

Artificial Intelligence in Music: Applications, Challenges, and Future Prospects

Yichen Zhu

*Nanjing International School, Nanjing, China
yichenzhu@nanjing-school.com*

Abstract. In recent years, Artificial Intelligence (AI) has been remarkably progress in many field. Nowadays AI has rapidly expanded its influence into the field of music, introducing innovative approaches to music composition, music education and music performance assessments. This study discusses how AI has been used inside these areas, where assisting human at AI educational purposes and also in composition purposes. This paper also addresses key challenges, including issues of model interpretability, stylistic limitations and other ethical concerns that are related to authorship. Lastly, the paper indicates future directions for AI usage in the music domain. In particular, further research may focus on developing more transparent algorithms to improve user trust, exploring hybrid systems that integrate human creativity with machine intelligence, and establishing clearer frameworks for copyright and ownership of AI-generated works. By providing this structured overview, the review seeks to promote a deeper understanding of AI's potential as a collaborative tool in reshaping the future of music.

Keywords: Artificial Intelligence, Music, Machine Learning.

1. Introduction

In recent years, Artificial Intelligence (AI) has transformed in numerous industries, mathematic calculations to literature and to people's daily life, and the field of music as well. Advanced machine learning models, deep neural network, audio signal detection have allowed AI not to only be able to "hear" the music, but also being capable to evaluate, analysis, and even create music. AI is changing the industry of music from its production to its evaluation. This transformation redefines the roles of musicians, educators, and audiences alike.

One of AI's applications nowadays is in music performance assessments. Traditional music evaluations and gradings are mostly relied on judges and audiences' personal opinion where inaccuracy or inequality of grading would be given to the performers individually, where some performers may get high marks with rather original music, and other performers with pieces contains creativity and innovations may be neglected by the judges. In comparison, AI grading system can analyze pitch accuracy, rhythm precision, dynamics, and expression in real time [1]. By processing audio features through advanced algorithms, these systems offer consistent and objective feedback, helping musicians identify specific areas for improvement.

AI has also become as a valuable tool in music education [2]. Intelligent tutoring systems can adapt to the learner's skill level, providing personalized exercises and instant feedback. For example, some platforms allow AI to recommend practice routines, analyze techniques and discover errors, allowing students to rehearse with virtual ensembles. This adaptive learning approach not only enhances the efficiency of practice sessions but also makes quality music education more accessible to learners without direct access to expert instructors.

One of the most ground breaking technique that AI has developed in music area is that its use in music generation. AI has developed useful models such as Recurrent Neural Networks (RNNs), transformers, and diffusion-based systems allowing AI to compose melodies, harmonies, and full arrangements in various styles. These systems ,for example, can mimic famous musicians' composition style and generate background music for movies even just to create absolute music. While AI-generated compositions have sparked debates about originality and authorship, they also open new possibilities for artistic exploration.

The aim of this study is to provide a comprehensive overview of the applications of AI use in music. This paper is structured into four main sections: Section 1: introduction of this topic. Section 2 related work and case studies on AI technologies in music. Section 3 discusses the challenges and the limitations. Lastly, section 4 concludes the paper with key findings and emphasizes the future path of AI in music.

2. The application of AI in music

2.1. Music performance assessment

One of the earliest and used most widely used of AI in music is its application of performance assessments. Traditional evaluations rely heavily on human judges, whose grading may be influenced by subjective preferences and inconsistent criteria. AI-based grading systems, by contrast, employ audio feature extraction and machine learning to deliver objective evaluations. For example, Ye et al. [1] proposed a deep learning framework that analyzes pitch accuracy, rhythm alignment, and dynamic expression in real time. The workflow involves recording an audio signal, extracting temporal and spectral features, and comparing these with an "ideal" performance model. Their findings demonstrated that AI assessments could achieve a high correlation with expert evaluations while maintaining greater consistency across different performers. Such systems not only reduce bias but also provide detailed feedback on specific technical weaknesses, enabling musicians to make targeted improvements. Li et al. expanded on audio-only systems by designing a multimodal AI platform to assess violin performance using both sound and visual cues. Their workflow integrated pitch-tracking algorithms with computer vision analysis of bowing technique, hand positioning, and finger movements. This dual-modality allowed the system to capture subtle technical details that would otherwise be overlooked in audio-based assessment, such as excessive bow pressure or incorrect fingering patterns. The researchers reported that their system achieved higher accuracy in detecting technical mistakes compared to audio-only systems. Furthermore, performers received comprehensive feedback that addressed not only sound quality but also physical playing technique, which is essential in mastering string instruments. Findings revealed that this approach could serve as a valuable assistant for violin students who may not always have access to in-person teachers, thereby enhancing practice efficiency and long-term skill development.

