

Musical Harmonization with Constraints: A Survey

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Overview

- Why tonal music
 - with some theory and history
- Example Rule Formulations
- Automatic composition
 - The problem
 - Survey of constraint based solutions
 - A few other approaches
- Conclusion
- Discussion

Computers and Music

- Computer generated music is almost as old as computer science itself
 - Earliest systems developed in the 50s
 - ILLIAC generate random numbers then filter with rules
- Computers and music work better together than other traditional art forms
 - Representation
 - Mathematical Formalisms

Tonal Music

- Based on tonality
 - Groups of similar notes organized together as scales
 - Notes from these groups are in turn grouped together hierarchically to form entire pieces
 - One tonality considered primary
 - Notes in this key are considered more important
- The art is in organizing the notes to cause interesting interactions with the tonal centers

Serial Music

- Attributed to Schoenberg
 - Gives each note of the 12-tone scale equal importance
 - Create sets of 12 note (non repeating) sequences from the chromatic scale
 - Chromatic Scale: "the scale that contains all twelve pitches of the Western tempered scale" (Wikipedia)
 - Tempered: divide the octave into twelve equal parts
 - Use these sets as the basis of the composition

So Why Tonal Music?

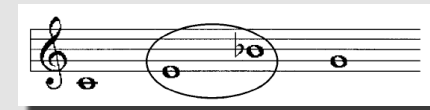
- Short Answer
 - Lots of Treatises
 - Johan J. Fux, 1725 (Used by Bach and Haydn)
 - Jean-Philippe Rameau, 1722 (Formalization of Tonality)
 - Schoenberg, 1983 (Comprehensive and authoritative)
 - Just about every composer of tonal music has their own
 - Evolution of tonal music considered "finished"
 - Not all rules are shared by all treatises but most treatises share at least some of the rules

Simple Rules of 4 Voice Harmonies

- Four-Voice Harmonization:
 - Prototypical problem that is under consideration
- Simple rule
 - Each melody within a range
 - e.g. between C_1 and C_3

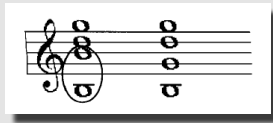
Horizontal Rules of 4 Voice Harmonies

- Horizontal Rules
 - Governing choices for successive notes
 - e.g. tritone interval is forbidden (an interval that spans three whole tones)



Vertical Rules of 4 Voice Harmonies

- Vertical Rules
 - How chords can be put together
 - e.g. only allowing 3 pitches in a chord



Chord Rules of 4 Voice Harmonies

- Rules for chord sequences
 - Parallel fifth rule
 - between any two successive chords there should not be a parallel fifth

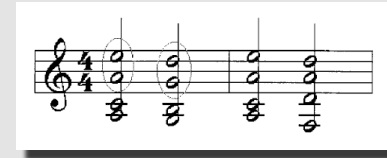


Figure Rules of 4 Voice Harmonies

- Chord Figuring
 - Used to give some kind of semantic information on the harmony
 - Initially used as shorthand for chords
 - give the bass + a figure
 - Allow performer to reconstruct the original chord (or a similar one)
- Two main systems
 - Baroque
 - Indicate interval of the chord
 - Functional Notation
 - Indicate the harmonic function of the chord

Automatic Composition

- Early work
 - Using weighted finite state automata (Markov Chains)
 - No real search is done and results not spectacular
- The problem
 - Search space becomes combinatorial when producing a harmony given a preexisting fixed voice

Levels of Complexity

- Informally
 - Can impose a melody (e.g. soprano)
 - must harmonize the other 3
 - gives some structure which reduces the search space
 - Impose the bass
 - Very difficult and under specified
 - Figured bass
 - The bass is given and figures for the chords on top of the base
 - Much easier
 - Two-voice problem:
 - Give the melodies and find the bass only

Modeling with Constraints

- Some approaches
 - Steels
 - used to generate passing chords
 - insert a chord between to given chords
 - uses a frame system with BFS and lazy evaluation
 - also tried 4 voice harmonization
 - combine brute force with heuristics
 - try to learn heuristics from solutions
 - Courtot
 - Prolog system to create polyphonies (multiple independent melodic voices played together)
 - Levitt
 - Defines a music constraint language
 - Detailed enough to produce Ragtime pieces
 - Uses backtracking, can't handle large problems

Constraint Satisfaction

- Schottstaedt
 - Four-part harmonization based on Fux's treatise
 - Classifies rules based on importance
 - Impossible rules given infinite penalty
 - e.g. parallel fifth
 - Very bad rules -200
 - range rule
 - etc
 - Uses best first backtracking
 - abandons branch after finding first solution
 - incomplete but fast

Constraint Satisfaction

- Ebcioglu
 - First high quality four-part harmonization entirely automatically
 - Uses a proprietary constraint language BSL
 - CLP using backjumping (speeds up search)
 - About 350 rules
 - Style of Bach
 - Not sure what to make of the system
 - Hard to understand
 - Hard to reproduce
 - Tried in Eclipse but no full arc-consistency (given two variables one is arc-consistent with the other if for all values of variable 1 are consistent with some admissible value for variable 2)

Constraint Satisfaction

- Ovans and Davidson
 - Advocated deep combinatorial aspect and pushed for use of full arc-consistency
 - Implemented a 2 voice harmonization system trying several different approaches
 - Backtracking
 - Forward Checking
 - Full arc-consistency
 - No system consistently outperformed the others
 - They still criticized Ebcioğlu for not using full arc-consistency however

Constraint Satisfaction

- Tsang & Aitken
 - Uses CLP [R]
 - Only 20 rules
 - Straight forward representation of musical objects
 - Slow and uses lots of memory
 - Used as a reference because of its simplicity

Constraint Satisfaction

- Ballesta
 - Uses Ilog's PECOS
 - Solves the Figured Bass problem
 - Considered "good"
 - Performance is considered unacceptable

Some Issues

- Constraint satisfaction shown useful
- Not without problems
 - Not able to handle realistic melodies in real time
- Some possible enhancements
 - Consider notes and chords separately
 - two phases
 - considerably reduce search space
 - Build a harmonization plan first
 - e.g. through figure information
 - gives the intention of the piece
 - and reduces search space

Some Other Solutions to the Problem

- Situation
 - Built at IRCAM
 - Uses forward checking with lazy evaluation
 - Can build polyphonies
 - Used as a real composition tool
- Ramirez & Perlata
 - Generates a sequence of chords by trying to maximize the number of well-known chord progressions
- Two others
 - Explicitly representing symbolic knowledge
 - Genetic Algorithms

Conclusion

- Pachet considers harmonization with constraints solved
 - Seems strange
 - No commercial systems available
 - Slow (can't use in real time)
 - Not general purpose
 - rulesets for each genre must be hand authored
- Generating melodies however is not solved
 - Rules for generating melodies is unknown
 - Interesting things probably happen by breaking rules

Discussion

- What are the evaluation metrics
 - Why are some considered good and others not?
 - Did a panel of experts review them?
 - Are they run through an automated scoring system (e.g. BLEU or ROUGE)?
 - Because Pachet says they are?
 - The audience?
- Why is Tsang & Aitken exemplary even though it is slow yet that is the primary criticism of Ballesta?