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Reimagining Musical Collaboration: AI and Music Real-Time Communication (M-RTC), The Future of Musical Creativity

Dana Kemack Goot
Indiana University, Indianapolis, danalkg@yahoo.com

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Reimagining Musical Collaboration: AI and Music Real-Time Communication (M-RTC), The Future of Musical Creativity

Dana Kemack Goot, Ph.D.
Music Technology & Human Computer Interaction
Indiana University, Indianapolis

ABSTRACT

This project explored the intersection of Music Real-Time Communication (M-RTC), artificial intelligence (AI), and machine learning (ML) in online musical collaboration. Presented at the 2023 National CMS/ATMI conference, the project served as a preliminary inquiry into how online musicking technologies impact human-to-human interactions and sought out the capabilities in creativity in music technology. The live performance featured three musicians performing from different geographic locations using an AI-generated composition and an AI-powered accompaniment application. The project demonstrated the creative potential of integrating AI and ML into M-RTC, expanding the possibilities for remote collaboration, composition, and performance. The musicians navigated both the opportunities and limitations of the chosen technologies. Their reflections highlighted how advancements in Internet connectivity, platform design, and AI responsiveness could further optimize real-time musical collaboration. These findings contribute to discussions on the future of AI-enhanced music education, cultural exchange, and remote collaboration. As AI continues to shape educational methodologies, its thoughtful integration into M-RTC may offer more engaging and personalized learning experiences, prompting further exploration of policy and technical development.

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Introduction

At the 2023 National CMS/ATMI conference, I presented a Music Real-Time Communication (M-RTC) project that served as preliminary inquiry on the impact of online musicking technology on human-to-human interactions. M-RTC refers to the use of Internet-based technologies that allow musicians in different locations to collaborate in real time during rehearsals or performances. While related to concepts like Networked Music Performance (NMP), M-RTC emphasizes both the musical and communicative aspects of remote, synchronous collaboration (Goot, 2024; Rottondi et al., 2016). I featured a recording of a live performance utilizing the Internet, an Artificial Intelligence (AI)-powered accompaniment application, an AI-generated composition, and three female performers located in three different geographic locations.

An additional objective of the project was to demonstrate the effectiveness and creative potential of music technology, specifically machine learning. The multi-dimensional format highlighted the application of machine learning in music composition and live performance over the Internet. The capabilities of music technology were illustrated through our recorded real-time collaborative performance across different locations. The trio performed an AI-generated composition developed using machine learning algorithms trained on songs inspired by nature.

Artificial Intelligence (AI) and Machine Learning (ML)

The terms AI and Machine Learning (ML) may be used interchangeably in this narrative. However, to be clear, ML is a subset of AI, whereas AI as a branch of computer science develops systems capable of mimicking human intelligence, enabling learning, reasoning, planning, and decision-making. AI aims to create expert systems and integrate human-like intelligence into machines, enhancing efficiency, speed, and adaptability in various applications, including robotics and automation (Lalitha, 2021; U.S. Department of State, 2024).

ML is a subset of AI that focuses on enabling systems to learn from data, identify patterns, and improve performance over time without explicit programming. ML is particularly necessary for processing large datasets, automating repetitive tasks, and making predictions in complex environments where rule-based coding is impractical. ML algorithms adapt to new information, derive insights, and optimize decision-making from a vast amount of data through the compounding of computer science, mathematics, and statistics (Lalitha, 2021; IBM, n.d.).

While AI encompasses a broader goal of replicating human intelligence, ML specifically refers to the techniques and algorithms that allow systems to learn and improve autonomously. In other words, AI is the overarching concept of intelligent machines, whereas ML is a primary method through which AI achieves its learning and adaptability (Massachusetts Institute of Technology [MIT] Sloan, 2020).

Project Conceptualization and Implementation

In conceptualizing M-RTC with AI, I planned to develop an AI written song which would then be sung by the vocalist in San Antonio, Dr. Orit Eylon (University of the Incarnate Word), accompanied by a pianist from a second location in San Antonio, Dr. Ara Koh (University of the Incarnate Word). In addition, I would manage a real-time AI generation of a secondary accompaniment from Carmel, Indiana.

