ONE EXAMPLE OF HOW ARTIFICIAL INTELLIGENCE CAN BE USEFUL IN MUSIC FIELDS

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ABSTRACT: Musical listening is a complex phenomenon, and its computational approach asks Artificial Intelligence (AI) many questions, such as the question of musical representation, and the recognition of composer-intention. An intelligent system may find ways of paying attention to the recognition of some musical intuition. Particularly, this vision offers to Machine Learning (ML) a large field of experimentation, opened up by the possibility of learning from the observation of communication between teachers and learners, through an educative model.

Introduction: why are many AI results applicable to musical tasks?

We are developing a Learning Apprentices System, called "Le Musiconologue", dedicated to Music Education; it has been first implemented in La Litié and we are running it on Macintosh computers. An implementation in HyperCard and C language, more interactive, is also running in the Sorbonne Musicology Department, and a commercial version is now proposed by Act Informatique and Fondation TOTAL pour la Musique.

Music is a multi-representational language, and to practice music typically requires some culture as a way of finding a reference scenario and events1, but also some knowledge concerning the musical objects and their usual context, and some experiments about the way of transforming representations or changing from one representation to another2. But how could a processing environment provide all those features, dealing among others with the difficult question of time representation in music, and graphical representation? First of all, let us examine quickly the different representations used to structure musical information in our system.

As far as the score is concerned, one needs notation tools appropriate to the high complexity of musical language, tools able to provide transformation for a musical piece, supposing a theory of formal musical languages3, and some way of reading the structure to get musical events, which is a way of transforming that particular kind of representation into a sound representation4.

Another representation is the sound representation (in-time), or the gestural representation if you think about the Musical Instrument Digital Interface communication standard; and here again, music is polysemous: there are several ways of transforming the musical object from sounds to graphics, and the better solution seems to be obtained by giving the user intelligent tools responsible for decisions like quantization or enharmonicity for example.

Furthermore, there is another important way of representing music as far as education is concerned: that is the semantic one, a description in terms of the rudiments of music, which is the only one able to provide explanations to the user and a base for the guided management of his own progression. As a matter of fact, although the correction of an exercise can take place in a graphical environment (with pattern recognition techniques for example, to compare different instances of a musical piece), or in a sound environment with score-following and obligatory musical tasks5, evaluation, explanations of

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the case and propositions for evolution must rely on a semantic analysis.

Thus, we need a way of representing musical knowledge as a semantic network, to support a Knowledge Based System; in "Le Musicologue", we wanted this network to provide a sort of evaluation grid of how the lesson is understood, so that it is a representation of the lesson, and one's evaluation provides explanations and justifications about the results of the training process.

To realize that kind of semantic representation dynamically, we need many technologies of ML, and among them:

- clustering: given some knowledge field, how to discover similarities between some part of that knowledge to cluster the field in simpler but meaningful sub-fields?
- discrimination: given a field of concepts, how to find a way to recognize efficiently every concept?
- generalization: from some examples of one situation or one rule, how to deduce a formula general enough to describe the situation or the rule, and to explain the descriptive power of this formula.

Overview of our system "Le Musicologue"
Regarding music and cognitive research, here are our system's features:
- it provides the teacher with a new environment of music representation, able to describe as many different situations as he wants, and allowing the creation of pedagogic methods and appropriate environments for evaluation of students' learning paths;
- the teacher alone is responsible for building a semantic network of musical concepts, and for representing his pedagogic message;
- it provides the learner with explanations of his mistakes;
- it provides the learner with directions of progression suited to his own wants and his own problems.

Actually, our system "Le Musicologue" contains an interactive problem-solver that integrates new knowledge by observing, analyzing, and questioning its user, as a normal way of functioning. Our first application concerns instruction for musical dictation. Trying to learn music through the exercise of musical dictation, the main problem we encountered is the link between evaluation and composition of musical pieces.

