Music theoretical approach to auditory interface design: progressive, explainable, and accessible

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ABSTRACT

Music activities offer individuals an opportunity to engage in various cognitive interactions with sound, a phenomenon which has been studied from music theoretical perspectives. This cognitive trait is not limited to the arts but also extends to the development of auditory interfaces for everyday products. However, uncertainties still exist regarding the current theoretical framework to move beyond abstract concepts and towards practical design methodologies. To address this issue, my doctoral research focuses on exploring a method for sound production that employs tonal music theories, creating an accessible and explainable system for auditory interface design. This approach will result in a systematic methodology covering sound progression that can respond to user scenarios, allowing designers and researchers to better describe their design and analysis. Ultimately, this research aims to enhance the end-user experience by making sound design more accessible to a broader people, opening the door to diverse and logical sound creation.

CCS CONCEPTS

• **Human-centered computing → User interface design**; • **Applied computing → Sound and music computing**.

KEYWORDS

auditory interface design method, auditory display, sonification, sound design methodology, sound design theoretical framework, tonal music theory, music progression, user-centered design

ACM Reference Format:
Minsik Choi. 2023. Music theoretical approach to auditory interface design: progressive, explainable, and accessible. In *Creativity and Cognition (C&C '23), June 19–21, 2023, Virtual Event, USA.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3591196.3596814

1 INTRODUCTION

Musical experience, such as listening to it, is a complex yet innate cognitive interaction with sound that is unique to human species [1]. Engaging in musical activities, people might create auditory imagery, anticipate the musical progression, and are even induced to perform certain behaviors through subtle sound stimuli. Cognitive interactions of this musical nature have been a significant consideration throughout the extensive music history. This is evident in various aspects, for instance, the functional harmony in tonal music analysis, as well as the prominence of Wagner's light motifs during the late Romantic period [15]. However, this phenomenon is not confined to the arts, including contemporary popular music, but extends to the development of auditory interfaces for everyday products. It employs human auditory cognition, which is demonstrated by cognitive science concepts such as musical schema, auditory gestalt, and musical expectancy [17, 18], to sonify data by considering the user's psychological factors in conjunction with the physical parameters of sound [28].

> "In particular, classic psychoacoustics has dealt primarily with simple stimuli. Music, on the other hand, is concerned with larger structures. Hence, melodic recognition and the perception and understanding of simultaneously sounding auditory streams (as in counterpoint) is of great relevance to audio's use in HCI." [27]

The concept of musical factors within the auditory interface design process did not arise unexpectedly. Gaver [13, 14] conceptualized auditory icon design as a means of mapping the listener's inherent knowledge acquired from music-listening experiences, whereby everyday materials are sonified using features of auditory imagery [27]. In addition, Blatter [3] identified four categories of earcons that are based on fundamental musical elements, which were later augmented by Brewster [4–6, 26]. Auditory icon is driven by the sonification of users' intrinsic cognitive characteristics formed by everyday musical activities, and the hierarchical classification of non-speech interfaces based on musical elements like pitch and rhythm is done to integrate them with basic music theory.

However, there is still uncertainty regarding the adequacy of the current theoretical framework to progress beyond abstract concepts and towards a practical design methodology. It is also unclear how designers and researchers can effectively utilize the methodology to explicate their work. Although related ISO standards has been developed [9, 11], designers and researchers lack access to sufficient evidence and their experience as users might fail to be reflected in them. As unifying the methods to study auditory interface would be challenging due to its transdisciplinary nature [16], It should be possible to create a theoretical foundation for an explainable and accessible design method that is based on the theories of tonal music. In addition, there is a dearth of concrete endeavors to tackle the progression of sound from a design perspective, as opposed to relying on a rather discrete approach to sound. The harmonic functions and syntax of sound progression can be utilized in auditory interface design, extending beyond individual and vertical sound

C&C '23, June 19–21, 2023, Virtual Event, USA

ACM ISBN 979-8-4007-0180-1/23/06.
https://doi.org/10.1145/3591196.3596814

compositions. In this regard, Newbold [22–24] proposes a groundbreaking approach that takes into account musical progression and expectancy. However, it is modest to consider the viewpoints of designers or researchers, merely suggesting that such cognitive and music theoretical foundations can serve as a significant basis for sonification.