Several inspirational pieces of a nature theme for learning material for the song generation were narrowed to two songs. The first being *Trees*, written in 1922, with music composed by Oscar Rasbach and lyrics by Joyce Kilmer. The second song was *Autumn Leaves* with music composed by Joseph Kosma in 1945, and lyrics by Johnny Mercer.

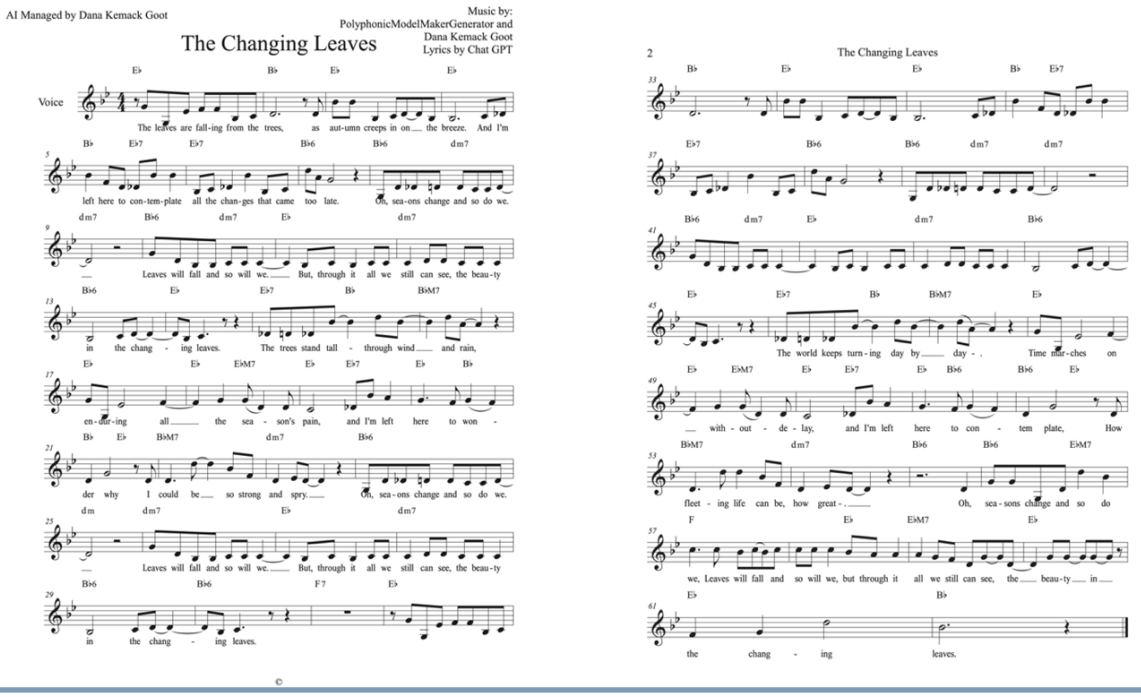
I utilized the Polyphonic Music Generator Max patch by Dr. Jason Palamara of Indianapolis University Indianapolis to produce melodic material for the new song. In order for the Max patch to learn the material, it first needed to be in MIDI format, which I accomplished by playing the melodies of *Trees* and *Autumn Leaves* on a keyboard, which were routed to the Digital Audio Workstation (DAW), Ableton Live 11. MIDI data was recorded and refined within the DAW, enabling adjustments to timing, note length, and velocity. The data was then

transferred to Finale for lyric placement on the melody, followed by further cleanup of the MIDI data after its transfer.

The lyrics were generated by ChatGPT, with learning material from both *Autumn Leaves* and *Trees*. Three attempts were made to create the lyrics, with the first attempt ultimately chosen as the final version. The lyrics were set to the generated melody, which was done in a mostly syllabic manner, with adjustments made only as necessary for musical cadences, phrases, etc. Chords were then chosen to fit the melody. Sheet music (Figure 1) was created and then sent to the vocalist and accompanist.

