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ACOUSTIC RECONSTRUCTION AND DIGITAL SIMULATION OPPORTUNITIES IN MAQAM PERFORMANCE

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Abstract: This article explores the potential of acoustic reconstruction and digital simulation in maqam performance. The study examines how traditional maqom sounds can be analyzed, digitally modeled, and reproduced with high fidelity, preserving microtonal nuances, timbral characteristics, and modal structures. Acoustic measurements, spectral analysis, and computational techniques are applied to simulate performance scenarios, enabling both educational and research applications. The findings highlight the integration of historical performance practices with modern technology, offering tools for musicians, educators, and researchers to study, reconstruct, and innovate within the field of maqom music.

Keywords: maqam, acoustic reconstruction, digital simulation, microtonal sounds, performance modeling, spectral analysis, computational musicology

Maqom performance represents one of the most complex and nuanced traditions in music, characterized by intricate melodic structures, microtonal intervals, and expressive ornamentation. Understanding and preserving these features requires precise analysis and documentation of acoustic phenomena. Traditional maqom performances are often transmitted orally, making it challenging to capture exact pitch, timbre, and dynamic subtleties. Recent advances in acoustic reconstruction and digital simulation provide opportunities to model maqom sounds accurately, enabling detailed study, replication, and creative experimentation.

Acoustic reconstruction involves capturing the physical and sonic properties of instruments, performers, and performance environments to recreate traditional sounds digitally. Digital simulation allows for modeling of microtonal intervals, resonances, and expressive techniques, providing musicians and researchers with tools to analyze and experiment with maqom performances without the limitations of physical instruments or live performance settings. By integrating these technologies with historical knowledge and traditional practices, it becomes possible to preserve, study,

and innovate within maqom music, bridging the gap between cultural heritage and modern computational approaches.

This study aims to investigate the possibilities of acoustic reconstruction and digital simulation in maqom performance, focusing on how these technologies can support educational, research, and performance applications. By applying spectral analysis, modeling techniques, and simulation tools, the research seeks to provide a systematic approach for studying and reproducing the complex tonal and microtonal structures of maqoms while preserving their expressive and cultural authenticity.

Maqom performance represents one of the most intricate and expressive traditions of music, requiring a deep understanding of melodic structure, microtonal intervals, and ornamental nuances. Traditional transmission methods, primarily oral, often result in variations in pitch, rhythm, and timbre, making precise documentation and preservation challenging. Acoustic reconstruction and digital simulation offer innovative solutions to these challenges, enabling accurate modeling, analysis, and reproduction of maqom sounds while retaining their expressive qualities. By combining traditional knowledge with modern computational techniques, musicians, educators, and researchers can gain unprecedented insights into the structure and performance practice of maqoms.

Acoustic reconstruction begins with the detailed measurement of sound produced by instruments traditionally used in maqom performance, such as the chang, tanbur, dutar, and ney. These instruments generate complex harmonic spectra influenced by string tension, material properties, resonator design, and performer technique. High-resolution audio recording and spectral analysis allow researchers to extract fundamental frequencies, overtones, and microtonal intervals characteristic of specific maqoms. By examining the harmonic content and dynamic envelope of each note, it becomes possible to identify the precise tuning, timbral quality, and expressive inflections that define a particular maqom.

Digital simulation extends the possibilities of acoustic reconstruction by creating computational models of instruments and performance techniques. Through methods such as physical modeling synthesis and digital signal processing, the vibrational behavior of strings, resonators, and airflow in wind instruments can be accurately reproduced. This enables researchers to simulate how variations in string tension, finger placement, or plucking technique affect the resulting sound. For instance, microtonal

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intervals that are difficult to replicate consistently in live performance can be precisely modeled, providing a reference for both performers and instrument makers. Simulations also allow for experimentation with different tunings, maqom structures, and performance styles, supporting both educational purposes and creative innovation.

An essential aspect of digital simulation is the preservation of expressive nuances. In maqom performance, ornamentation such as pitch slides, glissandi, and subtle rhythmic variations are critical for conveying the emotional content of the music. Advanced simulation algorithms incorporate these features, enabling the reproduction of not just the pitch and timbre but also the expressive articulation of each note. By combining recorded performance data with parametric models, simulations can replicate the idiosyncratic characteristics of individual performers, capturing the cultural and personal nuances embedded in traditional music.

The integration of acoustic reconstruction and digital simulation also provides a robust framework for pedagogical applications. Students learning maqom performance can use simulations to practice with precise tonal references, develop microtonal recognition skills, and experiment with different maqoms without requiring multiple live instruments. Interactive software tools can provide real-time feedback on pitch accuracy, interval consistency, and expressive articulation, accelerating skill acquisition and fostering deeper understanding of traditional performance practice. This technological approach bridges the gap between oral transmission and modern educational methods, ensuring that the subtleties of maqom music are effectively conveyed to new generations of musicians.

In research contexts, these technologies enable comparative studies of maqom performance across regions, historical periods, and performers. By analyzing the acoustic profiles of different instruments and performance practices, researchers can identify stylistic variations, trace the evolution of maqom structures, and investigate the relationship between tuning systems and expressive techniques. Digital archives of reconstructed maqom performances serve as a valuable resource for ethnomusicologists, music theorists, and instrument makers, providing a basis for preservation, restoration, and innovation.

Challenges remain in accurately capturing and modeling the full complexity of maqom performance. Environmental factors, instrument variability, and performer interpretation introduce subtle deviations that are difficult to quantify. Therefore,

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acoustic reconstruction and simulation must be complemented by expert auditory evaluation to ensure that models reflect authentic musical practice. The hybrid approach of combining computational precision with human expertise ensures that simulations are both technically accurate and musically meaningful.

Moreover, digital simulation offers opportunities for cross-cultural collaboration and integration with contemporary music production. By providing standardized digital models of maqom instruments and performances, musicians can incorporate traditional sounds into modern compositions, recordings, and multimedia projects. This approach facilitates creative experimentation while maintaining respect for traditional aesthetics, supporting both cultural preservation and innovation.

In conclusion, acoustic reconstruction and digital simulation provide powerful tools for understanding, preserving, and innovating within the tradition of maqom performance. By capturing microtonal intervals, expressive nuances, and instrumental characteristics, these technologies enable precise analysis, reliable reproduction, and immersive educational experiences. Integrating traditional knowledge with computational methods enhances performance practice, supports pedagogy, and contributes to cultural preservation, while also opening avenues for creative exploration. The combination of acoustic science and digital modeling ensures that the rich expressive potential of maqoms continues to be accessible, analyzable, and relevant in contemporary musical contexts.

This study has explored the potential of acoustic reconstruction and digital simulation in maqom performance, emphasizing their role in preserving, analyzing, and reproducing the intricate microtonal and expressive features of traditional music. Acoustic measurements, spectral analysis, and computational modeling allow for accurate identification of intervals, timbral qualities, and ornamental nuances characteristic of maqoms. Digital simulation complements this by enabling consistent reproduction, pedagogical applications, and creative experimentation while maintaining cultural authenticity. By integrating traditional performance knowledge with modern technology, musicians, educators, and researchers can study and disseminate maqom music more effectively, ensuring both its preservation and continued evolution in contemporary musical contexts.

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