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Towards Accessible and Inclusive Remote Musical Interactions

Challenges and Advancements in Networked Music Performances

By

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Declaration

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Towards Accessible and Inclusive Remote Musical Interactions

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Networked Music Performance (NMP) refers to a real-time interaction between geographically distant musicians, enabled by solutions for audio streaming over a telecommunication network, that allows them to play together as if they were physically located in the same room. While the concept has roots in early technological experiments, its importance has intensified in recent years, driven by advancements in the Internet infrastructure. These advancements include the widespread availability of higher bandwidth, reduced latency, and more reliable network connectivity, which are crucial for supporting the demands of real-time audio streaming. Furthermore, the recent global pandemic and its associated restrictions on physical gatherings have dramatically highlighted the importance and potential of NMP technologies.

Commonly used communication platforms often fall short on replicating the experience of a co-located performance. This is partly due to the reliance on general-purpose tools, such as videoconferencing applications, which, while user-friendly, typically suffer from network latency and limitations in audio quality, detrimental to musical interactions. Conversely, dedicated NMP solutions, while addressing the performance requirements of low-latency and high audio fidelity, are often perceived as complex to use, particularly for individuals with diverse technical backgrounds or specific accessibility needs.

This thesis attempts to address these limitations by presenting a comprehensive investigation on how to enhance NMP systems, exploring innovative solutions and strategies designed to promote more accessible, high-quality, and user-friendly remote musical interactions. This research involves the development and evaluation of web-based NMP systems, specifically by investigating an alternative, unconventional use of WebRTC technologies to achieve low-latency, high-fidelity (uncompressed) audio streaming. Furthermore, it explores the design of hybrid web-native architectures, aiming to integrate user-friendly web interfaces with the improved performance of dedicated native applications. Moreover, the thesis details the investigation of dedicated hardware acceleration for NMP through the design and implementation of an FPGA-based system intended to minimize audio processing delays. Advanced techniques for packet loss concealment are also investigated, focusing on the ap-

plication of autoregressive models to enhance the robustness of audio transmission over the network. To support the broader NMP research community, the thesis also presents the collection process of a specialized dataset, named DUST, of real-world NMP network traffic, carefully designed to facilitate the development and evaluation of NMP-specific algorithms. The potential of immersive technologies is also explored through the investigation of a Virtual Reality system for remote orchestral conduction, as a new approach to provide visual feedback to musicians. Finally, the thesis places a strong emphasis on inclusivity in music education, detailing the investigation of cross-modal associations to design accessible interfaces and providing a comprehensive analysis of technological solutions for users with diverse abilities.