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Generating tree structure of musical piece on GTTM

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In this paper, we propose a harmony analysis by the Tension-Relaxation structure and automatic analysis of the grouping structure, each of which generates a different tree structure based on the Generative Theory of Tonal Music (GTTM).

Today, many approaches on dealing with music on computers have been studied. These studies are important for realization of automatic composition and arrangement, support of our performance, search of music, and so on. In order to realize these applications, it is effective to analyze the music structure.

So we try to realize automatic music structural analyzer based on GTTM. GTTM is one of the theories of music structural analysis, which is based on the Ursatz concept of Schenkerian, and generative grammar theory of Chomsky, and it is considered to be one of the most promising theories of music with regard to computer implementation. GTTM generate two music tree structures, one is called 'Time-Span Tree', and the other is called 'Prolongational Tree'. Time-Span Tree describes hierarchy of important tone based on music phrase or rhythm. Prolongational Tree describes hierarchy of 'tension' and 'relaxation'. Tension is a feeling of continuation, relaxation is a feeling of resolution. GTTM says musical piece is a sequence of tension and relaxation. Tension and Relaxation is generated by two events, and the relations between two events into the three types of, ‘progression’, ‘weak prolongation’ and ‘strong prolongation’. For example, chord progression ‘I–V’ is a tension, and the type is ‘progression’, by contraries, chord progression ‘V–I’ is a relaxation, but the kind is ‘progression’.

GTTM is composed of four components, ‘Grouping Structure’, ‘Metrical Structure’, ‘Time-Span reduction’ and ‘Prolongational reduction’. Each component has some rules, and these rules are ambiguous and conflictive. So it is very difficult that GTTM analysis is realized on computers.

In this paper, we study harmony analysis by HPSG (Head-Driven Phrase Structure Grammar) as a preceding stage of getting Prolongational Tree. In order to generate Prolongational Tree, it is necessary to get the information of tonality, chord and cadence. Harmony analysis is tonal analysis, Chord analysis, and Cadence analysis. The tonality means a set of a sequence of notes. Basically, a musical piece is composed by using these note which belong to a tonality. A chord is regularly constructed by notes obtained from the tonality. A cadence means a sequence of chords which are generated from the tonality.

In this approach, we pay attention to the similarity of Music and Natural Language, that is to say, music correspond to natural language, cadences correspond to sentences, and chords correspond to words. So, the technique of Natural Language analysis is available to harmony analysis. HPSG is a grammar theory based on constraints, so it requires fewer rules for analysis than other grammar theories. We prepare the dictionary of chord based on theory of harmony, and define ID-schema and principle for harmony analysis. The dictionary has such items as, a degree of cord, an inversion form, prohibited progresses, and so on.

We choose some music pieces for experiments the beginning of Mozart, Piano Sonata, K.545, Mozart, Serenade No.13, K.525, and Beethoven Piano Sonata, Op.49, No.2. The result of this experiment shows that 90 % cadences is recognized. Some cadences which are not recognized are prohibited in theory of harmony, for example the sequence of chords “I – ii – I”, because the chord ‘ii’ dose not allow to progress to the chord ‘I’ in theory of harmony.

In order to solve this problem, we propose an approach of harmony analysis by a new function, that is not define in the theory of harmony but is defined in the tension-relaxation structure on GTTM. We call it ‘expanded harmony function'. We make the new dictionary of chord based on tension-relaxation structure. and change ID-schema and Principle for using 'expanded harmony function' in harmony analysis by HPSG. We confirm that it is possible to analyze the sequence of chords which is prohibited progress in theory of harmony.

But only this analysis, we cannot get a Prolongational Tree. To obtain one Prolongational Tree, it is necessary to analyze a Time-Span Tree.

Time-Span Tree is composed of 'Grouping Structure' and 'Metrical Structure'. We try automatic grouping structure analysis on GTTM. The grouping structure is intended to formalize the intuitive belief that tonal music is organized into groups that are in turn composed of sub groups. There are some rules for grouping in GTTM, but there is no strict order for applying these rules. So the conflict between rules often occurs when applying these rules and result in ambiguities in analysis. The system in this paper introduces adjustable parameters, which enables us to give priority among rules. As a result, grouping performance improved. But these parameters are controlled manually. So we need to think about automatic parameter tuning.

There are many parameters in this system, and each parameter affects on other parameters. To get the optimal parameter set, it is effective to search all the parameter at once. So we propose automatic parameter tuning by GA (genetic algorithm). GA is one of the searching method and its performance is excellent. Each individuals allocated to a parameter set. As the crossover operation, we use UNDX (Unimodal Normal Distribution Crossover). The UNDX generates children near the line segment connecting two parents so that the children lie on the valley where the two parents are, and UNDX can efficiently optimize various functions. In selection strategy, two individuals from family are chosen, which are left to the next generation is chosen from family. The family here is the group of the parental individuals chosen by duplicate selection, and children are generated by the crossover operation. One is of the highest evaluating value, the other is chosen by the roulette selection. Each parameter of GA is decided resulting from pilot experiments.

In the experiments, we use not only GA but also Random searching and Hill-climb searching to examine the efficiency. Random searching is evaluated at 20,000 points, because GA is evaluated about 20,000 times in our experiment setting, also Hill-climb searching is evaluated about 20,000 times.

As a result of these examine experiments, an average F-value by GA is the best. So it is effective to tune of parameters by GA.