Figure 1

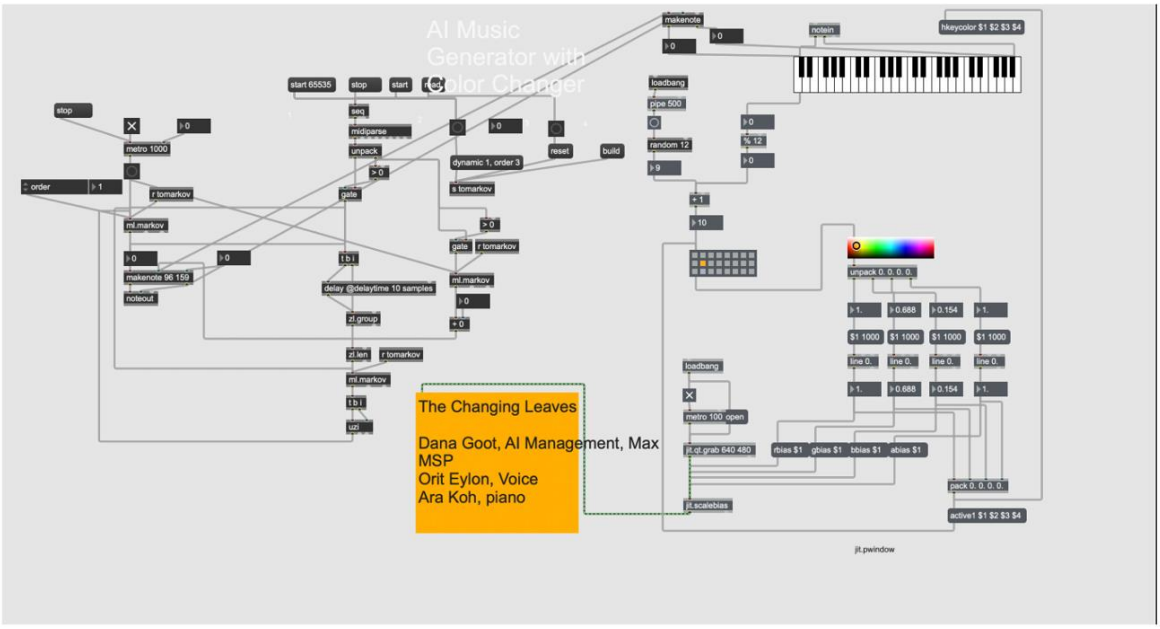
Sheet music for the AI-generated composition "Changing Leaves." The melody was generated by AI, with syllabic lyrics set to the melody and accompanying chords chosen to complement the musical structure.



After creating the AI-generated song, which was human-managed, I aimed to develop a system for real-time accompaniment. To achieve this, I built the AI Music Generator with Color Changer using Max MSP as seen in Figure 2.

Figure 2

AI Music Generator with Color Changer developed in Max MSP

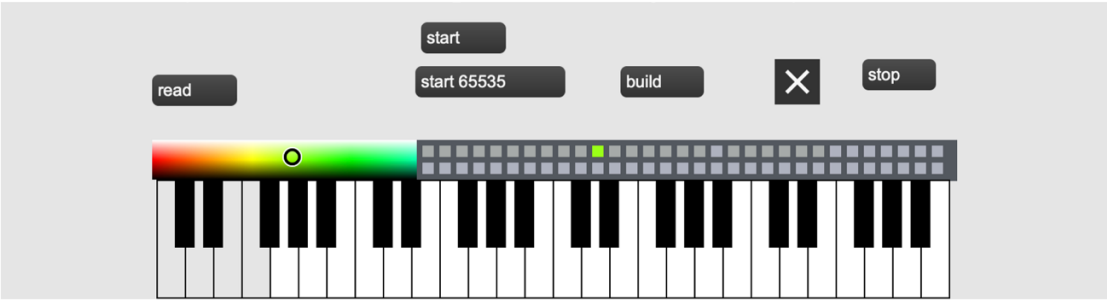


In Max's presentation mode of the AI Music Generator, buttons prompt the user from left to right (Figure 3). The `read` button signals the reading of the MIDI file for the learning material for the accompaniment. The newly written AI piece, *The Changing Leaves*, was the learning material for the accompaniment. The next prompts are the `start` commands. In the Max patch, users can choose between `start` and `start 65535`. The `start` command plays the file at its default speed, while `start 65535` forces an immediate start and dramatically increases playback speed—65535 times faster in the case of a MIDI file. The `build` command, which follows either

