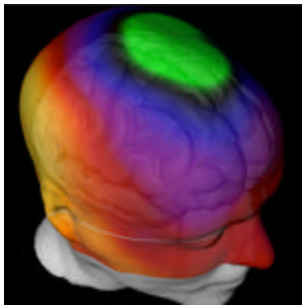


Artificial Intelligence and Music

One of the key feature that distinguishes humans from other animals is the fact that we are intrinsically musical. Music is generally associated with the expression of emotions, but it is also common sense that the intellect plays an important role in musical activities. The interplay between these two elements figures in the research agenda of a variety of scientific fields, including Neuroscience, Cognitive Sciences and Artificial Intelligence (AI), to cite but a few. This essay introduces some fundamental issues of AI and its interplay with music.

The Musical Brain

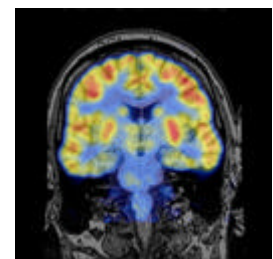


From a number of plausible definitions for music, the one that frequently stands out in musicological research is the notion that music is an intellectual activity; that is, the ability to recognize patterns and imagine them modified by actions. We understand that this ability is the essence of the human mind: it requires sophisticated memory mechanisms, involving both conscious manipulations of concepts and subconscious access to millions of networked neurological bonds. In this case, it is assumed that emotional reactions to music arises from some sort of intellectual activity. Different parts of our brain do different things in response to the stimuli we hear. Moreover, music is not detected by our ears alone; for example, music is also "heard" through the skin of our entire body. The brain's response to external stimuli, including sound, can be measured by the activity of the neurons. Two measuring methods are commonly used: PET (Positron Emission Tomography) and ERP

(Event-Related Potential). PET measures the brain's activity by scanning the flow of radioactive material previously injected into the subject's bloodstream. Despite its efficiency, this method is rather controversial because the long term side effects of the radioactive substances to the health of the subject are not entirely known. ERP uses tiny electrodes placed in contact with the skull of a person to measure the electrical activity of the brain. As far as the health of the subject is concerned, ERP is safer than PET, but the measurement is different. Whilst PET scans give a clear cross-sectional indication of the area of the brain where the bloodflow is more intense during the hearing process, ERP gives only a voltage level vs. time graph of the electrical activity of the areas of the brain where the electrodes have been placed. Our understanding of the behaviour of the brain when we engage in any type of musical activity (e.g., playing an instrument or simply imagining a melody) is merely the tip of an iceberg. Both measuring methods have brought to light important issues that have helped researchers uncover the tip of the iceberg. PET scans have shown that listening to music and imagining listening to music activate different parts of the brain and ERP graphs have been particularly useful to demonstrate that the brain expects sequences of stimuli that conform to established circumstances. For instance, if you hear the sentence "A musician composes the music", the electrical activity of your brain will tend to run fairly steadily. But if you hear the sentence "A musician composes the dog", the activity of your brain will display significant negative electrical response immediately after the word "dog". The human brain seems to respond similarly to musical incongruities. Such behaviour obviously depends upon one's understanding of the overall meaning of the language in hand. A number of enthusiasts believe that we are born "programmed" to be musical, in the sense that almost no-one have difficulties in finding coherence in simple tonal melodies.

Understanding Intelligence with AI

The understanding of the behaviour of the human brain is not, however, identical to the understanding of intelligence. Physical measurements of brain activity may certainly endorse specific theories of intelligence, but not all theories seek endorsement of this sort. One of the goals of AI is to gain a better understanding of intelligence, but not necessarily by studying the inner functioning of the brain. The methodology of AI research is largely based upon logics, mathematical models and computer simulations of intelligent behaviour. Of the many disciplines engaged in gaining a better understanding of intelligence, AI is one of the few that has special interest in testing its hypotheses in practical day-to-day situations. The obvious practical benefit of this aspect of AI is the development of technology to make machines more intelligent; for example, thanks to AI computers can play chess and diagnose certain types of diseases extremely well. It is generally stated that AI as such was "born" in the late 1940's, when mathematicians began to investigate whether it would be possible to solve complex logical problems by automatically performing sequences of simple logical operations. In fact AI may be traced back far before computers were available, when mechanical devices began to perform tasks previously performed only by the human mind, including some musical tasks. Is intelligence synonymous to the ability to perform logical operations automatically, to play chess or to diagnose diseases? Answers to such types of questions tend to be either biased to particular viewpoints or ambiguous. The problem is that once a machine is capable of performing such types of activities, we tend to cease to consider these activities as



intelligent. Intelligence will always be that unknown aspect of the human mind that has not yet been understood or simulated.

Intelligent Computer Music

Machines Music is without doubt one of the most intriguing activities of human intelligence. By studying models of this activity, researchers attempt to decipher the inner mysteries of both music and intelligence. From a pragmatic point of view, however, the ultimate goal of Music and AI research is to make computers behave like skilled musicians. Skilled musicians should be able to perform highly specialized tasks such as composition, analysis, improvisation, playing instruments, etc., but also less specialized ones such as reading a concert review in the newspaper and talking to fellow musicians. In this case the music machine would need to have some basic understanding of human social issues, such as sorrow and joy. Will computers ever display such highly sophisticated and integrated behaviour?


