Statistical vs. Connectionist Models of Bebop Improvisation

Dominik Hörnel[*+], Joachim Langnickel[*], Börje Sieling[+], Bastian Sandberger[*]

[+]Forschungszentrum Karlsruhe, Germany
[*]Institut für Logik, Komplexität und Deduktionssysteme,
[*]Institut für Betriebs- und Dialogsysteme,
Universität Karlsruhe, D-76128 Karlsruhe, Germany
dominik@ira.uka.de, langnick@ira.uka.de

Abstract

In recent years, various systems of Jazz improvisation have been developed, based on different computational and knowledge representation models. Two main categories of computational models arise: statistical rule-based and connectionist learning-based methods. We developed two different systems solving the same task in order to find out the specific advantages of a statistical and a connectionist approach. JazzRule is a rule-based system where all rules have been defined by statistical evaluation of Jazz transcriptions. JazzNet is a multi-scale neural network system. Its main idea is to categorize and learn predictions at various fixed time-scales in order to get coherent musical structure. Both models were built upon bebop style improvisations of Charlie Parker. In this paper, we give an outline of the two systems and compare the statistical properties of generated improvisations to the Parker originals.

1 Introduction

Many different styles of improvisation have appeared in Jazz since 1880. One of these styles is *Bebop* which was mostly influenced by the saxophonist Charlie Parker and the trumpet player Dizzy Gillespie. Young musicians tried and still try to imitate this Jazz style. Many of them learn to play by studying great Jazz solos, listening to and transcribing the improvisations and playing them on their own instruments. After a while they are able to reproduce learned phrases on different harmonic contexts. This kind of learning and generalizing from examples is an important aspect in Jazz music.

In recent years, various rule-based and learning-based systems of Jazz improvisation have been developed ([1-5], and others), based on different computational and knowledge representation models. While it is interesting to listen to the improvisations produced by these systems, it is almost impossible to compare them because the data sets of the underlying models are completely different.

Following we present two systems – JazzRule and JazzNet – built upon bebop-style improvisations of Charlie Parker. Given a chord sequence, the task is to find a monophonic Parker-style improvisation. We define a set of criteria for evaluating the improvisations produced by the systems and report about the main results.

2 JazzRule

In JazzRule all rules have been defined by statistical evaluation of Charlie Parker-transcriptions. JazzRule mainly concentrates on melodic shape, but also on rhythm, while dynamics and phrasing are neglected. In bebop style melodic improvisations are often built by long chains of eighth notes, so that the system defines the melodic output as sequences of eighth notes, which can be tied (longer note values) or omitted (rests). In Charlie Parker's improvisations classical musical structures like cadences, periods or motives can not be found. Therefore JazzRule only uses statistical features, which have been analyzed in the Parker originals and the results have afterwards been used to define rules that generate melodic improvisations in similar style.

Rule 1 describes the percentage of all intervals between eighth notes. The result is very characteristic, because the smaller the intervals the more often they occur, with the only exception of the prime, which does not appear at all.

Rule 2 describes the relationship between melody and underlying harmony. A melody note is called *inside*, if it also occurs in the underlying triad including seventh; and it is called *outside* otherwise. 66.6 % of the notes on stressed eighth note positions (1,3,5,7) of the 4/4-meter are inside and 33.3 % outside; and vice versa with eighth notes on unstressed positions (2,4,6,8).

Rule 3 is shown in Table 1 presenting the percentage of certain lengths of eighth note chains moving up or down only.

Table 1 Percentage of lengths of eighth note chains moving up or down only

Chain Length	Percentage
2	26.3
3	28.9
4	. 18.4
5	13.1
6-10	< 3.0

Rule 4 limits the ambitus of melody notes to the range from G below middle C to C3.

Rule 5 limits the number of successive outside melody notes to five.

Rule 6 defines that eighth notes on the first or fifth eighth note position followed by a rest, are tied to a quarter note in 33.3 %, to a half note in 33.3 % and remaining eighth notes also in 33.3 %.