`start` or `start 65535`, processes and optimizes the playback data. Finally, users can stop playback using `X` or `stop` as needed. During playback, the color-changing square will display colors corresponding to the frequency (note) being played.

Figure 3

Presentation view of AI Music Generator with Color Changer



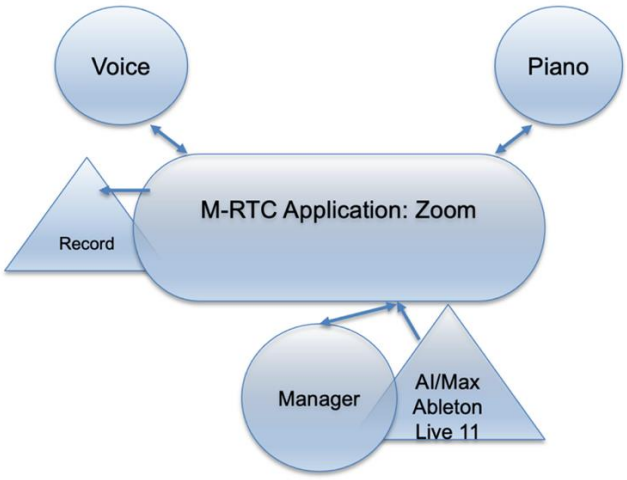
My project aimed to engage willing participants. I assisted the vocalist and pianist to prepare musically in advance, and offered that a technical and musical group rehearsal and recorded performance be conducted in a single session. Accordingly, I prioritized a simple setup for both Internet connectivity and the use of a familiar platform, Zoom. I was concerned that a complex setup, requiring additional time from their already busy professional schedules, could result in participant attrition. As illustrated in Figure 4, the vocalist, Eylon, located in San Antonio, connected via Ethernet to Google Fiber and used a Snowball microphone without headphones. The pianist, Kor, also in San Antonio but at a different location, relied on Wi-Fi and positioned a microphone inside the piano to capture its sound, using headphones for monitoring.

On my end, I managed the AI accompaniment and recorded the session. The output of the AI accompaniment from the Max patch was routed to Ableton Live 11, where I assigned the sound to the track, selecting piano as the instrument for audio playback. I initiated the continuous melodic output of the Max patch and at the end of the performance chose to conclude the AI

accompaniment on the tonic note of the song's key. The AI-generated accompaniment, managed by myself, was then routed from the Max patch to Ableton and into Zoom, alongside the piano and vocals, all of which were received through my system and headphones and recorded via Zoom.

Figure 4

Audio and visual routing and system setup for Recording M-RTC Performance



For audio routing, the Audio MIDI Setup used a multi-output device with external headphones and Zoom audio. In Zoom, I configured the speaker and external headphones, using an aggregate device for the microphone. The Zoom settings were as follows for all participants: Original Sound for Musicians, High Fidelity Music Mode, Auto Level Off, Echo Cancellation Off, and Stereo Audio.

Reflections and Limitations

Reflecting on the technical aspects of Music Real-Time Communication (M-RTC), my experience has been shaped by both the challenges and rewards of navigating this modern blend of music and technology. One key realization was the profound impact that M-RTC interaction has on musical collaboration, despite the technological challenges. While M-RTC offers new

possibilities for distance collaboration, it demands technical fluency to ensure a seamless and engaging musical performance. Moreover, cognitive and musical adaptations are essential for successful engagement in M-RTC. This consideration led to further research, culminating in my published dissertation, *Exploring Human Adaptations in Music Real-Time Communications (M-RTC): A Qualitative Study*, which delves deeper into these adaptations (Goot, 2024).

