First species counterpoint music generation with VNS and vertical viewpoints

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Computer aided composition is a research area that focuses on using computers to assist composers. In its most extreme form the computer generates the entire musical piece. This can be done by realizing that composing music can—at least partially—be regarded as a *combinatorial optimization problem*, in which one or more melodies are "optimized" to fit the "rules" of their specific musical style. In a previous paper, a *variable neighbourhood search (VNS)* algorithm was developed that could generate first and fifth species counterpoint fragments based on an objective function that was manually coded from music theory [5]. In this research *machine learning* is used to automatically generate the objective function for a VNS that generates first species counterpoint.

When composing or generating counterpoint fragments, it is essential to consider both vertical (harmonic) and horizontal (melodic) aspects. These two dimensions should be linked instead of treated separately. Furthermore, in order to confront the data sparsity issue in any corpus, abstract representations should be used instead of surface representations. These representational issues are handled by the *vertical viewpoints method* [1, 3].

A first species counterpoint fragment can be viewed a sequence of *dyads* (two simultaneous pitches). Every dyad is represented by three linked features: two pitch intervals between the two melodic lines (previous and next dyad), and the pitch interval within the dyad. The dyad sequences are transformed to abstract feature sequences with the vertical viewpoint method [1] and a first order Markov model is constructed. A total of 1000 first species fragments were used as training data for the Markov model. They were generated by the approach described by Herremans and Sörensen [4].

To generate counterpoint, the VNS algorithm receives a cantus firmus as input (composed by the user or automatically [4]) and generates the corresponding counterpoint line. The quality of a counterpoint fragment is evaluated according to the cross-entropy (average negative log probability) of the fragment computed using the dyad transitions of the transition matrix. This forms an objective function that should be minimized. This minimization is done with a local search strategy. Three different move types are defined to form the different neighbourhoods that the algorithm uses. The first move type swaps the place of a pair of notes (swap). The change1 move changes the pitch of any one note to any other allowed pitch. The last move, change2, is an extension of the previous one whereby the pitch of two sequential notes is changed simultaneously to all possible allowed pitches. The VNS performs a *tabu search* in each of the neighbourhoods. When no improving solution can be found in any of the neighbourhoods, a *perturbation* strategy allows the search to continue out of the local optimum by changing a predefined percentage of notes to new random pitches.

The results are very promising as the algorithm converges to a *good solution within very little computing time.* The described VNS is a valid and flexible sampling method and was successfully combined with the vertical viewpoints method. This research shows that it outperforms both Random Walk and Gibbs Sampling. In future research, these methods will be applied to higher species counterpoint [5, 3] with the multiple viewpoint method [2] whereby training will be done on a real corpus of music.

The approach used in this research shows the possibilities of combining *music generation* with *machine learning* and provides us with a method to generate music from styles whose rules are not documented in music theory.

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