In conflicts between rules 1, 2 and 5, rule 5 has highest priority, followed by rule 2 and finally by rule 1. In conflicts between rules 3 and 4, rule 4 has higher priority.

3 JazzNet

JazzNet is a multi-scale neural network system. Its main idea is to categorize and learn predictions at various fixed time-scales in order to get coherent musical structure [6]. The improvisation is first divided into *subphrases* which are classified by a self-organizing map. Each subphrase has half measure length. Four neural networks are used to predict musical structure at different time scales in a sequential manner. The *reference note* network predicts the first note of the next subphrase. The *subphrase class* network computes the class of the current subphrase which has been classified by the self-organizing map. Based on this information an *improvisation line* of eighth notes is produced by another network. Finally, sixteenth note *ornamentations* may be inserted. Figure 1 shows an example. The training and validation set were built from 11 transcriptions of the Charlie Parker Omnibook [7].

A note is encoded as a 14-dimensional *piano roll* vector [5] representing the rest, ligature, and the 12 pitch classes of the chromatic scale. Another unit is added to determine the direction of the note interval by distinguishing between small or big leaps. A reference note is determined based on harmony and preceding reference note and is encoded relative to the root of the corresponding harmony.

The subphrase class prediction network chooses one from n classes determined by the self-organizing map. In our experiments we have chosen n=15. The output units of the network are interpreted as a posterior distribution, and the classes are selected according to this distribution. In this way there is more freedom in the choice of a subphrase.

The most important component of the system is the computation of the improvisation line because a direct abstraction of the musician's style has to be found, together with the reference notes. In JazzNet the three remaining eighth notes are produced at once, given reference note, harmony and subphrase class.

Many Jazz improvisations have triplets, sixteenth notes or faster note values. If one studies the transcriptions, it is easy to see that most of these notes just fill in the gaps between eighth notes. Triplets are represented as one eighth note and two sixteenth notes.
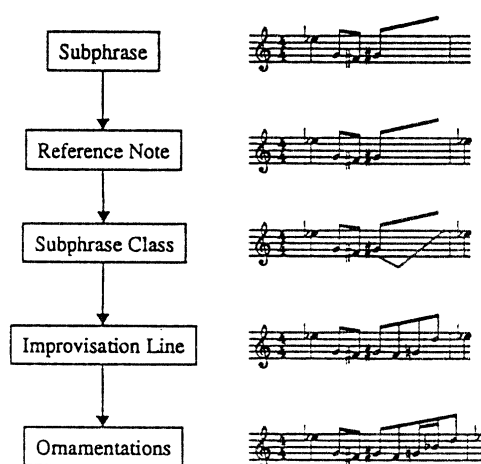

Figure 1 Hierarchical production of a subphrase by JazzNet

4 Comparison

We compared the resulting improvisations according to the following criteria:

- course of melodic contour
- harmonic relationship between melody notes and underlying chords
- appropriate use of target notes
- appearance of typical, Parker-like patterns

The melodic contour has been described by three direction values +1, 0 and -1, which do not regard any size of intervals. The accumulation during the melodic improvisations are shown in Figure 2 for improvisations of Charlie Parker and the two systems. For these three styles typical examples have been chosen. The figure clearly shows that Parker mainly improvised in

downward direction, so that his downward chains are longer than his upward ones. It is also obvious that this tendency is much better described by JazzNet, while the local fluctuation of the JazzRule improvisation is closer to the Parker original.
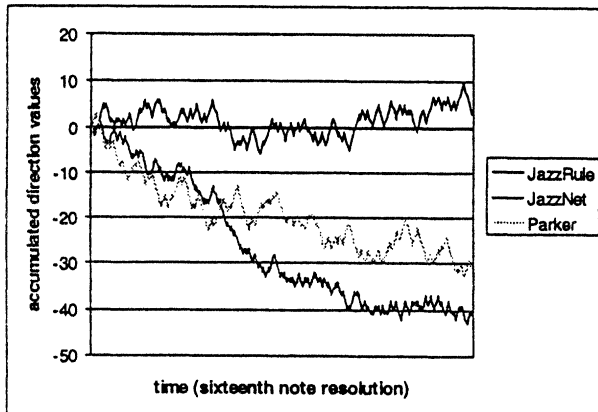