2.2. Music education

In music education, AI has become a transformative tool that expands learning opportunities and also improves accessibility. The AI tutoring system powered by reinforcement learning and also adaptive algorithms are able to adjust to the student's proficiency level. Yu et al. introduced a piano learning platform where an AI system provided personalized practice schedules, detected mistakes in fingering and rhythm and generated corrective exercises. The workflow integrated the computer vision of hand tracking, audio recognition for pitch detection, and also for feedback modules of error correction. Their study shows that students using AI-assisted tools demonstrated faster progress and higher retention compared to those that never experienced AI assistance.

Snyder et al. developed AIJam [3], a collaborative learning and improvisation tool designed to support students in developing creativity and performance skills. Unlike systems that focus solely on technical accuracy, AIJam provided a virtual ensemble that responded interactively to a student's musical input. Using machine learning algorithms, the AI companion adjusted its improvisational style, tempo, and harmonic progression according to the student's skill level and musical direction. This allowed learners to engage in dynamic "jam sessions" without requiring access to other musicians. Results from classroom trials revealed that students practicing with AIJam demonstrated higher motivation and engagement compared to those using traditional practice methods. Participants also reported increased confidence in improvisation and creativity, skills often overlooked in conventional training. This system highlighted the broader role of AI in nurturing not only technical mastery but also musical expression and artistic growth.

2.3. Music generation

Perhaps one of the most groundbreaking advancements lies in AI's usage in music composition. Recent innovations employ architectures such as Recurrent Neural Networks (RNNs), Transformers, and diffusion-based generative models, Miguel et al. developed Music transformer which leverages self-attention mechanisms to capture long term musical dependencies, enabling the generation of coherent melodies and harmonies over extended passages [4]. Their work involved numerous amounts of deep-thinking training on large symbolic music datasets, encoding note sequences, and decoding outputs into stylistically consistent compositions to their model. This allows AI to generate pieces in diverse styles such as jazz, classical or pop style. often passing "Turing tests" where listeners struggled to distinguish between human and AI compositions. While some concern about the authorship and the creativity remain, this system is already employed in film scoring, background music generation for games, and real-time improvisation. This shows the wide range of usage and the growing role of AI as a creative partner rather than merely a robot.

Dong et al. proposed MuseGAN, which is a Generative Adversarial Network (GAN)-based system designed to create multi-track music arrangements. Unlike earlier models that only generate single melodies, MuseGAN is capable of producing simultaneous tracks for instruments such as drums, bass, chords, and lead melody, enabling the composition of complete musical pieces in various genres. The workflow involves large number of pieces with multiple tracks for the model to learn in a large scale of database. Results showing that the system could produce musically convincing arrangements, particularly in pop and rock styles. Listener evaluations showed that MuseGAN's compositions were often rated highly in terms of rhythm, harmony, and stylistic consistency. This research indicates AI's potential to function as a collaborative tool for music producers, film composers, and content creators by automating parts of the creative workflow while still allowing for human artistic direction.

3. Discussion

3.1. Challenges

Although there are several significant progresses in the application of artificial intelligence in the field of music, some limitations and challenges still remain in this area. One of the primary concerns is the issue of interpretability in music area. Many AI systems that generate music functions like a “black box” where it is very difficult for users to understand the real reasoning behind their algorithm and its generated outputs. In musical context, this lack of transparency became particularly problematic. For example, when an AI system that tries to create a piece, where rather than giving you the understanding and the inspiration of how this piece was created, it only throws out a mechanized piece blank where there are no instructions and logical reasoning of the creating process of this piece. Another example can be when AI is evaluating a performance, it doesn’t provide clear explanations of why certain music choices seemed inaccurate or why specific piece was created. This opacity can undermine trust among musicians and composers, potential limiting the understanding of “why” behind the feedback and the piece, which may be very critical for feedback or educational purposes.

Secondly, another significant challenge is that the applicability of AI system across diverse musical contexts. For most AI models, they are trained on specific datasets that they use for deep learning which represent particular genres, styles or cultural traditions. When these systems encounter musicals outside of their training domains, their quality of the performance might be unable to be sustainable. This limitation restricts the generalizability and practical utility in global musical contexts where the stylistic diversity in the norm. Furthermore, musical meanings often depend on and represent a type of cultural context and subjective interpretation, which may be elements that are particularly challenging to capture and represent through algorithmic processes. Therefore, AI generated music might sometimes lack authenticity, and unable to represent the specific study of human that shows personal emotional feeling and cultural context meaning that characterize human-composed works.

