Autonomous Intelligent Music Teacher

Lavanya Aprameya

Abstract *– Researchers in the field of artificial intelligence are trying to create technology that acts in a truly human way. This research, spread over fields such as speech communication and medicine, has also been used to fashion computers into music composers, accompanists, etc. This paper proposes a system that teaches people to play music via artificial intelligence, or AI, rather than teach computers music. Existing teaching software, SmartMusic, holds a similar goal without the enrichments of artificial intelligence. The proposed system creates an electronic musical teacher designed to help budding musicians master the basics of their instruments. The system composes its own music for teaching by identifying and using musical patterns with which the student tends to struggle. It provides a tool created to enhance students' performance levels to their full potential.*

1. Introduction

The attempted combination of music and AI has always been seen as the jamming together of two puzzle pieces which are not meant to fit together. It is the opinion of some musicians that music is a purely human feat, a privilege that computers will never be able to achieve. Several members of the artificial intelligence (AI) community, however, have fought this mindset with their belief that music is, in more ways than one, founded on mathematics [1]. What computers lack in emotions, they make up for with computational capabilities. The attempted combination is not only a possible, but also an achieved concept, as proved by the Hiller-Isaacson system (discussed further in the paper) and many more [1]. In order to understand the ways in which AI and music, two fields which seem to be on opposite ends of a spectrum, can fit together, it is important to establish what each term truly means.

Music can be defined as a) “vocal or instrumental sounds (or both) combined in such a way as to produce beauty of form, harmony, and expression of emotion” and also b) “a sound perceived as pleasingly harmonious.” Both definitions build on the understanding that, for something to be labeled as music, it must have some form of aesthetic. This, however, lends itself to subjectivity. Fans of classical music may claim that Mozart and Beethoven composed the only real music, while the younger generation believes that rap and dubstep are the new breakthrough musical genres. Therefore, music cannot be defined in terms of aesthetic features for computational purposes. In order to create an idea of music that is not overly influenced by the programmer's personal taste, music must only be regarded in its more concrete senses. All music has the following aspects: key, tempo, rhythm, pitch, and more. These aspects not only have a clear-cut definition, but also draw heavily from math. Greek mathematicians, for example, created scales still used today on the basis that the notes were "mathematically pleasing". When music can be broken down into pieces that can be comprehended and created by a computer, using AI with music is a reasonable approach.

AI is a field of computer science that is based on "the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages." Simply put, AI works to create systems that act as humans would, coupled with the efficiency and ease of computational processing. Computer systems are equipped with artificial intelligence in a variety of ways dependent on the programmer. This process of "learning," or instilling knowledge in a computer, is known as machine learning, in which systems acquire information through examples. Machine learning works in several ways, employing tactics such as neural networks, which mimic aspects of the human nervous system, and transfer learning, which works to minimize learning from scratch by borrowing from previously attained knowledge [2] [3]. AI finds itself at work in several different projects and fields. IBM's Watson managed to triumph over *Jeopardy*'s two best players, and several creations in the field of robotics are now enabled with AI systems. Computer systems are also being used to aid doctors by serving as data analysts, providing insights into what treatments might be fit for a certain patient. In addition, Google's self-driven car is helmed by AI [4]. Artificial intelligence has enabled computer systems to speak, think, and make decisions in a process somewhat similar to that of human beings, but they have yet to feel and emote like us.

Nevertheless, the fields of AI and music have come together to create computer systems that play the role of musician to a certain extent. Systems in the past have been focused on music analysis, computer accompaniment, standalone computer composition, and more [5]. Computers attempt to analyze music by breaking down the notes, rhythms, and patterns in search of the flow and purpose of a piece, another term for a musical composition. AI scientists hunt for understanding as to why a note in the harmony is emphasized more than a note in the melody, and they seek to know why the dynamic softens at the climax of the piece. Some computer systems are also designed to act as accompanists to performers. These systems provide music complementary to the actual piece, working to recognize the more emphasized aspects of the piece and to find a way to complete the performance. This goal is sometimes carried out before a performance, with the computer having "heard" the performer and putting together an accompaniment afterwards; on the other hand, it can be achieved during a live performance itself. Several programmers also turn computers into composers by feeding them examples of what the programmers think to be good music [1] [5]. However, AI cannot yet completely grasp the emotional twists in music, causing some computer-made pieces to fall flat on human ears.

