AUTOMATIC JAZZ HARMONY EVOLUTION

Kjell Bäckman
IT University
kjell.backman@hv.se

ABSTRACT

Jazz harmony has during jazz history mainly been functionally based on principles of tonality derived from the classical and romantic periods of the 18th and 19th centuries. In the Evolutionary Jazz Harmony project we introduced a functionless harmony system that impacted the musical feeling in jazz compositions to imitate the harmonic feeling in an avant-garde way. The main features of that new harmony system were chords not built on any specific base note and not necessarily connected to the major/minor concept. In this project we introduce an automatic evaluation of the produced harmony sequences that both looks at each individual chord and the chord progression. A population of chord progressions is evaluated and the highest ranked ones will most likely be used for breeding of the offspring.

This project is one of the sub-projects of the EJI (Evolutionary Jazz Improvisation) project, where we explore various aspects of jazz music; improvised solo, harmony, tune creation, algorithmic creation of piano, bass and drum accompaniment, communication between instruments etc. The results have been evaluated by a live jazz group consisting of professional jazz musicians.

1. INTRODUCTION

Jazz harmony has since the birth of jazz been functionally based, which means that each chord has been related to a base note and classified as minor or major, and optionally also enriched with colouring, such as:

Cm, Eb7, G13b9, A7#11

This situation has prevailed throughout jazz history, with some exceptions however. The earliest experiments with other kinds of harmony were made in the 1950's by advanced and forward-thinking musicians like Ornette Coleman, Cecil Taylor, Don Cherry and others. Experiments have also been made during the 60's and 70's by e.g. Herbie Hancock, Miles Davis and fusion musicians like the Brecker Brothers. Not to mention all the experiments in the classical music domain during the 20th century from Schoenberg and onwards.

However, from the last quarter of the 20th century a stagnation of the harmonic development in jazz ensued, and very little harmonically essential has occurred. The Automatic Jazz Harmony Evolution project is an attempt to break the ice and open new dimensions in harmonic thinking. Persichetti [11] has made a harmony study that has been a valuable resource in this project. Pachet [10] has designed a system for rhythm and harmony evolution, however without the automatic evaluation feature of this project.

The Automatic Jazz Harmony Evolution project uses a non-functional harmony philosophy (no specific base note and not necessarily connected to the major/minor concept), where the "chords" are built up by means of the computer using evolutionary principles.

The produced chord progressions are used by the automatic jazz composer function described in another paper to produce tunes, and by the generative jazz improvisation program to produce jazz solos based on this kind of harmony. Some of these papers are still work in progress but others have been published. There are some publications written by the author that provide valuable background information to this project [1,2,3].

Dahlstedt [4,5], Dean [7], and Thywissen [14] have made valuable contributions in the same area and have been sources of inspiration for this project.

2. BACKGROUND

The harmony organization in jazz has already from the beginning and during its first two decades of the 20th century been systematically organized around a tonal centre by fifth progressions, see Levine [8]. Blues and ragtime harmony mainly used simple major/minor triads at a distance of fifths. Swing music enriched the chords with sixths and ninths but the chord progressions were mainly the same. Bebop further enhanced the chords with colouring such as b9, #9, #11, 13, b13 etc. and exchanged some chord progressions by inserting an extra subdominant parallel, e.g. *G7 – C* was replaced by *Dm7 – G7 – C*. However the focus was still on major/minor and fifth progressions. The main harmonic contribution of cool jazz and hardbop during the 50's meant further advanced chord colouring. A few forward-thinking musicians began at the end of the 50's to split up the harmonic foundation prevailing until then, and this development continued during the subsequent decades under the stylistic classification of “modal jazz”, “avant-garde”, “free form” etc. To some extent current jazz musicians have adopted this break-up tendency.

However, mostly in the “modern” jazz styles some remainders of the functional harmony principles and the fifth circle basis can be traced. When traditional musicians create compositions with new harmony, there is still a risk of getting stuck in conventions dictated by routine behaviour and idiomatic properties of the instrument. An evolutionary algorithm has no such restrictions but creates harmonies controlled by the algorithms having been programmed. The aim is to free oneself from traditional thinking and create other kinds of harmony.

3. AUTOMATIC EVOLUTION

A typical evolutionary algorithm process starts with a basic set of parameters, from which it creates an initial random population of pictures, melodies, chord progressions or whatever. The evaluation function then examines the population individuals and gives each one a score. Individuals with the highest score have the highest probability of becoming parents of the next generation. The breeding is done by combining the genome of two or more parents, optionally by applying a mutation somewhere in the genome. The mutation might imply a shift between two genome values, or a slight modification of a genome value.

