Modeling Michael Jarrell's CSP in Gelisp

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October 4, 2018

1 Introduction

A *Constraint Satisfaction Problem* (CSP) is a mathematical problem where one must find objects that satisfy a number of constraints (i.e. criteria over those variables). CSP's provide a declarative way to represent combinatorial problems, specifying constraints instead of a sequence of steps to find the solution (as used in imperative programming). Additionally, it is possible to specify heuristics (rules to choose between branches during search).

CSP's in computer music are used to solve harmonic, rhythmic or melodic problems. In addition, they can be used for automatic generation of musical structures satisfying a set of rules. For instance, the CSP proposed by compositor Michael Jarrell, which we explain in this document and detail its implementation. Usually, a CSP is represented by a script defining the variables, their domain, and its constraints.

Instead of writing a script, in Gelisp for OpenMusic (OM) we represent a program with a special patch. A patch is a visual algorithm, in which boxes represent functional calls, and connections are functional compositions. Inside this *CSP patch*, we can place special boxes: to connect each constraint in the CSP, to define variable and value heuristics, to define a time limit in the search, to connect the list of variables that we want to observe, and a box to connect the variable to be the optimization criterion during the search.

Furthermore, we provide a variety of boxes to represent simple constraints (e.g., $a = b$ and $a < 2$) and high-level constraints (e.g., "the motive A occurs n times in the sequence S "). The output of a *CSP patch* can be connected to three different kind of boxes: to find one solution, to find all the solutions, and to perform propagation (narrow the domain of the variables) without search.

Process calculi has been applied to the modeling of interactive music systems [18, 17, 23, 28, 16, 27, 1, 24, 19, 4, 14, 11, 13, 15, 2, 22, 12, 20, 21, 10] and ecological systems [25, 6, 26, 7]. In addition, research on algorithms [5, 3, 9] and software engineering [8] also contributes to this field.

2 Michael Jarrell's CSP

Compositor Michael Jarrell proposed a CSP for automatic music generation. This CSP defines constraints to generate n notes. The notes have two type of segmentation: for the chords and for the motives. Each note belongs to a chord or an ambitus (e.g., the interval [60..70]). In addition, there are interval motives and number of occurrences in each segment.

Moreover, the first and the last note of the sequence are fixed (optionally). Finally, it is possible to have absolute or non-absolute intervals for the motives and allowing octavation for the chords, the limits, or the motives. For instance, using octavation, the pitch 62 (in MIDI format) is equivalent to 50, 74 or 86. On the other hand, using absolute intervals, the interval 4 is equal to the interval -4. Following, we define formally the CSP for non-absolute intervals. For simplicity (in the formal description), we do not include octavation, segmentation, nor ambitus.

Inputs:

- Motives $[M_1 \dots M_A]$

- Occurrences $[OM_1 \dots OM_A]$
- Chord C
- Limits L_1, L_2

Variables: $V_1 \dots V_n$

Domains: $[0..127] \dots [0..127]$

Constraints:

- $C_0 \ V_n = L_2$
- $C_1 \ V_0 = L_1$
- $C_2 \ \forall_{1 < i < n} \text{Dom}(V_i) = C$
- $C_3 \ \forall_{1 < i < A} |\{M_i, M_i \text{ is a subsequence of } \{V_{i+1} - V_i, i < n\}\}| = OM_i$

A previous attempt to solve this problem used OmBacktrack. Unfortunately, that library is no longer available in current version of OM. For that reason, we decided to model this problem in Gelisp using graphical boxes.

2.1 The boxes

The graphical representation is composed by a few graphical boxes, without representing loops explicitly. The CSP is defined using the *CSP box* (fig 1). This box is used to define the constraints and the search heuristics.

Figure 1: OMCsp Box

The limits are easily represented by an *upper limit* box and a *lower limit* box (fig. 2). Those boxes receive the list of variables, the value for the limit, and the octavation parameter. The domain of the variables is easily determined by the *member-of* box (fig. 3). Using this box, we can post a constraint depending on the chord segment. In addition, it allows octavation or ambitus (considering two notes as an ambitus or as a chord). Fig.4 presents the constraint C_3 . Note how we use map iterators, the $x \rightarrow dx$, and *motives-occurs*= boxes to find the intervals of each motives segment and to say how many occurrences of the motives are, respectively.

2.2 The Inputs

0. **Motives.** This is the list of motives desired for each segment.
1. **Quantities.** These are the quantities desired for each segment and for each motive.

Figure 2: Constraints C_0 and C_1 of Jarrell's CSP

Figure 3: Constraint C_2 of Jarrell's CSP

2. **Intervals type.** The intervals can be absolute, non-absolute or modulo 12.
3. **Motives segmentation.** This is a list with the length for each motives segment.
4. **Chords.** These are the chords to setup the domain of the variables.
5. **Chords Octaviation.** This is a parameter to allow or not octaviation of the chords.
6. **Chords segmentation.** This is a list with the length of each chord segment.
7. **Optimization criterion: Increase.** This is the optimization criterion. 1 - means the optimization criterion is the number of increasing intervals. 2 - the number of decreasing intervals. 0 - No optimization criterion.
8. **Limits.** This is a list with the lower and upper limits. If the list is empty, this constraints are not posted.
9. **Limits octaviation.** This parameter setup the octaviation for the limits.

Figure 4: Constraint C_3 of Jarrell's CSP

10. **Time limit.** Time limit is a parameter for the maximum waiting time to find a solution.
11. **Minimum value.** This is the maximum value a pitch can have.
12. **Maximum value.** This is the minimum value a pitch can have.

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