The history of AI coupled with music, though vast and growing, can be briefly told with a few landmark inventions. ILLIAC, created by Hiller and Isaacson in 1956, is one of the first successful combinations of music and AI. The Hiller-Isaacson system works to compose music via the generate-and-test method, which revises its music as it creates it. It also puts to use Markov chains to compose music based on probability, a technique followed by many programmers to this day. David Cope's EMI has also gathered appraisal for its success in composing music in the style of various well-known composers. Programmers have also attempted to tackle the issue of emotions in AI, with "Director Musices" being one of the more successful systems [1]. SaxEx, a more recent project, is able to create expressive music played on a saxophone [5]. Several musical computer systems utilize Musical Instrument Digital Interface (MIDI), one of the earliest achievements in the field, to achieve their goals. MIDI permits a musician to physically play an instrument and then captures the sound, creating an editable musical score on the program [1]. All of these systems have made an impact on the AI and music society, but few have to do with AI and music designed for teaching.

SmartMusic is a computer program created to serve as a teaching aid for music teachers by providing an easy method to assess a student's performance, and it also proves to help music students through its feedback. In this system, students and teachers pick a piece from a library of sheet music and then go on to play it according to the notes displayed on the screen. SmartMusic records the performance via microphone, turning it into sheet music. The student's interpretation of the piece is subsequently displayed on the screen along with the original work. The program highlights the instances in which the student either matches or misses an aspect of the score, allowing students and teachers to self-assess while also providing a score out of 100% [6]. This system works well as a quick tool for performance analysis but lacks in the ability to truly respond to a performance's result.

In this paper, the author proposes a computer system, Autonomous Intelligent Music Teacher (AIMT), which builds on the foundation of SmartMusic but integrates AI's abilities to compose music, analyze data, and adapt to certain circumstances. This system strives to bring about an intelligent program that can perform all of the following tasks:

• Generating new music based on what the piece is meant to teach,

• Evaluating a student's performance to discover which musical aspects are more difficult to grasp for a learner, and

• Using this information to generate more music which allows the student to practice and understand those aspects.

The proposed system is not only a musical tool for a student, but also acts as a teacher by providing a more interactive environment. Section 2 of this paper describes AIMT in detail and concludes in Section 3.