Therefore, my doctoral research focuses on exploring a method for designing auditory interfaces, which can be elucidated using tonal music theories. Applying the principles of tonal music and extending the scope beyond individual sounds to encompass progressions between related sounds can facilitate the systematization, explainability, and artistic diversity in the design, analysis, and evaluation of auditory interfaces. Designers can systematically yet philosophically create auditory displays that respond to various contexts and scenarios, while researchers can interpret and present the evaluation results of displays based on an explainable foundation, rather than solely on user preference. An explainable and accessible system for auditory interface design will be developed that can be applied across the entire design process, and this will broaden the range of sounds covered, adding a new dimension to auditory interface design.

2 RESEARCH OBJECTIVE AND SCOPE

My doctoral research aims to establish a methodology for designing auditory interface based on the tonal music theoretical perspectives. The methodology will consider the functional context of tonality and the varied chords associated with each function. Additionally, the study intends to adopt a user-centered approach to meet the needs of sonification designers and researchers responsible for analyzing auditory displays. While the perspective of the end user will also be dealt with, it will be given more weight in the later phases of the research. Also, the initial target interface type might be on earcons, but the research is not limited to them and will be approached as an underlying basis for all kinds of auditory displays. Due to the potential interplay of multiple physical variables and the ambiguous boundaries between different types of auditory displays [4, 6], the specific target interface type has yet to be defined.

3 BACKGROUND

3.1 Tonal Music Analysis: Rameau to Schenker

A chord refers to the simultaneous sounding of two or more notes and can be combined in various ways to produce different effects [19]. Furthermore, the progression of chords can be analyzed according to the nature of temporal art, forming a harmonic concept that involves not only the vertical relationship between notes but also their horizontal interconnectedness, known as functional harmony [19]. The functional harmonic concept emphasizes the role of individual chords in the interrelationship of notes, thereby forming a logical basis for their arrangement [2, 20]. Although this approach to the practice of tonal music has been formulated since around the 18th century, it was theoretically developed over a long period of time by Jean Philippe Rameau, Hugo Riemann, Heinrich Schenker, and contemporary theorists and continues to be central to the analysis of tonal music today [2, 8]. The method of harmonic analysis has evolved into a systematic approach, from Rameau to Schenker, that considers not only individual chords but also the entire system of musical pieces from a macro perspective. Therefore, an expanded user experience can be achieved by considering not only diversified chords of each part but also the progression of the sound relationship, which can serve as the basis for a progressive and describable design. Roman numeral analysis, functional harmonic concepts, Schenkerian analysis, and other related theories and approaches in tonal music provide a systematic basis for everyday product sounds.

3.2 Progressive, Explainable, and Accessible

Progressive: user experience research typically concentrates on cross-sectional tasks, while also giving consideration to user flows [21]. User scenarios, which represent more than just isolated situations, serve as integral components of the process, akin to a user journey [25]. As an illustration, the creation of a warning beep to indicate a hazardous condition necessitates considering not just the immediate danger, but also the larger process involved in responding to and mitigating that peril. This requires an understanding of the user's workflow and cognitive process, as well as the corresponding music progressive representation in auditory interface design.

Explainable: In terms of interface usability test, user experience takes center stage, and it is often open to subjective interpretation [7]. The usability test consists of three primary components, namely effectiveness, efficiency, and satisfaction, all of which could rely on both quantitative and qualitative indicators [10]. However, given that the outcomes are derived from user responses, the interpretation of the results can be rather simplistic and vague. While research that centers on users is commendable, the lack of ability to properly interpret results impedes significant progress in research. Therefore, interface design and analysis should be grounded on a comprehensible and logical foundation. Drawing inspiration from the systematically established methodology of tonal music analysis can help designers and researchers who create, analyze, and evaluate sound better explain the profound implications of their work.

Accessible: The accessibility of design logic to both designers and researchers is crucial, and user centered perspectives can facilitate this. Depending on the target user's specific situations, the details of the medium to the suggested method will vary. For instance, in the realm of data science and machine learning, different platforms have been developed for different user groups, including trained developers and non-specialists [12]. These platforms range from providing libraries for development to creating visual workflows environment using graphical interfaces [12]. When implementing the methodology proposed in this study, it is crucial to create a platform suitable for the main target users, which requires in- depth consideration of the user-centered design principles in multiple phases.

