

Genetic Hierarchical Music Structures

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Abstract

Music has structure at many levels, from grand arrangements of verses and choruses down to patterns in small riffs and themes. A bracketed L-system — the SARAH language — is used to represent compositions in terms of these hierarchical structures, allowing genetic programming to meaningfully mutate and crossbred compositions at all levels of structure. Automated composition becomes possible, using evolution with human aesthetic judgment as a fitness function. SARAH is also human-readable and can be used as a human tool for rapid structural composition development; or as a semi-automated composition system, mixing human and evolved contributions. The system has bred pleasing compositions starting from basic musical materials and has also been used to crossbreed Bach with the Spice Girls: these examples are presented as audio files.

Introduction

The majority of pop songs share an identical top-level structure (or simple variants of it):

```
POP-SONG => {INTRO, VERSE, CHORUS,  
VERSE, CHORUS, MIDDLE 8, CHORUS, OUTRO}
```

They also contain similar structure at lower levels. A VERSE may be decomposable as follows:

```
VERSE=>{RIFF-A, RIFF-B, RIFF-A, RIFF-B}
```

And a RIFF may be broken down into parts for different instruments (played simultaneously, not sequentially; we notate this by using square brackets instead of braces):

```
RIFF=>[ VOCALS, BASS, GUITAR ]
```

Structure is present even at the level of individual notes:

```
VOCAL-TUNE=>{G, G, A, A, C#, A, F#, G}
```

We could imagine describing a complete composition using such rules. When considered as a generative system (i.e. when used in conjunction with a compiler that creates actual musical output from the rules) they form an L-system (Prusinkiewicz & Lindenmayer 1990). Further, a *bracketed* L-system allows us to base all the rules on a single musical terminal. We use the terminal NOTE to represent a single whole-note tonic in C Major (i.e. middle C), played at medium volume on MIDI channel 1. A bracketed L-system is one which allows transforms in the rule definitions, for example:

```
SONG=>{VERSE, (^3)VERSE, (^5)(~2)(R)VERSE}
```

This describes a song consisting of a verse; then a copy of the verse raised by a major third; then another copy raised by a perfect fifth, timestretched by a factor of 2, and retrograded (played backwards). A simple melody fragment can be represented by transformed NOTES:

```
TWINKLE =>{NOTE, NOTE, (^5)NOTE, (^5)NOTE,  
(^6)NOTE, (^6)NOTE, (~2)(^5)NOTE}
```

Holtzman's GCDL language (Holtzman 1980) provided a notation for human composers to rapidly develop structured compositions by specifying production rules similar to those shown above. GCDL is a powerful language, allowing complex function definitions and computations. The present work provides a simpler bracketed L-system notation called SARAH, consisting only of term rewriting with transforms, and using a single terminal. Typically, a SARAH representation of a composition is longer than a GCDL program, requiring more rules and more transforms to compensate for the simpler language. The advantage of this representation (aside from its faster learning curve for human composers) is that simple rules are amenable to be operated on by Genetic Programming (Koza 1992), enabling SARAH to be used for automated and semi-automated composition as well as human composition.

The next section describes SARAH in detail. We then discuss its use as an aid to human composition; then as a tool for semi-automated evolutionary composition. Finally we touch on some cultural and philosophical issues raised by this mode of composition.

