Rhythm Performance from a Spectral Point of View

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ABSTRACT

Basic to both performance and experience of rhythm in music is a connection between musical rhythm and patterns of body movements. A main focus in this study is to investigate possible relations between movement categories and rhythmic expression. An analytical approach to this task is to regard a musician´s various ways of moving when playing an instrument as an expression of timbral aspects of rhythm, and to apply FFT to empirical data of the musician´s movements in order to detect spectral components that are characteristic of the performance.
In the present paper we exemplify this approach by reporting some findings from empirical investigations of jazz drummers´ movements in performances of swing groove. In particular we show that performances of the groove in three different tempi (60, 120, 300 bpm) yield quite different spectral characteristics of the movements. This spectral approach to rhythm performance might suggest alternative ways of constructing syntheses and models of rhythm production, and could also be of interest for the construction of interfaces based on detecting spectral properties of body movements.

Keywords

Rhythm performance, movement, gesture, spectral analysis, swing

1. INTRODUCTION

Most research on rhythm performance has focused on investigating attack point rhythm, i.e. attack points (the temporal start point of the sound) and durations. However, for the performing musician attack points and durations are audible sounding consequences of continuous interactions between the musician, a musical instrument and different physical/ social environments related to which the performance takes place. To obtain a more comprehensive understanding of various interactions of the parameters underlying the characteristics of a rhythm performance it is, therefore, necessary to take gestural aspects of the performance into account in addition to the study of attack point rhythm. It is interesting to know that this point was made already in 1929 by Bernstein and Popova. They carried out empirical investigations of movements in piano playing and stated:"One can say that, with the slow, middle and fastest paces, we are dealing with three totally different dynamical constructions, with 3 dissimilar movement mechanisms" (see [2]). In this paper we discuss to what extent the findings of Bernstein and Popova may be translated from investigations of piano performance to a situation where jazz drummers are playing the swing groove.

1.1 The Swing Groove

A swing groove, as played on a cymbal by a jazz drummer, is often written in the following way:

A jazz drummer may perform a swing groove in a number of different ways. Typically, the drummer will perform the rhythm by making various deviations from the exact note values in the notation above. Moreover, various performances of the swing groove may in varying degree be musical appropriate (more or less "correct" related to various styles or traditions of performance), and may also in varying degree be swinging (i.e. make you want to "swing along with the music").

Interesting studies of performances of swing groove in jazz are presented in [14], [13], [12], [4] and [8]. The main strategy in these investigations has been to measure to what extent live performances show deviations from exact note values, and to relate these deviations to various musical/ contextual parameters, such as individual preferences, musical style, tempo, and inter-ensemble relations (i.e. rhythmic deviations between the different musicians in an ensemble). Several empirical investigations detecting various deviations in performances of music belonging to other traditions than the jazz tradition have also been carried out (e.g. [1], [10], [7], and for and overview, see [3] and [9]).

Studies of gestural aspects of rhythm performance have also been undertaken, although not to the same extent as studies of attack point rhythm. With focus on the drummer´s movements, interesting results have been published by S. Dahl [5] and [6], and the author of this paper has also contributed to research in this direction through empirical studies of jazz drummers´movements (see [16], [17] and [18]). The present report is a continuation of these investigations.

Having established the background for our research, we will now address the following questions:

(a) What information is given by studies of gestural aspects of rhythm performance?
(b) How can spectral analysis of rhythmic movements contribute to new insight into gestural rhythm?

And to be somewhat more specific:

(c) To what extent can the findings of Bernstein and Popova (see above) be supported by analysis of a jazz drummer playing the swing groove?

Parts of these investigations were also reported by the author in an oral presentation at ICMPC, 2006, see [19], but the results here presented have not been published elsewhere.

2. METHOD

The experimental method and the equipment used for the collection of empirical data are both described below, and are well known within empirical movement science.

2.1 Subjects

The subjects participating in this experiment are semi-pro/ professional drummers acquainted with jazz drumming. All of the drummers were, at the time of the experiment, students or teachers at Section of Jazz Education, Department of Music, Norwegian University of Science and Technology (NTNU).

2.2 Task

The subjects were asked to use one drumstick to play the swing groove restricted to various performance conditions. The performance conditions applied for the results to be presented in this paper, were the following:

Play the swing groove as natural as possible:

(i) In tempo 60 bpm (beats pr. minute)
(ii) In tempo 120 bpm
(iii) In tempo 300 bpm

Results related to other performance conditions (e.g. different placement of accent on the beats of the swing groove) are published in [18].

