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A Computational Method for the Analysis of Musical Improvisations by Young Children and Psychiatric Patients with No Musical Background

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ABSTRACT

Improvisation is a common form of musical practice and yet remains the least studied or understood from a music analysis point of view. When populations with no musical background engage in musical improvisation (such as young children or patients in therapy settings) the analysis of the musical aspects becomes more challenging: The possible lack of common learned musical schemata and related technical skills requires the introduction of methods of analysis which can deal with these peculiarities. In this paper we propose a computational method for analysing such types of improvisations and apply it to the analysis of a small number of case studies. The analytical method is a type of semiotic analysis, where repetition, variation and transformation are brought forward. Musical parameters have to be defined, and a computational tool is built to reveal interesting patterns that repeat within the various musical parameters. The method is applied to the improvisations of six eight-year old children and two psychiatric patients with psychotic syndromes. For their improvisations they use the machine-learning based system MIROR-IMPRO, developed within the FP7 European Project MIROR, which can respond interactively, by using and rephrasing the user's own material. The results point towards the usefulness of more abstract types of representations and bring forward several general common features across these types of improvisations, which can be related to gestures.

I. INTRODUCTION

Improvisation is a common form of musical practice across cultures, and yet remains the least studied or understood from a music analysis point of view. To that end, there have been a number of approaches, especially in jazz and folk music (e.g. Berliner, 1994; for computational approaches see Sentruk and Chordia, 2011; Johnson-Laird, 1991). In music therapy, the analysis of improvisations is gaining more ground in recent years, informing directly the therapeutic process (such as Thaut, 1988; Lee, 2000; Erkkila et. al. 2004 for a computational tool). In young children's improvisations, various approaches exist to date, which however focus more on educational, psychological and sociological theories rather than the music per se, and explore the process rather than the product of the improvisation (such as Baldi et. al. 2002; Burnard, 2000; Young, 2005).

Music analysis is the discipline which "takes the music itself as its starting point rather than external factors" (Bent and Pople, 2001). In its formal part, it raises the question how does a piece of music work, what are its constituent parts and how they relate to each other, bringing out specific relations of similarity and difference. Where appropriate, it can provide interesting insights on related human perceptions and understanding.

When populations with no musical background engage in musical improvisation (such as the majority of young children and patients in therapy settings), the analysis of the musical aspects becomes more challenging: The possible lack of common learned musical schemata and related technical skills results in improvisations which do not have the expected musical characteristics and structure, to guide the analytical procedure. In this case, the introduction of particular methods of analysis that can deal with such aspects is called for.

In this paper the method employed is related to paradigmatic analysis as described by Nattiez (1975), also discussed in Monelle (1992) and Agawu (2009). In this method, analysis is carried out with as few preconceptions as possible, and is being based on creating a systematic account of repetitions and variations located in the music itself. In the present study a computational tool is used to locate repeated patterns in the corpus of improvisations.

For our corpus we take improvisations by young children and psychiatric patients, whom we recorded in a number of sessions each. The direct comparison of improvisations of these two populations might seem odd at first. Apart from the fact that all our improvisations are made by people with no musical background, there are no other unifying principles. However, the aim of this paper is to create an investigation on the purely musical level, without engaging with extra-musical associations, such as psychological, cultural, therapeutic and anthropological perspectives.

The rest of the paper proceeds as follows: Section 2 describes the method of analysis, starting from the description of the corpus, moving on to the issue of knowledge representation which is given particular emphasis in this paper, and ending with a description of the algorithm and related analysis methodology. Section 3 presents some sample results of the various representations, demonstrating why some representations might be more appropriate than others, section 4 includes a discussion on the results, while section 5 ends the paper with some general remarks and directions for future work.

II. METHODOLOGY

A. The Corpus

The corpus to be analysed is comprised of a number of improvisations made by six eight-year old children and two psychiatric patients. In their improvisations they use a MIDI keyboard and the *MIROR – Impro* system. This is a machine-learning system based on the older Continuator (Pachet and Addessi, 2004), which has been developed further during the European FP7 Project MIROR (Musical Interaction Relying on Reflexion, http://www.mirorproject.eu see also Addessi and Volpe, 2011). During the session with the system, the user plays a melody and the system responds by rephrasing and by using similar material to the user's input. This results in a musical dialogue between system and user, which is based on the user's own musical style. This follows the concept of

Interactive Reflexive Musical Systems, where musical concepts are taught by the interaction between system and user, mirroring the user's own ideas and pace.