In terms of equipment, there was a need for reliable, high-quality tools. The setup required the coordination of a combination of hardware and software, such as Max MSP, Ableton Live, and Zoom. The selection of microphones, headphones, and Internet connections was critical in ensuring clear audio and smooth communication. Lack of advanced audio engineering skills for the proper miking of the piano and the limitations of the pianist's Internet connection, being WIFI and not Ethernet, offered an imperfect audio setup up. Resultingly, the piano acoustics were often intermittent. Additional audio cutout disruptions were likely due to Zoom's limitations, as the platform is not optimized for music. Although, since that time, I have discovered advanced audio settings within Zoom that could have significantly enhanced our setup, though they would not have resolved the latency issues.

The logistics of setup, scheduling, and communication played a crucial role in the success of the project. Given that participants were located in different places, effective communication before and during the session was vital. However, balancing their busy professional schedules with my consideration of their time inadvertently led to limitations in conveying the ideal technical setup. I was mindful that imposing excessive technical requirements could deter participation or lead to participant withdrawal. As a result, this led to some compromises in the technical setup, which, combined with the constraints of their available technology and the information provided initially, prevented the ideal configuration from being achieved.

Latency was another major technical consideration. While efforts were made to optimize the system setup, the pianist's use of a WIFI connection significantly contributed to latency issues. Additionally, the Zoom platform itself introduced further delay, which was particularly noticeable in a real-time musical context. Other contributions to latency include encoding and decoding of data packets, video data transmission, and Internet traffic. Latency affected the timing and flow of the music, requiring intentional adaptations to maintain cohesion. Within both

rehearsal and performance, a more rubato approach in the vocal line, combined with arpeggiated chords that reduced emphasis on strict meter, helped mitigate the effects of latency and create a more fluid musical interaction.

I was satisfied with the AI-generated composition and accompaniment, fully aware of its limitations based on the intentionally limited dataset I provided. The occasional dissonance reflected this design and added nuance to the performance. While a more complex, reactive AI might reduce dissonance, it is unclear whether that would result in a more musically compelling outcome.

Finally, the overall quality of the M-RTC application itself emerged as an area for ongoing refinement. While the application allowed for real-time collaboration, the overall quality—particularly the audio fidelity and synchronization—was sometimes affected by external variables, such as network instability or hardware limitations. Achieving a balance between ease of use and high-fidelity output is a continual challenge in M-RTC, but it remains a goal for future applications.

Results

An interesting outcome of using the AI accompaniment was that its continual melodic output, set to a piano instrument track in Ableton Live, often masked the audio dropouts from the pianist's live signal. These cutouts, caused by the pianist's Wi-Fi-based connection, became less noticeable due to the timbral similarity between the AI-generated accompaniment and the acoustic piano. In moments when the pianist's signal briefly dropped or weakened, the AI filled the space with harmonic material that created a sense of continuity for the listener. This blending of sources appeared to smooth over technological imperfections and contributed to a more seamless performance experience. While not initially intended as a masking tool, the AI accompaniment functioned as a buffer against network inconsistency, offering a potentially valuable role in future remote collaboration scenarios.

Participants' Reflective Summary

In approaching this project, Dr. Eylon and Dr. Koh had a mix of curiosity and uncertainty. While both were open to the experience, they shared skepticism about how well a musical performance over Zoom would work, particularly given past experiences with latency and audio interference. At the same time, there was an eagerness to explore how AI-generated accompaniment would shape the performance and whether it could contribute to a cohesive musical experience. Given that there were updated Zoom platforms, quality microphones, and stable Internet connections, there was some confidence in the setup.