To be easily available, musical pieces are organized in a sort of database. In that database, the user can consult every piece by direct access by name to the three representations above; he can listen to the piece with some freedom axes, he can see the piece, and he can consult the composition of the piece. There is also another way of consulting a piece which proceeds by intelligent inquires about some analytic features of the piece (for example, you can ask for a Bach piece without any seventh interval but less than 24 bars long). The management system of that database permits editing a given piece graphically, to build another piece from the score or the gestural form, or from specifications in terms of rudiments of music. Of course, for the reasons we gave before, the user is responsible for some features of the transformed representations.

Main ML and KA aspects in "Le Musicologue"
Our LAS incorporates a traditional system and a Learning System, as follows: the user gives the system a problem to solve (a progression along his own path) and the traditional sub-system starts solving this problem. Therefore, during the course of its functioning as an Expert System, our system may encounter two situations: either the current problem-solving step is accepted by the user; then, the current state of the knowledge base is judged as satisfactory, and no learning will take place; or it is unable to propose any partial solution (or the solution it proposes is rejected by the user); then, the user is compelled to give his own solution.
Once the solution is given, a learning process will take place. The system will try to learn a general rule so that, when faced with problems similar to the current one (which it has been unable to solve up to now), it will be able to propose a solution similar to the solution given by the user. Thus, "Le Musicologue" should be able to solve problems which are more advanced than its implemented capabilities (this is how to lead student progression), and we can start using it even if its knowledge is very limited; it will be developed without requiring a long and difficult process of knowledge-base construction, as with a traditional Expert System.

As far as student progression is concerned, some rules may be inferred, dealing with analysis of musical pieces, and analysis of mistakes. To produce these rules, "Le Musicologue" needs some explanations: an explanation is the description of the validity domain of the variables contained in the rules: "Le Musicologue" will try to find an explanation of the user's solution in terms of the known relations between the concepts included in the solution. It will ask the user questions in order to distinguish between the relevant and the irrelevant links in the network. Since the user always provides totally instantiated rules, the system must automatically variableize them, and then must find the validity domain of these variables by asking "clever" questions of the user. The system over-generalizes (simply by turning all constants into variables) this rule to generate a generalized rule. The set of sufficient conditions of the application of the instantiated rule is kept as a set of sufficient conditions of the generalized rule. An over-generalization of the set of sufficient conditions is computed, and considered as a set of necessary conditions for the generalized rule.

The system looks again at its knowledge base in order to find instances that fulfill the set of necessary conditions. These instances are used to generate rules analogous with the example provided by the user, which are proposed for the user's validation. Those that are user-validated are considered as new examples of the rule. These new examples are used to generalize the sufficient conditions, and these negative examples are used to particularize the necessary conditions, as done in the Version Space.

The user has to characterize such system-generated instances as examples or counter-examples of the rules to be learnt. The idea behind the use of the explanations for learning is that an explanation points to the main features of the objects, that is, to the features which have to be kept in the generalization.

Conclusion
In its present state, "Le Musicologue" is still much nearer to a simple Expert System Shell for building practical Expert Systems than to a really clever "knowledge extractor". Its means for extracting knowledge are still rather stereotyped and too inefficient. They are perfectly suited for interaction with an everyday user who has a good, but not deep knowledge of his field. Nevertheless, the very fact that "Le Musicologue" has been built using ML techniques, will permit the improvement separately and continuously of its components, thus reaching a level of sophistication in the learning processes that may require the best experts in the field to answer its questions. This feature is far from negative since one must first build a Knowledge Base which is not too far from the desired one, and that contains most of the trivial information. Only on this Base can a really intelligent one begin to be built, containing subtle concepts and able to do deep reasoning similar to that of a good human expert.

"Le Musicologue" is able to build up a Knowledge Base in such a way that Interactive ML takes place, which contains some simple rule learning from the user's data. If two experts have opposite opinions on a diagnosis for a given situation, we have no way to prevent them introducing contradictions in the Data Base. When their disagreement is less strong, and the experts agree on the diagnosis but disagree on their justification of it, then "Le Musicologue" will not generate contradictory rules, but sets of different explanations.

Thus, our system seems to be, as pointed out earlier, a means of acquiring a social expertise, particularly well adapted to music education. Indeed, many copies of a Learning Apprentice System, distributed to a broad community of music teachers, could acquire the experience of this community.
that is, a base of educative experience which is very large, comparable to the experience from which a human learns.

References