The system has several settings which can be used, defining the various musical parameters and the degree of similarity between input and output. The system's answers range from identical responses, to very distant variations of the input. During our experiments each user had several sessions with the system, each session usually lasting between 5 and 30 minutes, and using a variety of settings, ranging from identical answers to distant variations. In our analysis we look only at the melodies produced by the users, and do not analyse at this stage the system's responses and the effect they potentially had on the improvisations.

The children had a total of 59 sessions, and the psychiatric patients a total of 19 sessions, each session including several improvisational melodies.

B. Knowledge Representation

The collected improvisations make out a corpus of melodies in symbolic format since they are played on a MIDI keyboard. The concept of a symbolic musical corpus raises the issue of the appropriate music knowledge representation. Having in mind the data manipulation task, the multiple viewpoint formalism is chosen (Conklin and Witten, 1995; for segmental viewpoints see Conklin and Anagnostopoulou, 2006), as it offers great flexibility in surfacing the attributes of the musical objects (notes, phrases, melodies). It also offers a direct and easy representation on corresponding data structures. A viewpoint sequence can be thought of as a sequence of values of a specific musical attribute, for example a sequence of intervals, pitches, contour directions, rhythmic values, and so on.

For the present study we take four different viewpoints which are related to pitch, each one progressively more abstract than the previous one. These are:

A. Pitch (MIDI number,)
B. Melodic Intervals (Number of semitones plus direction)
C. Interval Classes (Value of 0 when unison, 1 if small interval =< 5 semitones, 2 if big interval >5 semitones. Direction not taken into account).
D. Melodic Contour (Value of 1 if rising, -1 if falling, 0 if static)

We look for patterns in all these viewpoints sequences separately, and at the end we evaluate the results for each, checking to see which level of abstraction might be appropriate for this type of musical corpus.

C. Algorithm and related music analysis methodology

The algorithm proceeds by reading one by one all MIDI files in a directory and building from the corresponding MIDI events a sequence of viewpoints. Consecutively, all repeated patterns within each viewpoint sequence are extracted. The identification of repeated patterns can be seen as a problem within the stringology domain. As such, in order to identify common patterns, suffix arrays are employed (Manber and Myers, 1993). Suffix arrays provide an easy to implement and fast way to locate each and every common substring within a string. For constructing the suffix array, the well-known QuickSort comparison sort algorithm (e.g. Sedgewick, 1990) is used in this work. All common patterns of length less that 2 are ignored as trivialities. The suffix array is then scanned and the common patterns are reported, along with their frequency, their length and their locations. Patterns found are allowed to overlap.

In music analysis terms, the discovery of repeated patterns in a corpus can be seen as a type of paradigmatic analysis, in that repetitions of specific patterns are made apparent and located within the piece or pieces of music under analysis. The added advantage here is that each musical parameter is processed separately, and repetitions are located within each parameter (or viewpoint sequence), making thus explicit the type of repetition. We can therefore observe repetitions at different levels of abstraction.

III. RESULTS

We performed experiments using each of the four musical parameters described above, and using firstly all the corpus (A), secondly the corpus of children alone (C), and thirdly the corpus of psychiatric patients alone (P). A large number of patterns was collected, and below we summarise some of the most frequent and interesting results. For each pattern, we note its frequency, the number of different sessions found, and the corpus it came from.

1) Pitch

Pitch is the lowest level representation used in this study. A large number of short patterns was found, which did not have high frequency numbers. Amongst all patterns found, we notice several patterns of stepwise motion, going either up or down, and some patterns of repeated notes in the children's corpus. In Table 1 we quote some of the most frequent ones.