During the rehearsal, it became clear that latency and audio quality played a significant role in shaping how the performance was navigated. The pianist's reliance on WIFI, combined with the platform's limitations, meant that there were moments when it was difficult to stay connected musically. The vocalist found it somewhat isolating to sing without clearly hearing either the accompaniment or the AI-generated harmonies in real time, despite increasing speaker volume. Instead of responding naturally to the accompaniment, the performance became more about anticipating harmonic changes and relying on familiarity with the piece. This adaptation led to a more rubato approach in the vocal line and the use of arpeggiated chords to reduce the emphasis on strict meter.

After the final recording, reflection was made on the ways AI is shaping musical collaboration. The participants were intrigued by how the AI accompaniment thickened the harmonic texture, sometimes introducing appoggiaturas that subtly reshaped the pianist's playing. While they were surprised by how natural certain elements of the recording sounded, there were still noticeable audio dropouts, likely due to Zoom prioritizing different performers at different moments. This created occasional lapses where either the piano or voice was less prominent than intended.

Although participants did not explicitly frame the AI as either a tool or a replacement, their openness to collaborating within this setup suggests an orientation toward AI as an assistive and exploratory element. Unlike the skepticism historically associated with new technologies in music, the performers' engagement reflected curiosity and adaptability, rather than concern about displacement.

Overall, the two participants felt that their experience reinforced the idea that AI is best suited as a collaborative tool rather than a replacement for human musicians. While Eylon and Kor didn't know exactly what to expect at the start, the final result was more cohesive than they anticipated. However, it also highlighted the need for continued refinements in both technical setup and musical strategies. After reflecting on the experience, they were left considering how improvements in Internet connectivity, platform design, and AI responsiveness could further enhance real-time online musical collaboration.

Final Reflections and Future Directions

My experience in leading and conceiving of the project contributed toward my speculation of how musicians successfully participate in M-RTC, which was ultimately discovered through my dissertation research (Goot, 2024). It also supported the idea that the integration of AI and machine learning as tools of music technology, alongside M-RTC, significantly expands the range of possibilities for musicians. These technologies offer enhanced creative potential, providing musicians with new ways to collaborate, compose, and perform in real-time over the Internet. This convergence of AI, machine learning, and M-RTC not only enhances the capabilities of traditional music creation but also opens the door to entirely new forms of artistic expression.

As with music creation, new technologies, like artificial intelligence and virtual reality, could change educational methods by making learning experiences more personal and engaging, actions that may mean reforming existing policies, or launching new policies and initiatives (Chari, 2024). While these possibilities are promising, the integration of AI and M-RTC in education will require overcoming challenges in infrastructure, teacher training, and policy adaptation. These technologies hold the potential to transform not just music education, but all areas of collaborative and creative learning. As we move toward an increasingly interconnected world, their impact could reshape how we think about both teaching and learning, and may set the stage for the next wave of educational innovation.

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ABOUT THE AUTHOR

Dr. Dana Kemack Goot is an experienced Music Technologist, Educator, and Researcher with a Ph.D. in Music Technology and a Ph.D. minor in Human-Computer Interaction from Indiana University Indianapolis. She also holds a certificate in music composition. Her expertise lies in blending traditional music with cutting-edge technology to enhance both online and in-person music education and performance. With over two decades of experience in adult education, she brings a strong background in teaching, research, and leadership to every endeavor.

Dr. Goot has published extensively in the field, including *"A Spectrum of Online Rehearsal Applications: A Potential Means for Cultural Connection"* in *JONMA*, *"A Perceptual Evaluation of Music Real-Time Communication Applications"* in *IEEE Access*, and *"Exploring Human Adaptations in M-RTC (Music Real-Time Communications): A Qualitative Study"*, her published dissertation.

She has contributed to successful online festivals and conferences, demonstrating technical support proficiency and innovative teaching strategies. Additionally, she launched a monthly newsletter and organized a highly attended virtual forum for ATMI, and serves as a band leader for a world music ensemble. As a business owner and international artist-in-residence, she has performed in Israel and Italy, bringing diverse cultural experiences to her work. Dr. Goot's forte lies in merging academic and artistic pursuits, fostering cultural connections through music and technology on a global scale.

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