4 RESEARCH DESIGN: CURRENT AND FUTURE WORKS

As a first-year doctoral student, I intend to adopt an inductive research approach. While subsequent phases may demand deductive research problems for conducting experiments, I firmly believe that setting the foundation of my research curiosity inductively is necessary. By doing so, I can assess the needs of target users from a broader standpoint, facilitating me to explore theoretical correspondence and method design directions that align with my research objectives. A substantial amount of time is being devoted to conducting extensive literature review and delving into the overall research planning. It is paramount to possess a complete understanding of the tonal music theories and to effectively describe and represent them to yield ergonomic outcomes. Additionally, it is imperative to discuss the application of these theories to particular products or industries.

Phase 1: This involves identifying the current situations and needs of the targets, which may include designers, researchers, and end-users. However, the approach to each group will vary depending on their contexts. For designers and researchers, it is core to gain an understanding of the current situations in terms of creating, analyzing, and evaluating using current standards, as well as their opinions on how the proposed methodology can be integrated into their future works. For end-users, it is central to identify any limitations they may not have considered when listening to current auditory displays, as well as their detailed needs when experiencing auditory displays that is connected to their user scenarios. This information serves as the starting point to develop a more comprehensive understanding of user centered methodology design, which will guide subsequent phases of the research.

Initially, an inductive research methodology is adopted to gain a holistic understanding of the research. An ethnographic perspective is utilized, with interviews being the primary method to obtain an insight into the situation. If deemed appropriate, participatory observations are also conducted. The aim of this phase is to classify the qualitative data obtained into specific keywords and contextual categories, which would provide a broader but structural picture. Subsequently, a quantitative approach is taken. The identified keywords and categories, along with their details, are integrated to develop a quantified questionnaire. This questionnaire is then subjected to statistical analysis to extract the requirements of the target users.

Phase 2: The second step is constructing a design logic that is based on the problems and needs of the current design method, derived from the contexts of the targets. It entails developing a new methodology that corresponds to the principles of tonal music theories around the main factors that have been identified in the earlier phase. The methodology will consider different harmonic combinations that correspond to individual harmonic functions, the hierarchical progression of music, and the systematic description of these sound systems in a macroscopic manner. The structured methodology will also address user scenarios as task process. The focus at this phase is to carefully extract and combine relevant user characteristics and tonal music elements that are suitable for the development of the auditory interface design. The key emphasis is on identifying the most effective combination of these elements to ensure that the design is logically and contextually systematized. Moreover, various notation methods of music theories will be integrated to establish an ideal notation system that aligns with the requirements of the auditory interface design.

Phase 3: In this phase, it is crucial to create a prototype that can effectively demonstrate the design methodology developed in the previous stages. The prototype should be user-friendly and easily accessible to designers and researchers, regardless of their level of music theory knowledge. Thus, the details of the user platform for prototyping must be made beforehand to ensure the prototype's overall usability and effectiveness. Additionally, the sounds produced by the methodology must be effective for real users. The validation process, which includes the designed sounds, can also be seen as a form of prototype. The main challenge during this phase is to use the established methodology to produce real sounds that can be tested and validated by end-users, as well as creating a suitable platform for designers and researchers. The medium in which the sounds are formulated would be the most practical outcome of this lengthy research to explore.

Phase 4: The focus is on evaluating the completed prototypes, which involves two main aspects. The first is conducting a usability test of the design platform, which is aimed at assessing its user-centeredness and efficiency in creating and analyzing displays using the suggested theoretical methods. The second aspect is validating the auditory displays designed for end-users, which involves examining both the validity of the theoretical methodology and the effectiveness of the sounds produced by the process for real users. The evaluation will primarily rely on experiments and quantitative statistical analysis of deductive research questions, while also incorporating secondary qualitative data collection and analysis. The results of this phase will be used to refine the design platform including the methodology and optimize the auditory interface design system for all targets involved in the entire process.

5 EXPECTED CONTRIBUTION

Auditory interface design has the potential for significant advancement through the integration of music theory. By identifying the underlying principles that govern the creation and analysis of displays, current limitations can be surpassed. The theoretical framework can expand the scope of sound design from discrete to progressive in a way that can be described and understood. This approach provides a systematic methodology for sound design that responds to user scenarios and enables designers and researchers to better understand the logics behind the design. By utilizing an engineering approach to sound and music, which have been previously viewed as abstract concepts, this research can make sound design more accessible to a wider range of people, paving the way for diverse sound creation and ultimately enhancing the user experience.

ACKNOWLEDGMENTS

I thank my supervisor, Dr. Charles Martin of ANU computing school for encouragement and insightful comments.

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