Table 1: Example patterns of pitch for the three corpora

Pattern	Frequency	Number of sessions	Corpus
[D3,F3,E3]	59	10	A
[E4,A4,E4]	37	10	A
[F4,G4,A4]	214	25	A
[C2,C2,C2,C2,C2,C2,C2,C2,C2,C2]	107	2	C
[B2,A2]	134	22	C
[C3,D3]	145	8	P
[D3,E3]	183	7	P
[G4,F4,G4]	34	6	P

2) Intervals

A large number of interval patterns was found, from very short to very long ones. These included straight movements across the keyboard, either ascending or descending, oscillating movements (the alternation of two notes on the keyboard), some unison patterns, and others. Table 2 shows some characteristic ones. The second pattern, which is found in the A corpus, that is both in children and psychiatric patients, [-2,-2,-1,-2,-2,-1,-2,-2,-2,-1,-2,-2,-1,-2,-2,-2,-1,-2,-2,-1,-2,-2,-2,-1], presents a diatonic stepwise downward movement (for an example see Figure 2), probably using all the white keys of the keyboard. The third pattern [0,0,0,0,0,0,0,0,0] (Figure 1) denotes a repetition of the same note, and although it was very frequent, it was more common on the children's improvisations. The next two patterns found on the Children's corpus, [-2,2,-2,2] and [-27,27,-27,27], the first one much more frequent than the second, denote oscillating movement between two notes. The first one includes a tone, whereas the second one a very large interval of more than two octaves. The next two patterns by the psychiatric patients include another oscillating pattern of a tone, and a stepwise diatonic downward movement.

Table 2: Example patterns of intervals in semitones for the three corpora.

Pattern	Frequency	Number of sessions	Corpus
[-3,-2,-0]	23	7	A
[-2,-2,-1,-2,-2,-1,-2,-2,-2,-1,-2,-2,-1,-2,-2,-2,-1,-2,-2,-1,-2,-2,-2,-1]	16	6	A
[0,0,0,0,0,0,0,0,0]	376	7	A
[-2,2,-2,2]	266	29	C
[-27,27,-27,27]	16	1	C
[-2,2,-2,2,-2,2,-2,2,-2]	14	4	P
[-1,-2,-2,-1,-2,-2,-2,-1]	32	6	P
[-53,-2,52,-53]	5	5	P

Figure 1: Example of interval pattern [0,0,0,0,...]

3) Interval Classes

The representation of interval classes was decided in order to achieve a representation more abstract than intervals and less abstract than contour. It also seemed useful to be able to distinguish between smaller and larger intervals. Many patterns, short and long were found, and some results are presented below.

Table 3: Example patterns of interval classes for the three corpora.

Pattern	Frequency	Number of sessions	Corpus
[2,2,2,2,2,1]	757	37	A
[2,1,2,1,2,1,1,2,2,2,1,2]	16	7	A
[1,2,1,2,1,2,1,1,2,1,1]	26	11	C
[2,2,2,1,1,1,2,2]	89	17	C
[2,1,1,2,1,1,2,1,1,1,2]	106	3	P
[1,1,1,2,2,2,1]	149	7	P

4) Melodic Contour

Patterns of melodic contour found had high frequencies as they were the most abstract (and therefore most common) ones. As with intervals, we observe the same movements (oscillating motions, straight ascending or descending movements, unisons, and others). Here we present a few instances: The first pattern [1,-1,1,-1,1,1,-1, -1,1,1] is an example of a pattern moving in changing directions, the second one is a very common pattern which was found in all sessions – and thus perhaps trivial as it did not characterise any of the corpora. The first pattern on the children's corpus [1,-1,1,-1,1,-1,1,-1,-1] is a typical example of an oscillating motion (though the exact intervals in each direction might vary), whereas the second one, [1,1,1,1,1,1,1,1,-1] includes a long upward motion. The first pattern of the psychiatric patients, [-1,1,-1,1,-1,-1,**-1,-1**,1,-1,**1,1**,-1], is a good example of an almost oscillating motion, while the second one, [0,0], is a short example of the unison pattern found more often in the children's corpus.

Figure 2: Example of melody containing the pattern of stepwise downward movement.

Table 4: Example patterns of melodic contour for the three corpora.

