Music and lazy learning

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Abstract

"*We tend to think of what we 'really' know as what we can talk about, and disparage knowledge that we can' t verbalize.*" (Dowling 1989, 252)

In the Western civilization, including the modern Japan, and especially in the sciences, logical thinking, conceptualization, and generalization are highly valued as signs of intelligence. It is not surprising, therefore, that scientists emulate these types of intelligence using computers. Nevertheless, there are common human tasks, such as language acquisition, visual understanding, and music processing, that may involve other modes of intelligence.

Lazy learning is proposed here as a promising and alternative model for implementing many types of human behavior, including music perception and cognition. Lazy learning, which includes instance-based learning, exemplar-based learning, memory-based reasoning, and case-based learning, does minimal work during input of data and defers processing until requested.

Greedy learning, represented by rule-based reasoning, decision-tree induction, and neural networks, on the other hand, tries to learn as much as possible in an architecture that is relatively small, explicitly producing generalizations to solve problems.

Lazy learning becomes useful where greedy learning fails. It is particularly applicable to domains in which there are only a few underlying principles and a large amount of exceptions—such as music. The study of music may also give insights into temporal representation, emotional information processing, and creativity.

Introduction

Most research in artificial intelligence and music has used rule-based models. Exemplar-based model, which is analogous to the idea of “learning by examples,” is proposed here as an alternative approach to modeling many aspects of music cognition.
Although humans are capable of consciously abstracting concepts and deriving rules, there are other cognitive tasks such as music knowledge acquisition that are largely non-verbal and defy generalizations, consequently making the application of traditional rule-based AI models problematic.

This paradigm, also known as the lazy learning model, is attractive because training is not necessary, learning is extremely fast, algorithms are simple and intuitive, rules are not sought, and learning is incremental. The major drawback has been the high memory requirement, since all examples must be stored, but the recent decrease in memory cost makes this model quite feasible.

Exemplar-based recognition models have been successfully applied in weather prediction, cloud identification (Aha and Bankert 1994), natural language translation (Sato 1995), and the acquisition of pronunciation skills (Cost and Salzberg 1993). Furthermore, cognitive psychologists have found this model evident in human and animal learning. In music, style recognition, harmonization, expressive performance, instrument recognition, and structural analysis are some of the obvious targets for the deployment of this model.

We are capable of consciously abstracting concepts and deriving rules. But it does not necessarily follow that we do so when we recognize a percept, such as chord, cadence, and phrase. Laske (1992, 251) remarked that “in AI generally, and in AI and Music in particular, the acquisition of non-verbal knowledge is difficult, and no proven methodology exists.” One of the ways to represent non-verbal knowledge is through examples. The implemen-tation of this model is based on a combination of a nearest neighbor classifier and a genetic algorithm, which is used for feature weighting.

Exemplar-based model

The exemplar-based model is based on the idea that objects are categorized by their similarity to one or set of stored examples. There is much evidence from psychological studies to support exemplar-based categorization by humans (Brooks 1978; Hintzman 1986; Medin and Schaffer 1978; Reed 1972). Furthermore, reliable pattern recognition tasks have been performed by computers using examples (Aha, Kibler, and Albert 1991; Cost and Salzberg 1993; Fujinaga, Pennycook, and Alphonce 1989).

Nearest-neighbor classifier

The exemplar-based model can be implemented by k-nearest-neighbor (k-NN) algorithm (Cover and Hart 1967), which is a classification scheme to determine the class of a given sample by its feature vector. Distances between feature vectors of an unclassified sample and previously classified samples are calculated. The class represented by the closest neighbor is then assigned to the unclassified sample. Besides its simplicity and intuitive appeal, the classifier can be easily modified, by continually adding new samples that it “encounters” into the database, to become a learning system. In fact, “the nearest neighbor algorithm is one of the simplest learning methods known, and yet no other algorithm has been shown to outperform it consistently” (Cost and Salzberg 1993, 76).

Incremental learning

By continually adding new samples that it “encounters” into the database, k-NN classifier improves its performance, thus learning to identify the symbols more accurately.
The recognition can be further enhanced by modifying the feature space, or equivalently, changing the weights in the distance measure. A commonly used weighted-Euclidean metric between two vectors **X** and **Y** in an N-dimensional feature space is defined as:

$$d = \left(\sum_{i=1}^{N} \omega_i \left(x_i - y_i \right)^2 \right)^{1/2}.$$

By changing the weights, ω_i, the shape of the feature space can be changed.

Although the problem is simple for a two-dimensional case, i.e. using two features, when many features (up to 20) are used, the problem of determining the set of weights that results in the optimal recognition rate becomes extremely complicated. Since no known deterministic method for finding a optimal solution exits, some other technique is needed to address this problem.

Genetic algorithms

The current implementation of NN classifier for optical music recognition by the author includes the use of genetic algorithms (GA) (Holland 1975) to find the optimal set of feature weights and thus further improving the recognition capabilities (Punch et al. 1993).

Genetic algorithms are often used whenever exhaustive search of the solution space is impossible or prohibitive. The set of weights are converted to "genes" and those that have high recognition rates are made to survive in this pseudo-biological environment. Briefly, the initial environment is randomly populated. Through the process of selection, fit individuals (those who perform well) are mated to produce offspring, who will hopefully outperform their parents. Although the optimal solution is not guaranteed by GA, near-optimal results can be obtained relatively quickly and preliminary experiments with the system have shown dramatic improvements in the recognition rate. This hybrid learng system, combining nearest neighbor classifier and GA has been successfully implemented in music (Fujinaga 1996; Fujinaga 1995) and other fields including biochemistry (Raymer et al. 1997b) and biomedicine (Raymer et al. 1997a).

By using GA from the beginning of the learning process, a set of good genes, or the set of weights, are saved so that they can be used as the starting points for the future selection processes.

Music applications

There are many possible areas in music where this model can be applied. Some of these are listed below:

- harmonization
- counterpoint
- orchestration
- piano reduction
- expressive performance
- automatic accompaniment
- composition / improvization
- score-based analysis
- transcription
- beat-induction, tempo tracking
- key finder
- phrase detection
- style imitation
- style identification
- intelligent instrument lessons
- optical msic recognition

Conclusions

The exemplar-based model offers a promising and alternative approach for music cognition and may be applied to other types of categorization and learning tasks.

Acknowledgments

I would like to thank Prof. Susumu Horiguchi for his support and hospitality. This research was partially funded by Nakajima Heiwa Foundation.

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