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AI and Music: Toward a Taxonomy of Problem Classes

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Abstract. The application of Artificial Intelligence technology to the field of music has always been fascinating, from the first attempts in automating human problem solving behavior till this day. Human activities related to music vary in their complexity and in their amenability of becoming automated, and for both musicians and AI researchers various questions arise intuitively, e. g.: What are music-related activities or tasks that can be automated? How are they related to each other? Which problem solving methods have proven well? In which places does AI technology contribute?

Actually, the literature in the intersection of AI and music focuses on single problem classes and particular tasks only, and a comprehensive picture is not drawn. This paper, which outlines key ideas of our research in this field, provides a step toward closing this gap: it proposes a taxonomy of problem classes and tasks related to music, along with methods solving them.

Keywords AI and creativity, music, problem classes, taxonomy

1 INTRODUCTION

Music is an important part of almost every culture. Though music is an emotional thing and strongly connected to the human mind, a variety of tasks exists that—at least in part—can be automated, reaching from the analysis of acoustic data up to high level composition tasks like song arrangement. The identification and organization of such tasks within a taxonomy T of problem classes is of a high value:

- T may serve as a scheme for classifying existing problems and discovering unapparent similarities between them.
- Since T associates problems with methods solving them, a solution for a new but structurally similar task may be derived from existing solutions—where, at least, some proposition regarding its complexity can be stated.

Here we introduce such a taxonomy, from which Figure 1 captures the main aspects. The remainder of this section reports on existing classification work; Section 2 explains our classification paradigms, discusses music-related tasks under this perspective, and illustrates the research activities in the field of AI.

1.1 Existing Work

Roads identifies a set of general problem classes, covering the topics from composition to digital sound processing [7]. However, he neither defines relations between the problem classes nor unveils his classification paradigms. Similar shortcomings apply to the taxonomy of computer music by Pope [6]. Padadopoulos and Wiggins, as well as Tahiroglu, restrict their taxonomy to the classification of algorithmic composition systems along with the utilized computational methods [5, 8]. Ariza presents a survey of algorithmic composition tools and identifies seven primary descriptors [1].

Furthermore, schemes for special problem classes exist, such as the taxonomies for sound synthesis methods or for sequencer user interfaces by Duignan et al. [4]. Biles proposed a taxonomy for music and art systems that use evolutionary algorithms [2].

Our approach goes beyond existing work within two respects: it provides a framework that (*i*) is more generic, and (*ii*) makes the underlying classification paradigms explicit.

2 TAXONOMY OF PROBLEM CLASSES

The formation of our taxonomy is task-driven, i. e., the problem classes are formulated from a musician's point of view. We identified three orthogonal paradigms that govern its structure and that proved to be qualified for classification purposes.

1. *Problem Type.* The most fundamental distinction follows Clanceys's ideas, where operations are grouped *"[...] in terms of those that construct a system and those that interpret a system, corresponding to what is generally called synthesis and analysis."* [3]
2. *Modeling Level.* Defines the degree of abstraction; music becomes manifested both at a symbol level and a subsymbolic level. The transition between these levels is continuous and may form an additional level of sound:

Modeling level	Materialization	Human perception
symbolic	notes, accords	style, genre
sound	pitch, timbre	instrument, vocal tone
subsymbolic	amplitude, frequency	volume, sonority

3. *Arrangement Direction.* Explains music-related tasks as being of horizontal, vertical, or combined type:

Arrangement direction	Materialization	Musician's viewpoint
horizontal	tone sequence	melody
combined	accord sequence	harmonizing
vertical	sound synthesis	instrumentation

Each task can be explained in the three dimensions. The composition of a melody theme, for example, is a horizontal, symbolic, synthesis task. By contrast, instrument identification is an analysis task that happens at the subsymbolic level.

2.1 Music Analysis

In the following, the analysis part of our taxonomy is presented, covering the fields of subsymbolic data analysis, i. e. the analysis of acoustic data, symbolic data analysis, and the connection between both, the so-called transcription.

Signal Analysis and Filter Theory Physical feature extraction pertains to both horizontal aspects along the time axis and vertical aspects like sound. Sound analysis basically exhibits vertical components, with the small exception of filter and amplifier envelopes