2. Autonomous Intelligent Music Teacher (AIMT)

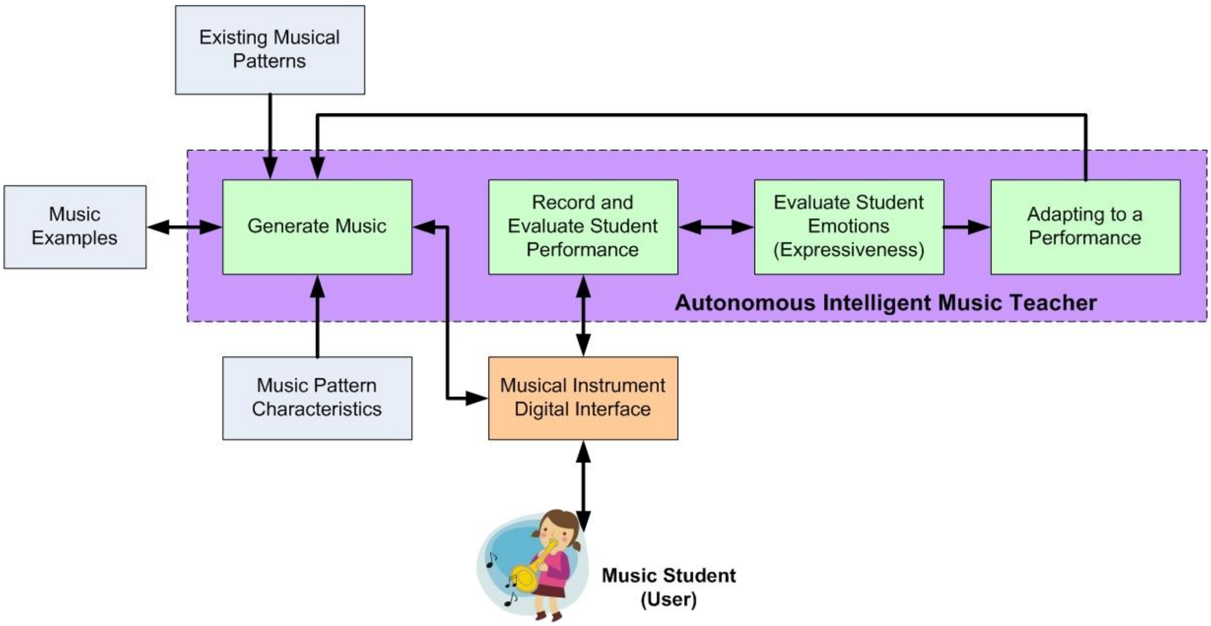

Figure 1 Autonomous Intelligent Music Teacher System Architecture

Figure 1 depicts the AI process and the system architecture of AIMT, which teaches students how to play music based on their performance. The four blocks (i.e., "Generate Music", "Record and Evaluate Performance", "Evaluate Student Emotions (Expressiveness)", and "Adapting to a Performance") inside the system architecture implement AI algorithms. The system is at a conceptual level, and this paper analyzes and develops its detailed procedures to demonstrate the application of AI. Sections 2.1 through 2.3 describe the details of AIMT's process flow.

2.1 Generating Music

Music designed to teach students how to play their instruments is almost completely made up of predictable musical patterns, therefore making it very simple for a computer to compose. A student is simultaneously exposed to multiple patterns such as those of pitch, or sound frequency; dynamics, or volume; rhythm, or timed movement; and articulation, or execution of a single note when a song is played from a music book. This type of music is built entirely around these mathematically-based patterns, and with a certain amount of parameters, the possibilities for pieces are almost endless.

As Figure 1 shows through the blocks leading to "Generate Music", knowledge of these musical patterns should be instilled in the system from the beginning, serving as the tools which it can use to create music. Since these patterns can fall into categories, the information should be programmed in groups, with one cluster referring to key, another referring to dynamics, and so on. Machine learning comes into the picture when the computer learns how to put these patterns together to create music. Basic understanding of two elements is not enough to combine them. AIMT must learn through examples the specific characteristics of one pattern that are highlighted when matched with one or more other patterns. For example, the placement of certain dynamic patterns in a G minor piece varies depending on tempo, or speed. As AIMT produces more music and learns from previous examples, it should begin to understand the patterns behind these patterns.

AIMT strives to generate music by prompting the student for some specifications, such as key and form. Given a general backbone for what the piece is meant to teach, the computer can go on to build on this foundation by adding in specific notes and rhythms. Once the music is created, the system should then display the sheet music on the screen for the student to play, bringing the proposal to its next stage.

A system which generates music rather than present existing pieces leads to many advantages for the student. This process provides the student with more than just one piece highlighting a certain aspect, allowing for a better understanding. Instead of playing the same song again, the student can break away from repetition and become more engaged in the learning process. New music allows for a large and diverse library, as opposed to a set list of fifty songs.

2.2 The Performance

Once a piece has been written, the student is presented with the sheet music. As the student plays, AIMT, using MIDI, records this performance, as stated in Figure 1. Then, the "sheet music" of the performance appears over the original score. This portion of the system, presented in the Figure 1 block "Record and Evaluate Student Performance", externally borrows greatly from SmartMusic but seeks to internally assess the performance in more depth.