Figure 2   Accumulated direction values of JazzRule, JazzNet and Parker improvisation

To describe the harmonic relationship between melody and underlying harmony we classified all eighth notes into three classes: inside, outside and leading notes. An outside note is defined as a *leading* note if it is followed by an inside note, and when it is one or half step below or above this note.

Figure 3 shows the distributions of the eighth notes averaged over several improvisations. The distribution of the JazzNet improvisations is rather close to the Parker examples whereas the JazzRule system produces too many outside notes.
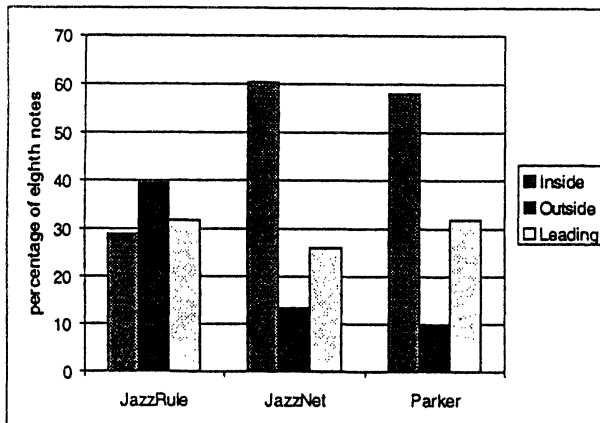

Figure 3   Distributions of inside, outside and leading eighth notes

The definition of *target notes* is useful in search for notes being more important than others. Our definition was inspired by the approach of Schoenmehl [8], who described a target note as a longer note or as a final note

of a phrase. For JazzRule, JazzNet and the Parker originals notes greater or equal quarters and notes before rests greater or equal quarters have been defined as target notes. Table 2 shows how often the root, fifth, major or minor third and major or minor seventh occur as target notes, where the range is ++ (very often), +, =, - and -- (very rare). The appropiate use of target notes can be described as mostly being part of the underlying triad including seventh like in the Parker originals, which can be seen in the Parker-column of table 2. In contrast both JazzRule and JazzNet have enormous variances in their use of underlying chord notes as target notes, so that both systems did not perform very well here.

Table 2   Frequency of occurrence of chord notes as target notes (ranging from ++ to --)

	JazzRule	JazzNet	Parker
Root	-	++	+
Fifth	++	=	+
Major/Minor Third	too different	+	+
Major/Minor Seventh	=	-	+

The discovery of typical patterns in Jazz improvisations has been studied in [9]. In general it was difficult to find typical patterns in the examples of the three styles. Those we found were too short to be characteristic enough. However this needs further study. The use of rests is appropriate in both systems.

5   Conclusions

Our general impression was that JazzNet works better on higher level and considering harmonic relationships, while JazzRule performs well concerning local fluctuations of the melodic line.

However, the performance quality of both systems is still not comparable to the Parker originals. After listening to improvisations for a while, they sound monotonous and tend to be boring because of no external input except harmony.

In future, melodic features should be represented more explicitly, e.g. the use of chromatics, arpeggios, scales based on modal keys, outside playing and sequencing techniques. Then it will be possible to vary between different ways of improvising.

6   Examples

Figure 4 shows three short musical examples. The first one is produced by JazzRule, the second one by JazzNet, and the third example is an improvisation by Charlie Parker entitled "Chi Chi".

Figure 4 Examples improvised by JazzRule, JazzNet and Charlie Parker

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