The principle of using evolutionary algorithms to develop new artistic production, enhance artistic thinking and stimulate creativity, first started on a broader scale in the digital graphics area, by forerunner Karl Sims [13]. The evolutionary algorithms principle is well accommodated to that area because when using interactive evaluation of a created generation, as described by Dawkins [6], you can swiftly scan a great number of pictures and select the best according to your personal preference. With audio material, however, the evaluation procedure is much slower since you will have to listen through each music individual produced in a generation, one at a time. The first experiments in the music area were made by Collin Johnson and Palle Dahlstedt.

The evaluation, selection and breeding is repeated generation by generation until you arrive at a genome good enough to be used for the reproduction of artworks (pictures / melodies etc.).

This process is much the same as the genetic process of creating a new species generation in nature, only that it must be sped up considerably to have a chance of being completed in the proper time. The number of generations used for one evolution session must be limited, the calculation of parameter values must be optimized and efficient to allow for a rapid development towards a good genome, and the fitness function must be user friendly to minimize tedious manual intervention. Therefore, to take full advantage of the strength of the evolution process in terms of a large population and a great number of generations, we have in this project made an automatic process, which has required a careful analysis of abstract items such as tension, climax, phrasing, musicality etc. Such a function has also been developed by the author for jazz improvisation solos [3].

The genome in this project consists of parameter values specifying the internal structure of each chord and the progress from one chord to the next. For each new generation one parent chord progression is combined with another by selecting various portions of each of the parents’ genomes. For each child different sections of the parents’ genomes are selected, optionally also by performing a mutation which might consist of a slight modification of some genome parameter values.

4. METHOD

There are a number of parameters controlling the overall behaviour of the genetic evolution process:

- Number of notes per chord (4-5)- Number of notes to change from chord to chord (1-5). A higher value gives abrupt chord changes, while a lower value gives a more homogenous chord sequence.

- Maximum number of half-note steps to be allowed when a voice moves from chord to chord; 1, 2 or 4. Also in this case, greater tolerance gives more abrupt chord changes.

These parameter values can be manually set prior to starting an evaluation session. We have experimented with different settings, where the following seems to produce the best result: 4 notes per chord, 2 notes changed per chord, maximum 2 half-note steps.

A genome consists of the absolute MIDI pitches for the initial chord. The pitches are randomly created within a specific pitch range around middle C. For each chord change the genome holds the number of half-note steps per note (fig. 1).

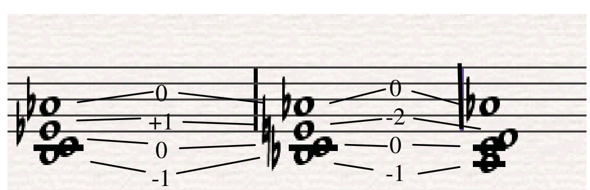

Figure 1. Chord genome

In this case the genome will be:
59 60 63 68 -1 0 +1 0 -1 0 -2 0 …

From the beginning, an initial population of 100 individuals (chord sequences) is created.
Each individual is then evaluated. The evaluation of a chord sequence is based on the principles that small chromatic steps from chord to chord have the strongest emotionally pushing character, and that upward intervals tend to increase the intensity at most. Therefore, such characteristics will be favoured (table 1).

Type of interval	Contribution
Upward minor second	3
Upward major second	1
Downward minor second	2

Table 1. Voice step scoring.

The internal structure of each chord is also evaluated, where intervals like small seconds and quarters are premiered, since they tend to avoid tonal centres, while intervals like thirds and fifths are avoided for the same reason. However, within one chord, only one small second is allowed to avoid cluster chords. The same applies to quarters. Table 2 shows the contribution figures from the internal chord analysis.

Type of interval	Contribution
Minor second	3
Major second	2
Fourth	1

Table 2. Internal chord interval scoring.

The contribution total for the entire chord sequence is saved for each individual of the population. The individuals with the highest score will most likely be subject to parentship for the next generation. A probability figure corresponding to the score of the individual impacts the random selection of parents.
On breeding, the crossover is made by combining different sections of two parents' genomes just like the process of combining DNA for species. The two parents are randomly selected with consideration to their probability figure based on their evaluation score. This means that the figures (e.g. -1, 0, 1, 0) are taken from one of the parents from the beginning of the genome, up to the randomly selected break point, from where the remaining figures are taken from the other parent.
At the end of the breeding a mutation is made by amending a few values one step up or down, so -1 might be -2 or 0, etc.

When a child has been created in this way, it is evaluated as described above. If the child's score exceeds that of the worst parent, it will replace that parent, which is discarded. If the created child is worse than the worst individual of the population, the child will be discarded. Thus, the elitism principle is used, which means that a created child, if kept, will always improve the quality of the entire population.
In this experiment 1000 iterations are used in each run. The solution acquired should not be considered a global optimum. In relation to the evaluation function we can not even be sure that we have arrived at a local optimum, since further iterations might have given still a better score. Maybe a larger number of iterations could result in a still better solution, but by experimentation we have found 1000 iterations enough.
At each run we arrive at a new "near-local-optimum", and selection of the best of all solutions is a question of personal taste.
The program code is written in C++, including the MIDI compiler function, which makes it possible to use any media player to listen to the produced MIDI files, and also import them into a note editing program, such as Sibelius. The resulting chord progression is also stored in an ASCII file in a format possible to copy to the project folder for jazz improvisation solos [1,3].