2.3 Equipment

The measurements were carried out assisted by Geir Oterhals, Section of Movement Science, NTNU. Figure 1 illustrates how the experimental situation was constructed. The figure shows the drummer playing on a "force plate" using one drumstick. Markers were placed on the drummer´s arm and on the drumstick.

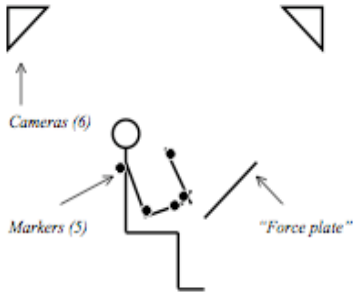

Figure 1. Illustration of experimental set up for measuring kinematic and dynamic aspects of performance of swing groove

For our set up we applied the following components:

- 6 cameras (Proreflex camera system) transmitting infra red light were used to measure movements of the arm and drumstick (kinematics). Sampling frequency = 240 Hz
- 5 markers reflecting the light were placed on the drummer´s shoulder, elbow, wrist and hand, as well as on the tip of the drumstick
- A force plate (Kistler) measuring force from the drumstick was used to give measurements of attack points. Sampling frequency = 960 Hz

3. RESULTS

We now outline some results to demonstrate how the spectral approach to movement analysis might give interesting information that complements insight into gestural aspects of rhythm performance which is achieved from the more commonly used time domain analysis. The results here are taken from a case study that investigates the movements of one drummer playing swing groove in the three different prescribed tempi.

3.1 Analysis in the Time Domain

Figure 2 illustrates the vertical movement (height vs. time) of tip of drumstick, hand and wrist, respectively, of one representative cycle in a performance of swing groove for one drummer in the three tempi: 60 bpm, 120 bpm, 300 bpm.

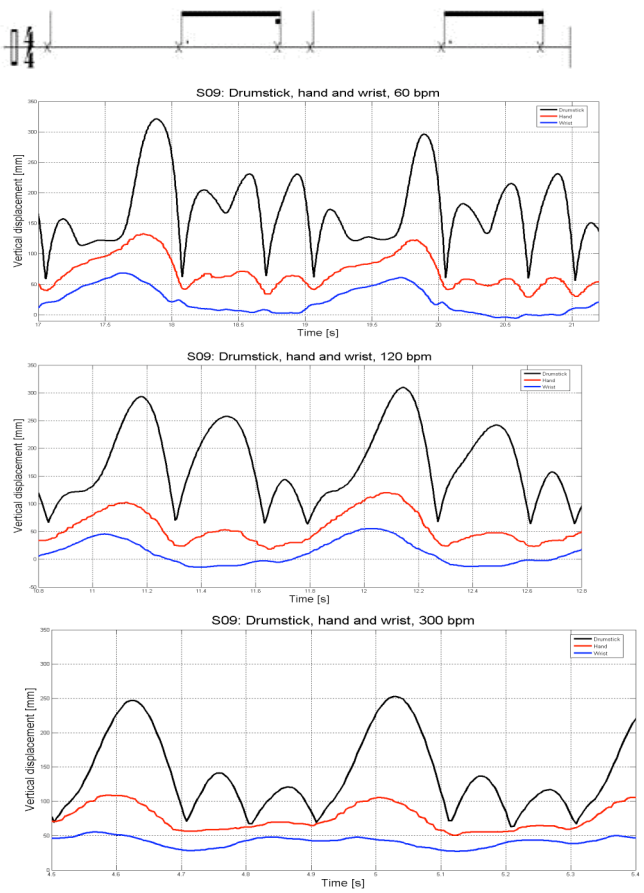

Figure 2. Vertical movement of tip of drumstick, hand and wrist in a performance of swing groove in three different tempi (from top to bottom): 60, 120, 300 bpm

From the illustration in Figure 2 we observe:

In tempo 60 bpm:

- Drumstick "drops" between attack points
- Hand follows every drumstick movement
- Wrist follows the largest hand movement

In tempo 120 bpm:

- No drumstick "drops" between attack points
- Hand follows the two largest drumstick movements
- Wrist follows the largest hand movement

In tempo 300 bpm:

- One large, two smaller drumstick movements in each cycle
- Hand follows the one largest drumstick movement
- Minor movement of wrist

Thus, it seems quite obvious that for this particular drummer, tempo has a major influence on movement patterns and strategy of performance of swing groove.