The student can, at this point, evaluate this performance visually. The system allows the student to see a forgotten note pitch or a failure to adhere to dynamics at the end of the piece. However, the student will not yet be aware of the true patterns that have not been comprehended. The student might not be at ease playing that scale, a set of notes ordered by pitch, or tends to play high notes more loudly than low notes regardless of the indicated dynamic. The computer system, working to examine every aspect of the performance, understands these things.

AIMT's assessment pinpoints each musical pattern and observes it separately. The evaluation of adherence to key signature is kept apart from that of tempo. The individual musical patterns are, like SmartMusic's overall rating, based on a numerical scale. The system starts out with full points (e.g., 50/50) for a pattern and then moves through the piece critiquing it. For every mistake, AIMT docks a certain number of points depending on how much the performance digresses from the score. After completing this process for a pattern, it then records the final score and determines whether the student has mastered this aspect. For example, a score lower than 30 indicates a need for more practice while 49 means near mastery. At the same time, it notes qualitative observations such as "dynamics increase when supposed to decrease" for more tangible feedback.

After performing these calculations internally, the system then displays these detailed evaluations to the student. The student can then observe that there were several mistakes in dynamics even though they seemed to be miniscule, but the tempo was not as off-point as anticipated. From here, both the computer and the student learn from this performance and adapt their actions to the circumstances.

2.2.1 Evaluating Emotion

The familiar issue of a computer dealing with emotions arises in this portion of AIMT, represented by the portion of Figure 1 labelled "Evaluate Student Emotions (Expressiveness)". Music designed for teaching does not lack in emotion, and therefore expressiveness must be taken into account in the evaluation of a performance. As with most aspects of this type of music, however, emotion comes with a pattern. A piece can indicate with just the word "agitato," an instruction for the piece to be played in an "agitated" tone, at the beginning what its expressive purpose is. This piece must be played quickly and with accents to deliver the intended effect, and these more defined terms can be assessed in the same way as the rest of the piece to deliver an overall score for emotion. While this system may not be able to fully understand emotion, it can still guide a student's expressive progress.

2.3 Adapting to a Performance

After evaluating a student's performance, the computer holds data on the student's strengths and weaknesses. This system, utilizing AI’s decision-making skills, strives to evolve to best fit a student’s needs. For example, if AIMT ranks the tempo of a performance as “failing”, it takes this into account when generating a new piece.

Demonstrated by the link in Figure 1 between "Adapting to a Performance" and "Generate Music", the process of creating music remains nearly identical to the method previously described, differing with respect to what AIMT knows about the student. It has now collected data on what musical aspects a student has yet to master; therefore, when asking for the parameters of the next piece, the system should fill in certain aspects on its own. If a student has yet to learn a scale, AIMT does not allow any new specification for the key signature, which indicates what scale a piece is in. It proceeds to create a piece with the same key signature as the previous one. Similarly, if the student scores highly on a pattern but chooses the same pattern for the next song, it should inform the student that this pattern might not need more practice. However, the student is here presented with a choice.

By allowing both the computer and the student to learn with each use of the program, AIMT creates an environment designed to cater to the student's requirements. It optimizes time for the student, highlighting what needs to be practiced and only moving forward with patterns that the student already knows well. In this system, the student can have twenty pieces to practice one musical pattern rather than be limited to three in a book. In addition, this calls for greater involvement of the computer than simply creating music to be played. The ability to provide a dynamic environment makes the proposed system not only a useful tool for teaching music, but also a teacher itself to a certain extent.

3. Conclusion

AIMT is a computer system that works as a dynamic music teacher. It utilizes machine learning to create musical pieces for a student to play while also harnessing AI's decision-making skills to assess performances and to adapt to them. It provides the student with a wide range of music and detailed feedback that an independent learner cannot access. This system aspires to create a model that can stand in for a human teacher; however, there is much to improve. Since music students eventually move on to true musical pieces, the system should one day be able to deal with music that relies less on patterns and more on the human touch.

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About the author

Lavanya Aprameya is a high school student currently in her senior year. She plays the flute, therefore being familiar with musical terms and patterns. She has previously used SmartMusic in her studies. She plans on furthering her study of computer science in college.