Music Analysis and Modeling Through Petri Nets

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Abstract. Petri Nets are a formal tool for studying systems that are concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic. They were used in a number of real-world simulations and scientific problems, but seldom considered an effective means to describe and/or generate music. The purpose of this paper is demonstrating that Petri Nets (enriched with some peculiar extensions) can well represent the results of a musicological analysis process.

1 Introduction

This paper represents the results recently obtained at LIM (Musical Informatics Laboratory, State University of Milan) in the area of Music Petri Nets (Music PNs). This mathematical formalism, shortly introduced and defined in the following sections, can be applied to music field according to different meanings. Roughly, we can recognize two possible categories of applications: analysis and composition. However, the former and the latter aspects cannot be considered completely independent. In fact, PN-oriented analysis would provide poor results, if not aimed at the comprehension of the original composition or even at the generation of a new music piece that shares some common features with the one previously analyzed. Moreover, PN-based composition itself would produce insignificant results, if not supported by a deep comprehension of the underlying structures, which involves – after all – an analysis process. In this paper, we will concentrate on the analytical possibilities and limitations related to the application of Petri Nets to music field. The possible consequences in music composition will not be explored, and will represent one of the subjects of our future work.

When applied to music analysis activities, the adoption of Petri Nets should not influence the approach of the researcher. In fact, Petri Nets should be thought as a way (one of many possible ways) to express the results of the analytical process. From our perspective, this formalism cannot limit or influence the analysis, which is an activity that obviously precedes the representation of its results.

We said that Petri Nets should not constitute a limitation, but this is not sufficient: we want to demonstrate that they are useful and effective. We will show that Petri Nets are a promising tool to represent and read music analysis results. Petri Nets were born to describe concurrent, asynchronous, and parallel processes, and these characteristics can be found in music as well. Other characteristics, such as non-determinism,

R. Kronland-Martinet, T. Voinier, and S. Ystad (Eds.): CMMR 2005, LNCS 3902, pp. 201 – 218, 2006.

can be useful for music composition through Petri Nets, but are not very significant for analysis.

In the following discussion, no constraints will be imposed about music to analyze: music works can belong to different genres, and come from different cultures, geographical areas and historical periods. On the contrary, we will underline the adequacy of Petri Nets formalism according to different degrees of abstraction in analysis, which will be the subject of next section.

2 Music Analysis and Grouping Structures

In this section we introduce the formal concept of *grouping structure*, as defined in [6]. A *group* can be constituted by any contiguous sequence of pitch events, undetermined beats or rests. Only contiguous sequences can constitute a group. A group can contain smaller groups, and in this case the subgroups must be completely contained in the former. Finally, if a group contain at least a smaller group, it should be possible to partition it exhaustively in smaller groups. These conditions define a strict, non-overlapping, recursive hierarchy, and constitute a set of grouping well-formedness rules. Intentionally, we don't introduce at the moment a set of grouping preference rules.

In this context, a music piece as well as a single note can constitute a group. Besides, the identification of grouping structures allows extracting from the score music objects such as episodes, themes, rhythmic patterns, or harmonic cadences.

Fig. 1 illustrates in a hierarchical fashion some possible groupings for a melody.[1] To reflect hierarchies, groups are represented by slurs placed beneath the music notation.

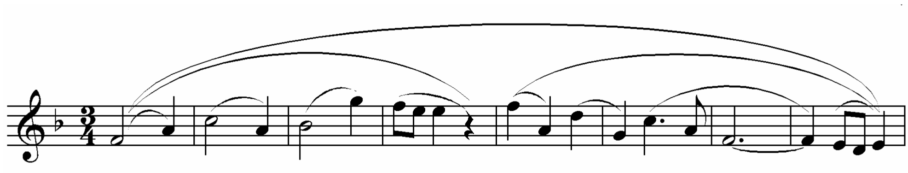

Fig. 1. Examples of grouping structures

Considering only 8 measures imposes serious limitations to the reachable degree of analysis: it doesn't allow the segmentation in episodes of the whole first movement, or the identification of recurrences of the music object represented in Fig. 1. Nevertheless, at least three categories of grouping structures can be identified. The most comprehensive structure (i.e. the largest group) embraces a whole period, whereas the two subsumed groupings reflect the subdivision of the 8-measures period in two 4-measures phrases. More interesting, the third proposed grouping structure tries to highlight relationships among smaller music objects: for

[1] W. A. Mozart, *Sonata in F major KV 332 (300k) – Allegro (I movement)*, bars 1-8 [8]. All the music examples in this paper have been extracted from this piece.