It is, moreover, interesting to note that tempo also affects the timing of the swing performance. By calculating time

differences in the distribution of attack points in these three performances, we find that the drummer is performing with a triplet-close subdivision at 60 and 120 bpm, whereas the performance approximates eighth note subdivision at 300 bpm (cf. Friberg and Sundström [8] for a similar result). These differences in timing are also reflected in the movement trajectories, as shown in Figure 2.

As indicated above, analysis of gestural aspects of swing performance in the time domain yields interesting information of how tempo influences movements on a local (i.e. time specific) level. Categorical differences in movement patterns are further demonstrated when we examine the global spectral properties of the performances.

3.2 The Spectral Approach

Applying FFT (Fast Fourier Transform) to the movement data of the swing performances, we get the results as shown in Figure 3 (the FFT-analysis was carried out in Matlab):

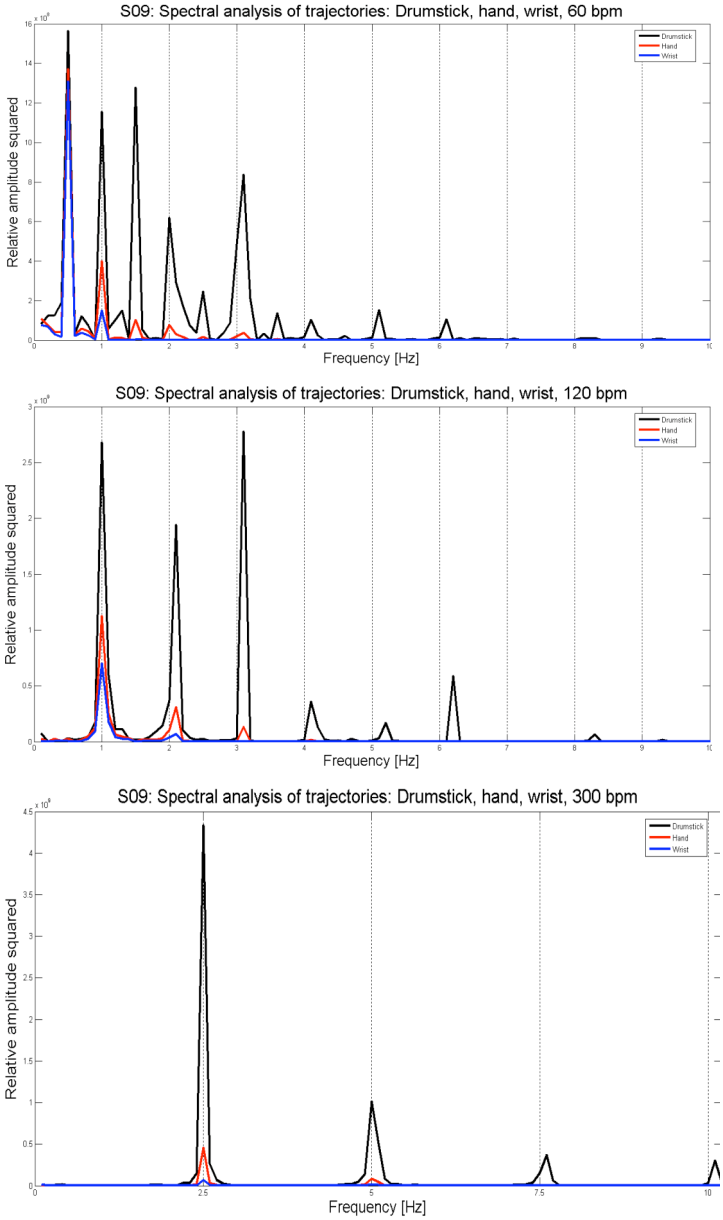

Figure 3. Spectral analysis of movements of swing performance in three different tempi (from top to bottom): 60, 120, 300 bpm

It is interesting to observe that the frequencies of the spectral components in Figure 3 correspond to note values in the different performances of the swing groove. Table 1 shows the relation between note values and frequencies for the three different tempi.

