Title

A Pitch-Based Framework for Musical Structural Complexity: Gravitational and Entropic Perspectives on Beethoven's Op.110

Author Name: Xiran Sun
Institute: the Victoria University of Wellington
Email Address: sunxira@myvuw.ac.nz sunxiran19990729@outlook.com

Abstract

This study presents a notation-based framework for analyzing pitch-related structural complexity, aiming to explore how musical structure affects performance, analysis, and listening experience. Using a key passage from the third movement of Beethoven's Piano Sonata in A-flat Major, Op.110 (from Adagio ma non troppo to the end of the first fugue section), the study introduces four core indicators: pitch center of gravity, pitch moment of inertia, gravitational centrality, and pitch-based Shannon entropy.

The research consists of two parts: the first part defines and applies these four indicators to quantify structural features and establish a pitch-complexity analysis framework; the second part applies this framework to the selected Beethoven passage, linking the quantitative results to interpretive decisions in performance. In the analysis, some segments exhibit high entropy and a wide pitch range, conveying a sense of freedom or instability, while others are more focused and gravitationally centered, displaying order and clarity.

These indicators provide perceptual insights for performance interpretation. For example, highly dispersed, high-entropy segments may call for more fluid phrasing and flexible pedaling, while low-entropy, gravitationally focused passages suggest stability and clearer articulation.

Beyond performance analysis, the framework has interdisciplinary potential. In AI music generation, these indicators can serve as control parameters for producing structurally coherent works; in neuromusicology, they can be used as input variables to study brain responses to structural features; in music education and visualization, they offer quantitative methods for illustrating structural complexity. The framework is reproducible and scalable, and it can be further extended to the analysis of rhythm, harmony, polyphony, and cross-cultural repertoire.