5. EXPERIMENT EXAMPLE

In this test run, one of the initial individuals had the genome shown in table 3.

58 59 62 69	-1 -1 1 0	1 1 0 0	0 0 1 0	-1 0 0 0	-1 -1 -1 2	-1 0 0 0	0 -1 0 0	0 1 0 0	-1 1 1 -1	1 0 0 0	1 0 0 0

1 1 -1 0	-1 0 0 1	0 1 0 -1	0 1 0 1	1 0 0 0	0 0 1 0	0 1 0 0	0 -1 0 0	0 1 0 0	1 0 0 0	0 0 1 0	0 0 1 0

Table 3. Experiment genome example.

The genome example corresponds to the first bars of the score shown in figure 2.

Figure 2. Experiment genome example.

Here is a link to the sound file:
http://oden.ei.hv.se/kjell/porto/Chords1.wav
Figure 3 shows the score after mutation (the mutations are indicated by X in the score).

Figure 3. Score after mutation.

Here is a link to the mutated sound example:
http://oden.ei.hv.se/kjell/porto/Chords2.wav
Figure 4 shows the score after 1000 iterations.

Figure 4. Score after 1000 iterations.

The sound file link for the score in figure 4 is:
http://oden.ei.hv.se/kjell/porto/Chords3.wav

The system also creates a scale per chord, which is used as basis for creating the tune and as basis for improvisations. Figure 5 shows the scales for the first chords.

Figure 5. Scales for the first chords.

One of the EJI sub-projects uses an algorithm for creation of a tune based on the chord progression and scales. That sub-project has not yet been completed, but a prototype has been developed, and the full algorithm will be documented in the future. Figure 6 shows the score for a tune generated by the prototype:

Figure 6. The generated tune.

The following link gives the complete tune with chords, melody and improvised solos:
http://oden.ei.hv.se/kjell/porto/Tune.mid
The drum, bass and piano accompaniment in this sound example are algorithmically created. The procedure for this

is documented in a paper not yet published. Further documentation will follow on this link:
http://oden.ei.hv.se/kjell/eji/eji.htm
A similar tune has been rehearsed and recorded by our live jazz group. The following link gives a recorded jam session:
http://oden.ei.hv.se/kjell/trio/Random2.mp3

6. RESULTS

Chord progressions created this way provide the feeling of a continuous progress towards new heights without arriving at rest points, which is the case with traditional functional harmony, where some chords have a striving character to dissolve into tonics. Compare the chord sequence of a tune like ‘Autumn Leaves’:

Am7	*D7*	*Gmaj7*	*Cmaj7*
F#m7b5	*H7b9*	*Em7*	*Em7*

There is an intermediate rest point at the chord Cmaj7 and then a final rest point at Em7. These rest points provide a relaxation at various positions of the tune, which gives a periodic character. Such relaxation points are not found in tunes with the new kind of harmony. Whether this depends on what people have been used to for a long time, or real built-in features of the functional harmony, is another topic not discussed here. Our conclusion is that this new kind of harmony has an on-going forward-striving feature not prevalent in standard jazz harmony.
Compared to manual evaluation, where you have to listen to each generated individual, one at a time, the automatic evaluation has a number of advantages. We can have a much larger population, the evaluation criteria are kept strictly constant i.e. we do not change focus on the objectives of our evolution process, and the evolution process is rapid. Of course there are also drawbacks with automatic evaluation. It is difficult, if at all possible, to make the computer evaluate abstract concepts such as musicality, tension, expectation, climax, relaxation etc. Anyway, with the automatic evaluation we obtain results that might not otherwise have been discovered.
When jamming with a jazz group on tunes with this new type of harmony, it has the effect on the soloist of continuously proceeding towards a climax never completely reached. The soloist is compelled to go on and on and on. The listener will be involved in this forward-striving feeling of wanting more all the time, and this is an interesting feature that some people might find valuable.
When I experimented with these ideas in a live jazz group, it turned out that the musicians had apparent difficulties in keeping chords and scales in their minds during their solos, since they had to learn completely new chords and scales. The harmony was of a kind that they could not apply their current knowledge and personal routine and not trust old learnt patterns of behaviour. Clever and experienced musicians appeared to be relative beginners, at least during the first rehearsals. Difficulties became obvious especially when playing tunes with an odd periodicity where a chord could last for 3 bars and the next chord for 2 ½ bar, etc. So the time required for rehearsal tended to grow remarkably. For example the bassist, who normally bases his walking bass paths on a base note accentuated at the first beat of each bar and scale walking at the remaining beats, got into problems when there was no specific base note. Learning to play this new kind of music is a laborious task that requires a new way of thinking and a lot of practice and patience.
Furthermore, to find the most adequate way of playing, a lot of time in discussion and reflection has been used in the acoustic live jazz group. For instance, a great deal of cooperative work has been spent by accommodating the bassist’s notes and the piano chord layout to each other.