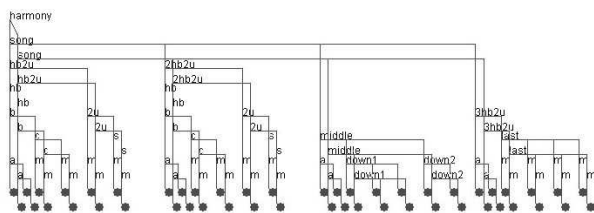


Figure 1: The compiled tree for Happy Birthday

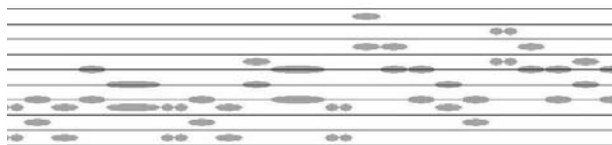


Figure 2: The compiled score for Happy Birthday

The SARAH Language

A composition is represented in SARAH by a list of context-free term-rewrite rules. The right-hand sides of the rules are enclosed in braces or square brackets to represent whether the structure is to be played melodically (in series) or harmonically (in parallel) respectively. Within these brackets is a list of structure names. The names must refer to structures that are previously defined in the list, or may be the terminal NOTE. Each name may be prefixed by a list of transforms. For example, here is Happy Birthday written in SARAH:

```

a => {NOTE, NOTE}
m => {(~2)NOTE}
down1 => {(^5)NOTE, (^3)NOTE, NOTE}
down2 => {(^-2)NOTE, (^-3)NOTE}
s => {(~2)m}
c => {(^2)m, m}
b => {a, c}
2u => {m, (^-2)s}
hb => {(^-4)b}
last => {(^3)m, m, (^2)m, m}
hb2u => {hb, 2u}
2hb2u => {hb, (^2)2u}
middle => {(^-4)a, (~2)down1, (~2)down2}
3hb2u => {(^4)a, last}
song => {hb2u, 2hb2u, middle, 3hb2u}
harmony => [song, (^3)song]

```

This generates the tree shown in fig. 1. Applying the transforms to the leaves gives the melody shown in fig. 2. Note that there is no nesting of brackets or transforms *within* each rule, as is generally allowed in bracketed L-systems.

The possible transforms are:

- (^n) shift pitch by *n* scale degrees
- (&n) shift key by *n* scale degrees
- (~n/m) timestretch by rational *n/m*
- (n/m) multiply amplitude by rational *n/m*

- (R) retrograde (play backwards)
- (I) inversion (reflect pitches about the tonic)

We use a *scale-degree* representation of pitch. Each note is represented by a 6-tuple: (key, degree, time, duration, volume, channel). Key is an integer MIDI note number which represents the root note of the (relative) Ionian major scale that the note is in. For example, for a piece in C major, D Dorian or A Aeolian it could be 60 (C3/middle C). For a piece in D Major, E Dorian or B Aeolian it could be 62 (D3). The pitch is then determined by the scale degree within that key. So in key 60 (C3 Ionian), a note of degree 3 would be the major third of the scale rooted on C3, i.e. E3. A note of degree 10 would be major tenth, i.e. E4. At present the scale pattern is fixed to the Ionian scale, allowing melodies in standard western modes to be represented without changing key. To represent accidentals, one must make a key change as well as a degree shift. For example, the following shows how to notate the melody A3,F3,B3 in G Major:

```

TUNE=>{(^2)NOTE, (&-5)(^4)NOTE, (^3)NOTE}
SONG=>{(&5)TUNE}

```

Recall that each NOTE starts out as the tonic in C3 Major. So SONG shifts the key of TUNE up a fifth to G3 Major. TUNE itself defines the melody, the second note of which is the fourth degree of a new key - changed down a fifth back to C Major. The accidental is thus conceived of as occurring in a temporary mode change.

We use the scale-degree representation for two related reasons. First, from a cognitive viewpoint, we believe it is closer to the way that human musicians think about music than absolute pitches are. It provides a higher level of abstraction for the composer to make use of: once she has changed to F minor she can then think and write in terms of that scale rather than have to worry about how to translate from that scale into absolute pitches. Secondly, we find it gives rise to more aesthetically pleasing compositions from the genetic composition system discussed later. This is because it allows the system to make musical changes at this cognitively meaningful layer. So for example, it may change the key or mode of a whole section of music with a single mutation; or shift the degrees of random notes *within* their home scale.

Human Composition

We have created a GUI environment for human composers to quickly edit, compile and view SARAH compositions (fig. 3). The user can examine the tree and score representations of the complete score or sub-scores, and may also force particular types of genetic operations to occur. This environment is called *Music Genie*. Audio example 1 presents a short minimalist-style composition written by a human using Music Genie. The composer commented that he was able to develop this composition much faster than by hand due to his enhanced abilities to replicate and transform existing structures.