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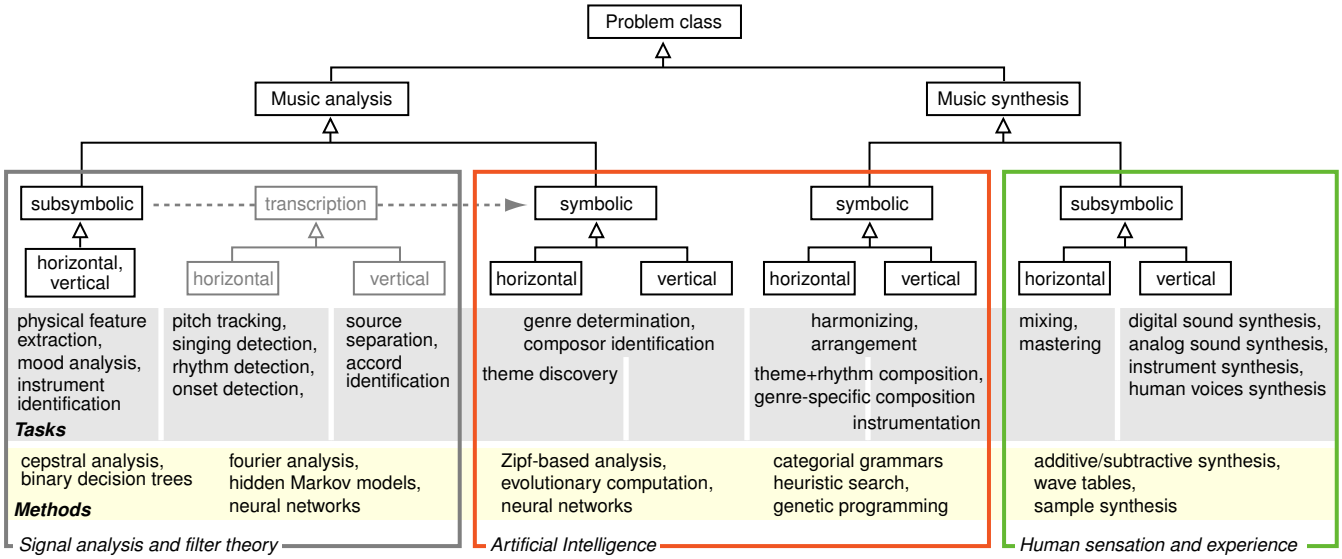

Figure 1. A taxonomy of problem classes in music. Note that the method section is not complete but shows representative methods.

or other parameter modulations. Further branches of subsymbolic music data analysis are mood and instrument classification. Transcription, which is the translation of acoustic information into notes, establishes an important field of operationable tasks. It connects the subsymbolic with the symbolic classes as its methods work on acoustic data but make use of symbolic background knowledge. Except for source separation and accord detection the remaining tasks exhibit primarily horizontal dimensions.

Analysis by Artificial Intelligence The symbolic counterparts of both analysis and synthesis tasks are the challenging field for AI methods. A typical horizontal task is theme discovery, i. e., the identification of melodies and interludes. Other interesting problems are genre determination and note-based composer identification. Various AI methods are applied in this context, reaching from evolutionary methods to knowledge processing. Interestingly, the AI research activities in the synthesis field are prevalent compared to the activities in the analysis field (cf. Figure 2).

2.2 Music Synthesis

At the symbolic level the synthesis part of our taxonomy covers tasks from the field of song composition and arrangement. Here, AI methods demonstrate their power. The subsymbolic part of sound synthesis and instrumentation is only partly operationable and comes within the limits of human sensation and experience.

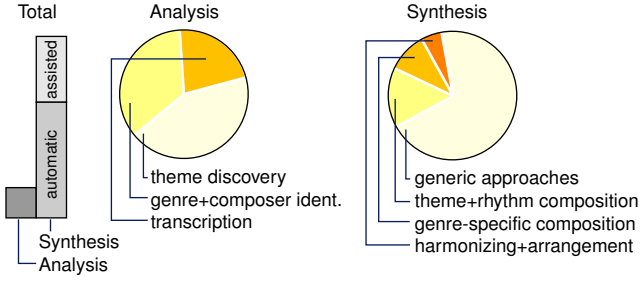

Figure 2. Distribution of research activities for AI and music. Basis for this investigation were 560 research papers, most of them published in the last twenty years. About 300 research papers fall into the area of symbolic problem classes (shown here), whereas 15% of them pertain to analysis tasks and 85% to synthesis tasks.

Synthesis by Artificial Intelligence The automatic composition of songs is probably one of the most interesting AI applications. Again, we can distinguish between horizontal and vertical problems. Theme and rhythm composition is a genre-specific horizontal task. The tasks of harmonizing phrases and arranging a whole song exhibit both vertical and horizontal aspects, whereas the instrumentation task is rather vertical. The applied AI methods vary from categorical grammars to computational intelligence methods like genetic programming.

Human Sensation and Experience Horizontal aspects of the subsymbolic synthesis class concern mastering and mixing tasks; vertical aspects cover the task of sound synthesis. The latter ranges from natural sound synthesis of human voices and classical instruments to digital sound synthesis.

2.3 AI Research Activities

To get an overview of the research activities in the last forty years we have analyzed more than five hundred papers from the field of computer music. Figure 2 illustrates the activities for the symbolic problem classes. Observe that much more research took place in the synthesis branch compared to the analysis branch. Moreover, the distribution of the research activities for the different subproblems is quite interesting and may serve as a guide to future research.

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