Pattern	Frequency	Number of sessions	Corpus
[1,-1,1,-1,1,1,-1,-1,1,1]	152	25	A
[1,1,-1,1]	1402	ALL	A

[1,-1,1,-1,1,-1,1,-1,-1]	62	19	C
[1,1,1,1,1,1,1,1,-1]	37	9	C
[-1,1,-1,1,-1,-1,**-1,-1**,1,-1,**1,1**,-1]	16	5	P
[0,0]	181	8	P

IV. DISCUSSION

- As expected, the most common patterns (with the highest frequencies) are the shorter patterns. The longer the pattern, the less likely to be repeated in other sessions.
- As explained above, most of the discovered patterns tended to fall in one of the following categories: denoting a straight upward or downward movement, oscillating motion between two pitches, repetition of the same pitch, and other patterns. In terms of paradigmatic analysis, these can be thought of as the main paradigms of a paradigmatic chart.
- In pitch patterns we had many of the instances of patterns found in more abstract representations. For example, the patterns [C3,D3, E3] and [D3,E3, F3] which were found, are both instances of the contour pattern [1,1]. Pitch patterns tended to have lower frequencies, since they were more specific patterns.
- In that respect, pitch patterns did not prove to be very interesting, as not many conclusions could be drawn from them.
- The similarities between interval patterns such as [-27,27,-27,27] and [-2,2,-2,2] (found in C) can be captured by the contour representation [-1,1,-1,1], whereas they can be distinguished in the interval class representation.
- The long pattern of repeated unison intervals is found mainly on the children corpus. In the psychiatric patients the longest repeated unison pattern with notable frequency was of length three ([0,0,0]).
- The pattern of oscillating movement (contour getting alternating values of -1,1) was found mainly in children. There were a large number of patterns in the psychiatric patients which were *almost* oscillating, e.g. pattern 5 in contour above ([-1,1,-1,1,-1,1,-1,-1,1,-1,1,1,-1]).
- The pattern of stepwise downward movement was very common in all corpora. However, clearer instances were found in children, as patients occasionally introduced intervals with opposite directions in their downward movement.
- Upward movements through the whole range of the keyboard were also found in all corpora.
- Although the melodic contour representation seems to capture all interesting patterns, there are also patterns that appear in all sessions and therefore might be considered trivial to mention (such as the pattern [1,1,-1,1]).
- The interval class parameter – viewpoint did not give any interesting results, and no further conclusions can be drawn from it. Perhaps this is due to the arbitrary choice of deciding which intervals are large (and thus have value 2) and which intervals are small (and thus have value 1) in the definition. A more informed representation is needed.
- Simultaneities of notes, that is clusters played by the whole hand, were also encountered in the data sets, but here they have not been analysed further. A vertical viewpoint representation (Conklin, 2002) is needed to capture these types of textures.

V. CONCLUSIONS

In this paper we presented an initial computational exploratory analytical study of young children's and patients' improvisations. In order to explore the corpus, we used a type of paradigmatic analysis, translated in computational terms into pattern discovery, to reveal interesting repeated patterns within the various musical parameters.

In general, patterns found, especially in children, tend to point to specific gestures. For example, the patterns of oscillation found in all representations (up and down interchangeably), the pattern of repeated notes found especially in children, the pattern of long downward and upward movements found mainly in children. In psychiatric patients, these gestural patterns were also found, but they were not always as clear (i.e. they contained a small number of elements which was not in agreement).

These gestural patterns can be well captured by more abstract types of representations, such as melodic contour. In other words, the level of abstraction in the initial representation needs not be very low level, in order to capture the similarities in the corpus. Melodic contour seems to be an adequate representation to capture pitch-related patterns. This observation might link to the fact that there is no musical background in any of the children or patients. More work is needed on this in order to verify the connection.

The topic of music in relation to gesture has received a lot of attention in the literature. Andrew Mead (1999) talks about “some of the ways physiology, the study of bodily function, inhabits how we talk and think about music, both directly and metaphorically”, introducing the idea of kinesthetic empathy as a significant contributor to our musical understanding. Discussing improvisation, Ashley (2009) points out that improvisation “connects musical structure, our bodies and our sense of selves as individuals”. In relation to young children's improvisations, Young (2003) discusses the gestural ways they improvise on various musical instruments.

Our results are still very preliminary. Further research will analyse a larger corpus where the statistical significance of patterns will be taken into account. A larger number of features and viewpoints will be explored, especially related to rhythm, texture, dynamics, and those musical attributes which can directly be related to gestures in music. At a second stage, the system's input will be taken into account to check how it affects the improvisation performance. Finally, a syntagmatic analysis of patterns found will help towards a structural analysis of the improvisations.

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