Lastly, the integration of AI in music also raises an important ethical and authorship concerns. As the AI system become more capable of generating original sounding music, questions about copyrights and creative ownership often emerged and became increasingly complex. Questions such as whether credit should be assigned to the AI developer, the user who provided input parameters, or the AI system itself deserves the credibility has been continuedly in debate. Additionally, there’s a growing concern that overreliance on AI tool might potentially suppress and limit human creativity and diminish the value placed on traditional musical training. The convenience of AI generated suggestions and compositions may be a helpful assistant tool that helps creators to create and compose more conveniently, however it may also lead to a musical homogenization, where distinctive artistic voices are overshadowed by algorithmically optimized patterns that prioritize predictability over innovations.

Technical limitations also present substantial challenges. AI systems nowadays often require extensive computational resources and large, high-quality datasets for training, resources that may not be equally accessible to all musicians and educational institutions. There are also ongoing challenges in developing AI systems that can adequately understand and process the temporal and emotional dimensions of music, aspects that are inherently subjective and context dependent.

3.2. Future prospects

Despite these challenges, there are still several solutions that can solve these challenges for the future development of AI in music. The integration of music domain knowledge represents a crucial avenue for advancement. Future AI systems could benefit from incorporating explicit musical knowledge [5-7], including music theory, harmony, counterpoint, and genre-specific conventions, into their architectures. By developing hybrid systems that combine data driven machine learning with rule based expert knowledge, researchers could create AI tools that produce more musically coherent and culturally informed outputs [8-10]. Such systems could also provide more meaningful, context aware feedback in educational settings, helping students not only identify technical errors but also understand the underlying musical principles

Also, the development of more interactive and collaborative AI tools that allow AI to replace for human musicians, but act as a creative partner that responds to and evolves with human input. These systems could enable real time co-creation, allowing musicians to intuitively guide and refine AI generated materials through natural interfaces such as gestures, voices, and even instrumental input. This collaborative approach would preserve humans with more creativity while also leveraging AI's capabilities for generating ideas, exploring possibilities, and also handling technical complexities. This allows AI to be particularly valuable in educational contexts, where they could provide students with responsive practice partners and composition assistants. Further allowing us to amplify the advantages of AI while preserving human creativity.

4. Conclusion

This review discussed how AI has undeniably transformed the music landscape, offering multiple options that allow composers and performers to get access to the innovative tools for performance assessments, education and compositions. By providing detailed feedback, personalized learning supports and new creative possibilities, AI supports and enhances musical practice in meaningful ways. While there are still some critical and thoughtful challenges that remain unresolved. Moreover, the future of AI use in musical area is still in a positive way where in future, it continues its support on developing that collaborates with human musicians that ensures the piece using technology amplifies creativity while preserving the artistry and emotion that defines music that expresses human's thought and creativity.

References

- [1] Ye, G., Liu, Y., Zhou, T., Li, X., & Zhang, Q. (2023). An automatic music generation and evaluation method based on transfer learning. *PLOS ONE*, 18(5), e0283103.
- [2] Zhou, X. (2023). Analysis of Evaluation in Artificial Intelligence Music. *Journal of Artificial Intelligence Practice*, 6(8), 6-11.
- [3] Yu, X., Ma, N., Zheng, L., Wang, L., & Wang, K. (2023). Developments and Applications of Artificial Intelligence in Music Education. *Technologies*, 11(2), 42.
- [4] Civit, M., Civit-Masot, J., Cuadrado, F., & Escalona, M. J. (2022). A systematic review of artificial intelligence-based music generation: Scope, applications, and future trends. *Expert Systems with Applications*, 209, 118190.
- [5] Swanwick, K. (2002). *Musical knowledge: Intuition, analysis and music education*. Routledge.
- [6] Omar, R., Hailstone, J. C., Warren, J. E., Crutch, S. J., & Warren, J. D. (2010). The cognitive organization of music knowledge: a clinical analysis. *Brain*, 133(4), 1200-1213.
- [7] Carroll, C. L. (2020). Seeing the invisible: Theorising connections between informal and formal musical knowledge. *Research Studies in Music Education*, 42(1), 37-55.
- [8] Johnson, M. L. (2002). Toward an expert system for expressive musical performance. *Computer*, 24(7), 30-34.

- [9] Raphael, C. (2001). A probabilistic expert system for automatic musical accompaniment. *Journal of Computational and Graphical Statistics*, 10(3), 487-512.
- [10] Cope, D. (1987). An expert system for computer-assisted composition. *Computer Music Journal*, 11(4), 30-46.