(1) Align parents:			
Parent1: RIFF	=> NOTE	Parent2: TUNE1	=> NOTE
CHORUS	=> {(^5)RIFF}	A	=> {TUNE1, (&5)TUNE1}
VERSE	=> {RIFF, (^3)RIFF}	B	=> {B, (^5)B}
SONG	=> {VERSE, (&2)VERSE, CHORUS}	RONDO	=> {A, B, A, B, A}
(2) Convert to standard form and select genes:			
Parent1: 1	=> NOTE	Parent2: 1	=> NOTE
2	=> {(^5)1}	2	=> {1, (&5)1}
3	=> {1, (^3)1}	3	=> {3, (^5)3}
4	=> {3, (&2)3, 2}	4	=> {2, 3, 2, 3, 2}
(3) Create child from selected genes:		(4) Rename with original string names:	
1	=> NOTE	RIFF	=> NOTE
2	=> {1, (&5)1}	A	=> {TUNE1, (&5)TUNE1}
3	=> {3, (^5)3}	B	=> {B, (^5)B}
4	=> {3, (&2)3, 2}	SONG	=> {VERSE, (&2)VERSE, CHORUS}

Figure 4: Example of the crossover process.



Figure 5: Music Genie’s evolution manager

run manually from the human composition environment in Music Genie, allowing a human composer to generate new works by controlled evolution of his existing works.

Results

Audio example 2 presents a typical example of a user working with the web-based selection system to evolve a new composition. Audio example 3 presents the result of such an evolution after about 100 generations. Audio example 4 illustrates the effects of various random mutations on an extract from Bach’s *Well Tempered Clavier*, and the effect of crossbreeding it with an extract from the Spice Girls song *Wannabe*. Most listeners find these compositions to be reasonably aesthetically pleasing.

Future Work

At present, the input compositions must be manually parsed into SARAH, by musically trained humans. This is time consuming and appears to require considerable intelligence and pattern recognition skills. Future work could examine the use of grammar induction methods to automate some or all of this process. See for example (Reis 1999) for an agent-based discussion of this area. Composers have also commented that the syntax can become unwieldy, is difficult to type, and could be simplified.

At present the alignment method used in crossover is heuristic, and future work could examine the use of structure mapping or other analogy-making methods to improve

it. Practical improvements could be made by implementing basic automatic fitness screening to save wasted user time listening to ‘obviously bad’ compositions. A related issue is that of limiting or probabilistically weighting the initial choices of mutations to avoid those which produce ‘obviously bad’ changes.

Discussion

We present SARAH and Music Genie not only as a useful tool for human composers and a fun way of evolving short compositions, but as raising questions about the nature of creativity: to what extent should creativity be credited to the machine and to the human(s) who participate in evolutions? A criticism of machine composition (e.g. (Cope 2001)) is that it cannot currently be called ‘artistic’ because it does not deliberately *express* anything: it does not start with a conceptual model of emotions or stories to be conveyed by the language of music. If a machine was to produce Beethoven’s Ninth by chance, it would still not be artistic unless it had started with a model of what it is like to be hurtling through a thunderstorm in the rain. Rather, this creative credit should be granted to the human *curator* who selects that chance composition — probably after considerable effort spent listening to millions of others — and perceives it as expressing those concepts. The chance composition acts like a ‘found object’. Hence the composer becomes synonymous with the curator.

Music Genie suggests a further shift in this direction, from the curator-as-composer to the listener-as-composer (fig. 6). Reminiscent of Turing’s notion of mathematical creativity (Turing 1938), listener-composers inject emotion and meaning to the creative process, but the laborious work of creating the actual structures and notes is performed by the machine. The composition could exist as a permanently-evolving population, and every listening acts as a further step in the evolution. The credit for composition should then be assigned to the community of listeners themselves rather than an *élite* creator or curator.