Table 1. Relation between note values and frequencies

	60 bpm	120 bpm	300 bpm
Half note	0,5 Hz	1 Hz	2,5 Hz
Quarter note	1 Hz	2 Hz	5 Hz
Quarter note triplet	1,5 Hz	3 Hz	7,5 Hz
Eight note	2 Hz	4 Hz	10 Hz
Eight note triplet	3 Hz	6 Hz	15 Hz
Sixteenth note	4 Hz	8 Hz	20 Hz

With reference to Table 1, Figure 3 shows:

- In all three performances, the largest spectral components for the hand and wrist movements are given at the frequencies corresponding to the half note (0,5 Hz, 1 Hz, 2,5 Hz resp.). This reflects the fact that the swing pattern is cyclic with a cycle length equal to the duration of a half note, and the movements of the hand and wrist constitute a cyclic-close trajectory.
- One would expect a similar result for the drumstick movements, and, indeed, this is very dominant for tempo 300 bpm, and is also the case for 60 bpm. In tempo 120 bpm, however, the largest component of the drumstick movement for this particular drummer is at 3 Hz, which corresponds to the quarter note triplet.
- In both 60 and 120 bpm the components of drumstick movements corresponding to quarter note triplets and eight note triplets are among the largest in the spectral resolutions. This reflects that our calculation of time differences in the attack point distribution shows that the drummer is performing with a triplet-close subdivision in these two tempi.
- Overall, we see that the number of spectral components decreases with increasing tempo, i.e. when the tempo increases, the movements of drumstick, hand and wrist tend to be more sinusoidal.

We now turn to a discussion of our findings.

4. DISCUSSION

Our approach in the study of gestural aspects of rhythm performance has here been to regard a musician´s movements as an expression of timbral aspects of rhythm, and to apply a combination of analysis in the time domain and spectral analysis of movements. There should be made some comments to the strategy of this study and to the way this experiment was set up:

(1) First of all it should be noted that all together, 10 drummers participated as subjects in this investigation. We have here presented only a case study involving one subject performing swing groove in different tempi. A natural further development would be to study which interactions of performance parameters are common among the drummers. All though it seems plausible that the results here reported show features of performance that are shared among several drummers, these matters should be investigated further in forthcoming studies of swing performance.

(2) In this experiment the drummers were asked to use one drumstick to play the swing groove on a force plate. Obviously, a more natural playing condition would be to ask the drummers to play the groove on a ride cymbal. The main reason for using the force plate is that this performance makes possible a more accurate detection of attack points needed for timing analysis than does a performance on a cymbal. At this point it should be mentioned that some of the subjects participating in the experiment commented that they would feel more comfortable playing the swing groove if they were allowed to use the whole drum set; "filling-in" on the snare, bass drum and hihat underneath the ride cymbal swing pattern. – All this said, it is important to emphasize that we here make comparisons between different performances within the well defined experimental situation, - and we suggest that it is likely that characteristics of various performance parameters that are detected within the experiment, will have validity also in the real "natural" world of music performance – outside the constraints given by the experimental setup.

(3) The study of gestural aspects of rhythm performance is important for the construction of continuous models generating syntheses of rhythm performance that approximate reality. One such model is developed by the author, [15]. It seems likely that results derived from these experiments will be valuable in the further development of this model. – For instance, it might be interesting to reverse the decomposition of movements given by the spectral analysis, in order to simulate rhythm performances on the basis of a given set of sinusoidal components.

(4) Our strategy in the study of swing performance is similar to the approach of Luiz Naveda in analyzing the relationship between samba dancing movement and music, [11]. In our future work it will be investigated to what extent analytical ideas in Naveda´s investigations can be applied to forthcoming studies of swing performance.

The findings reported in this paper show that when a drummer performs the swing groove in different tempi, the tempo is likely to affect the drummer´s movements in various crucial ways. In this respect, our analysis of a jazz drummer playing the swing groove clearly supports the statement made by Bernstein and Popova, [2], cited in 1.Introduction. As a consequence of the findings of Bernstein and Popova, as well as of the results here reported, a performance on the piano (or a performance of swing) in fast tempo is quite different from speeding up a performance on the piano (or a performance of swing) in slow tempo. These findings are likely to be valid for rhythm performance on a more general basis, and should be taken into account in musical training. Moreover, this result is of interest for the constructions of models of rhythm performance.

5. ACKNOWLEDGMENTS

The author is very grateful to Geir Oterhals, Section of Movement Science, NTNU, for fruitful assistance and cooperation in the measurements of rhythmic movements. Special thanks are also due to the drummers participating in the experiments. Moreover, the author would like to thank three anonymous reviewers for valuable comments on an earlier version of this paper. Economical support to this project was provided by The Faculty of Humanities, NTNU.

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