More optimistic enthusiasts believe so. As happens in other areas of AI research, however, computers have so far been programmed to simulate most specialized tasks, but fairly independently from each other. Current research work is now looking for ways to integrate the ability to perform a variety of such tasks; e.g., mechanisms from systems for music analysis are aggregated to systems for composition in order to allow for the computer to autonomously compose music in the style of analysed pieces. It is debatable whether musicians want to believe in the possibility of an almighty musical machine. Musicians will keep pushing the definition of musicality away from automatism for the same reasons that scientists keep redefining intelligence. Nevertheless, AI is helping musicians to better operate the technology available for music making and to formulate new theories of music.

Formal Grammars

The notion of formal grammars is one of the most popular, but also controversial, notion that has sprung from AI research to fertilize the grounds of these flourishing new theories of music. Formal grammars appeared in the late 1950s when linguist Noam Chomsky published his revolutionary book *Syntactic Structures*. In general, Chomsky suggested that people are able to speak and understand a language mostly because they have mastered its grammar. According to Chomsky, the specification of a grammar must be based upon mathematical formalism in order to thoroughly describe its functioning; e.g., formal rules for description, generation and transformation of sentences. A grammar should then manage to characterise sentences objectively and without guesswork. Chomsky also believed that it should be possible to define a universal grammar, applicable to all languages. The study of the relationship between spoken language and music is as old as the music of the Western culture. It is therefore not by accident that Music and AI research has been strongly influenced by linguistics and particularly by formal grammars. Many musicologists believed that Chomsky's assumptions could be similarly applied to music. A substantial amount of work inspired by the general principles of structural description of sentences has been produced, including a variety of useful formal approaches to musical analysis.

Who composed *Entre l'Absurde et le Mystère*?

Entre l'Absurde et le Mystère is a piece for chamber orchestra produced by CAMUS, a computer system designed by the author a few years ago. CAMUS uses a type of formal grammar to produce sequences of music structures (e.g., melodies, chords, clusters, etc.). The grammar of CAMUS was designed specially to produce music based upon computer simulations of biological behaviour using a class of mathematical formalisms called as cellular automata. The public warmly applauded its performance by The Chamber Group of Scotland in 1995 in Edinburgh. Martyn Brabbins, the conductor, was reluctant to believe that a computer had generated the piece and generally members of the audience found that the piece was pleasant. The general wonder of that evening was: "Was the piece really composed by a computer?" This question is debatable and has serious ideological implications. In our point of view, a distinction between author and meta-author should be made in such cases. The ultimate authorship of the composition here should be to the person who designed and/or operated the system. Even in the case of a program that has the ability to program itself, someone is behind the design and/or the operation of the system. Similarly, one would hardly consider that Pierre Boulez's *Polyphonie X*, for example, was composed by the serialism system.

 [Click here](#) to listen to an excerpt of the piece

Semantics

Formal grammars are suitable for the description of the syntactical rules of a language but they do not guarantee meaningful formations. If one wishes to program a computer to produce meaningful sentences automatically, some notion of semantics must be included in the system. Although semantics is a concept primarily related to spoken languages, it also applies to music to a certain extent. Semantics, often referred in AI jargon as declarative knowledge, is a crucial aspect of AI research. A substantial amount of research work is dedicated to the design of methods to represent knowledge effectively. Designers of AI systems require knowledge representation techniques that provide representational

power and modularity. They must capture the knowledge needed for the system and provide a framework to assist the systems designer to easily organize this knowledge. The primary assumption in AI is that mental activity is mediated by internal representations. Although there is no consensus as to what these representations actually are (some regard them as neurophysiological states, whilst others may define them as symbols or even images). The traditional approach to AI assumes that intelligent activity is achieved through:

- the use of symbols to represent a problem domain,
- the use of these symbols to generate potential solutions to problems,
- the selection of a suitable solution to a problem.

The use of an adequate knowledge representation technique is therefore one of the most important keys for the design of successful AI systems.

Conclusion

Mathematics and logics undoubtedly play a dominant role in the formalisation of intelligence for AI research. But is formalization the right approach to express intelligent behaviour?

Is it right to distinguish between mind and body, semantics and syntactic, knowledge and abstract representation schemes? The great majority of AI work to date assume that intelligence can be simulated by encapsulating chunks of data into static "packets" of information. Intelligent activity is then performed by an "engine" that picks and combines appropriate packets of information stored in memory in order to achieve specific goals. In this case, knowledge is often classified into two main groups: declarative (e.g., the semantics of the grammar or the "meaning" of the packets of information) and procedural (e.g., the grammar itself or the how the engine should function). In fact humans store knowledge in a more complex way. Our brains are stubborn systems which cannot be deconstructed so neatly. Human intelligence is formed by both conscious and unconscious elements distributed at different levels of layers in our mind. Only the conscious ones can be objectively accessed and manipulated. We seem to not have access to the levels which do most of our thinking. When we think, we certainly change our own rules and rules that changes the rules, and so on, but we cannot change the lower layers; i.e., neurons always function in the same way. Modern approaches to AI seek inspiration from this neurophysiological model. Traditional AI research methods are not necessarily inspired by neurophysiology but have, nevertheless, produced fruitful results. Perhaps the most fruitful of them all is the conclusion that there are many types of intelligence and each have their own characteristics. Music certainly involves a very distinct type of intelligence and it is up to Music and AI researchers to find the right approaches to it.

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