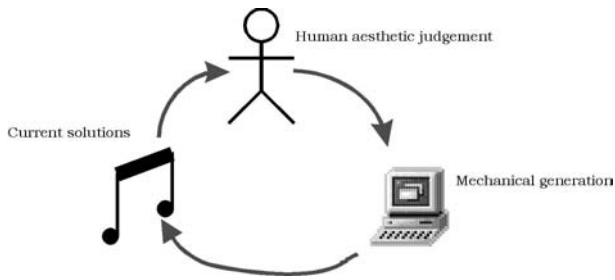


Figure 6: The creative process for semi-automated composition

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Appendix

The following is the code for the Bach example:

```
a => {($6)(&5)NOTE}
Bold => {a, (^3)a, (^-4)a, (~2)(^-5b)a,
        (~3)(^-4)a}
Cold => {(~1/2)(^-3)a, (~1/2)(^-2)a, a,
        (~1/2)(^-2)a, (~1/2)(^-3)a, (^-2)a}
Dold => {(^3)Cold, (^6)Cold}
B => {(^5)a, (^5#)(@5/4)a, a,
        (~2)(^-2b)(@5/4)a, (~3)(@5/4)a}
C => {(~1/2)(^2)a, (~1/2)(^3)a, (^4)a,
        (~1/2)(^3)a, (~1/2)(^2)a}
D => {(^3)(~2)a, (~3)a, (~1/2)(^2)a,
        (~1/2)a, (^-2)a, (~1/2)a,
        (~1/2)(^2)a, (^3)a, a,
        (^-3)a, (^4#)a}
E => {(^5)(~3)a, (^6#)a, (^7)a, (^6#)a,
        (^7)a, (^8)a, (^9)a}
```

```
t => {B, C, D, E}
tt => {t, (&5)t}
pause => {(@0)(^5)B, (@0)(^5)C, (@0)a}
delayed => {pause, Bold, Cold, Dold}
z => [tt, (v1)delayed]
```

The following is the code for the Spice Girls example:

```
A => {NOTE}
C => {NOTE}
dd => {(^3)(@5/4)(^-8)A, (^-8)A}
tail => {(^-2)(~3/2)(@5/4)(^-8)A,
        (~3/2)(^-2)(^-8)A, (^-2b)(^-8)A}
riff => {dd, (^3)dd, (^4)dd, tail}
chord => [A, (^3)A, (^5)A]
cnb => [(v1)(@2/3)chord, (@3/2)A]
dedah1 => {(~3)(^-4)cnb, (^-3)(~5)cnb}
dedah2 => {(~3)(^-5)cnb, (^5)cnb}
tellme => {(~1/2)(@2)A, (~1/2)A, (~1/2)A,
        (~1/2)A, A, (~1/2)A, (~1/2)A}
rvox => {tellme, tellme, tellme, tellme}
riffnvox => [riff, (v2)rvox]
2riffs => {riffnvox, riffnvox}
riffphrase => {($6)(&6)2riffs}
ifyouwanna => {(@5/4)(^5)C, (^5)C,
        (^5)C, (^5)C}
bemylover => {(@5/4)(^5)C, (^6)C, (^5)C,
        (~3)(^3)C}
youhavegottoknow => {(@5/4)(^2)C, C,
        (^2)C, C, (^3)(~3)C}
lineA => {(~1/2)ifyouwanna, bemylover,
        youhavegottoknow}
Abass => {dedah1, dedah2}
lineAall => [lineA, (v5)Abass]
lineAallH => [lineA, (^3)lineA, (v5)Abass]
thatstthewayitis => {(@5/4)(^8)(~1)C,
        (^8)C, (^9)C, (^5)C, (^6)(^2)C, (^5)(~2)C}
lineB => {(~1/2)ifyouwanna, bemylover,
        thatstthewayitis}
lineBall => [lineB, (v5)Abass]
lineBallH => [lineB, (^3)lineB, (v5)Abass]
verse => {lineAall, lineBall,
        lineAallH, lineBallH}
song => {riffphrase, (v1)(^8)verse,
        riffphrase, (v1)(^8)verse}
```

The MP3 audio examples and Music Genie software are freely available from www.charlesfox.org.uk.