, where stylistic inclinations are encoded as weighted rules. This allows intuitive control over complex variables such as timbre, pitch motion, or temporal gestures (Guliyev and Memmedova, 2018; Mugica et al., 2015). Unlike binary logic, fuzzy reasoning accommodates gradual transitions, maintaining a dynamic equilibrium between determinacy and openness—an essential condition for creative flow.

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Fuzzy systems also support expressive real-time environments, enabling systems to respond musically to affective or gestural cues in performance (Lucas et al., 2016; Cádiz and González-Inostroza, 2018). In this way, fuzzy logic is not merely a control mechanism but a compositional partner—shaping sonic material with interpretive nuance while embedding the composer's intent into algorithmic processes.

In *Incerta*, fuzzy logic acts as a "soft decision-maker", allowing the system to interpret musical parameters through shades of gray rather than black and white. This allows the composer to embed musical intentions into a framework that evolves continuously, while still staying within the boundaries of a coherent aesthetic vision. By translating fuzzy sets into spatial gestures and activation envelopes, the piece explores how uncertainty and imprecision can be artistically valuable. Rather than viewing fuzziness as a technical limitation, the composition embraces it as a metaphor for emotional and perceptual complexity.

This approach contrasts with traditional generative systems, such as those used in early algorithmic composition (e.g., Rowe 1993, Cope 2001), which often struggle with integrating subtle or subjective criteria. Furthermore, unlike current generative AI systems that rely heavily on training data, pattern recognition, and statistical modeling, the approach presented in *Incerta* is rule-based and does not depend on learned data representations. Instead of generating musical content from large datasets, the system uses a fuzzy inference engine to control spatial and temporal processes in real time. This allows for a more interpretable and intentional form of algorithmic composition, where compositional behavior is governed by human-designed rules that capture nuanced aesthetic preferences and uncertainties, rather than emergent patterns from opaque models. In summary, fuzzy logic provides a solution by treating ambiguity as a resource for creative exploration, thus expanding the vocabulary of AI-assisted music composition.

2 Overview of *Incerta*

Incerta is an 8-minute acousmatic composition for 8-channel playback, built entirely within the Max/MSP environment (Cycling '74, 2025). The work was designed as a testbed to explore how fuzzy logic could be used to control various aspects of a musical work in real time, particularly spatial diffusion and structural development.

The sound material consists of 21 fixed audio tracks, categorized into three groups based on spectral content: low, medium, and high frequencies. These tracks are triggered and spatialized dynamically during performance, using a real-time fuzzy inference engine.

2.1 Fuzzy Logic Control Toolkit (FLCTK)

The Max/MSP patch used in the piece incorporates the Fuzzy Logic Control Toolkit (FLCTK), a set of externals and abstractions developed by the author (Cádiz and González-Inostroza, 2018). This toolkit supports the design and execution of fuzzy inference systems (FIS) and is optimized for real-time control applications in music and multimedia.

2.2 System Inputs and Outputs

The fuzzy system in *Incerta* is structured around seven input variables:

- Three rotation angles ($\theta_1, \theta_2, \theta_3$) corresponding to the positions of Gaussian functions associated with low, mid, and high-frequency sound sources.
- Three standard deviations ($\sigma_1, \sigma_2, \sigma_3$) controlling the spread (density and width) of the same Gaussian functions.
- A global time variable, which provides a normalized timeline for the duration of the piece.

The output of the fuzzy system consists of incremental adjustments to each Gaussian's angle and standard deviation. These changes influence both the selection of sound materials and their diffusion in space. As the Gaussians rotate around a conceptual sound circle representing the eight loudspeakers, their overlapping regions determine which samples are activated and where they are projected.

2.3 Sound Diffusion and Dynamics

Each audio track is associated with a fixed spatial location on the circular layout of speakers. When a Gaussian function's peak or spread overlaps with a sound's assigned location, that sound is activated. The fuzzy system continuously updates these Gaussian curves based on evolving input conditions, resulting in dynamic and organic transitions.

This mechanism produces a form of gestural spatialization, where changes in the fuzzy variables cause subtle or abrupt shifts in spatial behavior. Sounds may fade in or out, move across the speaker array, or emerge in dense clusters depending on the interaction of variables.

2.4 Artist in the Loop

The compositional method in *Incerta* exemplifies the "artist in the loop" paradigm, where the composer plays an active role in shaping and configuring the behavior of the system. The fuzzy inference rules, membership functions, and sound material mappings are all designed and fine-tuned by the composer, not learned from data. This preserves authorial intent while leveraging algorithmic complexity, positioning the artist not only as a creative initiator but as a continual participant in the system's operation and its multiple realizations.

2.5 Video Demonstrations

Three different performances of *Incerta* were produced, each using a distinct configuration of the fuzzy logic system, allowing the audience to see the system's real-time responses as the music unfolds. While the underlying sound materials and algorithmic structure remain the same, changes to the fuzzy model result in different temporal and spatial behaviors, offering varied realizations of the piece. The resulting versions highlight how fuzzy logic enables controlled variability within a consistent compositional framework. These videos are available at http://rodrigocadiz.com/incerta.

3 Conclusion

Incerta is a compositional experiment in embedding artificial intelligence tools within the musical creation process. By using fuzzy logic to modulate spatial and temporal behaviors, the piece demonstrates how non-binary reasoning systems can open new expressive possibilities for computer music. The usage of a real-time environment created by the composer allowed for both precomposed structure and performance-based variability, contributing to a richly textured sonic experience.

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