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Music Harmonization with Constraints: A Survey by François Pachet and Pierre Roy

In this paper Pachet and Roy surveyed and compared existing systems for harmonization problem. The authors first introduced various kinds of harmonization problems in tonal music. Then they introduced some early attempts, approaches using constraint satisfaction, issues about problem structuring, and other related systems. At last, Pachet and Roy discussed about the overall completeness of the harmonization problem, and pointed out future directions for the research community.

In this survey Pachet and Roy focused on tonal music because of its suitability of mathematical formalization. In tonal music, there are several rules of harmony according to different styles from Baroque to Classical and Romantic music. Some typical rules of harmony in four-voice music include that each voice has a range of pitches and tends not to cross; certain intervals between pitches such as tritone are forbidden; only three different pitches are allowed in Baroque style; and certain chord movements such as parallel fifth/unison/octave are undesirable. Pachet and Roy indicated that producing harmonization can be regarded as a combinatorial problem. Several variations of this problem exist in the practice of musicologists, including melody imposed, unfigured bass, figured bass, and two-voice problem. Many systems from the constraints point of view to the aforementioned problems are surveyed.

Early attempts focused on mastering the combinatorial explosion by putting more knowledge in the solver. Steels first proposed to use constraints to create passing chords and an augmented breadth-first search. Steels later experimented with a more sophisticated system with heuristic search. Courtot proposed a system for defining musical structures and constraints to create polyphonic music, aiming at representing composer's models. Levitt described a music constraint language to define stylistic properties of harmonic accompaniments, from simple voice ranges to the motion of chord roots.

Various works applied fully-fledged constraint satisfaction to automatic harmonization. Schottstaedt proposed a complete four-part harmonization system, using Fux's theory to classify the rules according to their importance. Ebcioğlu is the first to produce high-quality four-part music entirely automatically. Ebcioğlu's system contains 350 rules for representing the style of Bach, and the rules are implemented in a constraint language with backjumping technique. Ovans argued that the arc-consistency should always be used for harmonization problems, which outperformed the backtracking and other techniques. Ballesta's Ph.D. thesis provided a detailed study of four-part harmonization using conventional constraint satisfaction techniques, showing musically good results for the figure bass harmonization.

Music representation is a crucial part for solving harmonization with realistic melodies in reasonable time. Several researchers, including Ovans, Ballesta and Tsang & Aitken, explored chord structures in a more active way. The authors suggested that the harmonization problem should be divided into two sub problems: note constraints and chord constraints. Another approach is to build a harmonization plan for the resolution. The authors also mentioned other related work such as the composition tool Situation developed in IRCAM.

Pachet and Roy concluded the paper by examining the completeness of the harmonization problems. They considered that the technical problem of four-voice harmonization as solved. According to Pachet and Roy, the remaining problem is the production of musically nice or interesting melodies. They suggested that a nice melody should have the following properties: should not change directions too frequently, should move in the contrary motion respect to bass

as much as possible, should move stepwise as much as possible, and keep the intermediary parts as close as possible.

Personally I think this paper is quite informative regarding applying constraints to harmonization problem. Having read it gives me a general view of the field. However, I cannot imagine the systems as not enough detailed information were provided. In addition, the differences between those systems are vague to me. I think the authors did a good job on explaining the harmony rules of tonal music and the general harmony tasks that music students are asked to accomplish. But in contrast, the descriptions of constraint techniques are not as clear as the musical parts.