7. CONCLUSIONS AND FUTURE WORK

Do evolutionary algorithms provide any valuable artistic material? At least some sounding examples are of interest and provide unpredictable and novel artistic output. A jazz tune composer often uses standard chord progressions learnt during a long time of practicing and concerting. He relies on routines built up through repeated usage of similar chord colouring.
The new harmonic system presented in this paper provides a tool for creating a new kind of harmonic base by means of evolutionary algorithms and automatic evaluation, enabling us to take full advantage of the powerful evolution process by virtue of hugh populations and a large number of generations. The resulting harmonic schemes can be used as a foundation for new jazz tunes and for exploring the world of jazz improvisation.
It may appear paradoxical to use tonal rules to build atonal music as implemented in the evaluation process (avoiding thirds and fifths), but since we during several hundred years have grown accustomed to tonal music, we have chosen to originate from that culture when designing the evaluation rule system. This may however be changed in future development, and we will welcome any feedback from the reader about the design of the evaluation process.
The main purpose of using computer based support to produce jazz music is that it opens your mind to new ways of thinking and frees you from old habits of reflection. Hopefully it can enrich your harmonic and improvisation style with new kinds of musical material.
However, introducing a new way of thinking revolutionizes the musical habits of experienced musicians. Such a new system requires considerable time for reflection and rehearsal, which has been proved by experience and discussions in the live jazz group. However, Psyche et al

[12] verify that learning a new musical grammar could be done by repeated exposure.

The project described in this paper is a subproject to the entire EJI (Evolutionary Jazz Improvisation) project, where we work with algorithmic production of jazz harmony, jazz tunes and jazz improvisation. The results of this subproject will be used for future EJI work which will be documented on the EJI web page http://oden.ei.hv.se/kjell.

Our plans are for instance to experiment with the application of PSO (partical swarm optimization), ACO (ant colony optimization), simulated annealing, multiobjective optimization, neural networks, artificial intelligence and other types of heuristics in jazz music creation. This work has been initiated with promising results.

8. REFERENCES

[1] Bäckman, K. (2008) A Generative Representation for the Evolution of Jazz Solos. In *Proceedings of EvoWorkshop Conference 2008, Napoli*.

[2] Bäckman K. (2008) Evolutionary Jazz Harmony, In *Proceedings of BIOMA Conference 2008, Ljubljana*

[3] Bäckman K. (2008) Automatic Fitness in Evolutionary Jazz Improvisation, In *Proceedings of ICMC Conference 2008, Belfast*.

[4] Dahlstedt, P. (2004) Sounds Unheard of - Evolutionary algorithms as creative tools for the contemporary composer, PhD thesis, Chalmers University of Technology, Gothenburg.

[5] Dahlstedt, P. (2001) Creating and Exploring Huge Parameter Spaces: Interactive Evolution as a Tool for Sound Generation In Proceedings of ICMC Conference 2001, La Habana, Cuba.

[6] Dawkins, R. (1976) The Selfish Gene. Oxford University Press Inc., New York , USA.

[7] Dean, T. (2003) Hyperimprovisation: Computer-Interactive Sound Improvisation. A-R Editions Inc.,Middleton, Wisconsin.

[8] Levine, M. (1995) The Jazz Theory Book. SHER MUSIC CO. Petaluma, CA, USA.

[9] Michalewicz, Z. and Fogel, D. (2000) How to Solve It: Modern Heuristics. Springer-Verlag, Berlin Heidelberg, Germany.

[10] Pachet, F. (2000) Rhythm as Emerging Structure. In I. Zannos, editor, Proceedings of ICMC, pages 316-319, Berlin, Germany. ICMA

[11] Persichetti, V. (1961) Twentieth Century Harmony. Vail-Ballon Press, Inc., USA.

[12] Psyche Loui, et al (2006) Acquiring New Musical Grammars: a Statistical Learning Approach, Proceedings of ICMPC06, Bologna, Italy.

[13] Sims, K. (1991) Artificial Evolution for Computer Graphics, ACM SIGGRAPH '91 Conference Proceedings, Las Vegas, Nevada, July 1991.

[14] Thywissen, K. (1996) GeNotator: An environment for investigating the application of generic algorithms in computer assisted composition. In Proceedings of International Computer Music Conference 1996 (ICMC96), pp. 274-277, Hong Kong.