What Signal Processing Can Do for the Music

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Abstract. In this paper, several examples of what signal processing can do in the music context will be presented. In this contribution, music content includes not only the audio files but also the scores. Using advanced signal processing techniques, we have developed new tools that will help us handling music information, preserve, develop and disseminate our cultural music assets and improve our learning and education systems.

Keywords: Music Signal Processing, Music Analysis, Music Transcription, Music Information Retrieval, Optical Music Recognition, Pitch Detection.

1 Introduction

Signal Processing Techniques are a powerful set of mathematical tools that allow to obtain from a signal the required information for a certain purpose. Signal Processing Techniques can be used for any type of signal: communication signals, medical signals, Speech signals, multimedia signals, etc. In this contribution, we focus on the application of signal processing techniques to music information: audio and scores.

Signal processing techniques can be used for music database exploration. In this field, we present a 3D adaptive environment for music content exploration that allows the exploration of musical contents in a novel way. The songs are analyzed and a series of numerical descriptors are computed to characterize their spectral content. Six main musical genres are defined as axes of a multidimensional framework, where the songs are projected. A three-dimensional subdomain is defined by choosing three of the six genres at a time and the user is allowed to navigate in this space, browsing, exploring and analyzing the elements of this musical universe. Also, inside this field of music database exploration, a novel method for music similarity evaluation is presented. The evaluation of music similarity is one of the core components of the field of Music Information Retrieval (MIR). In this study, rhythmic and spectral analyses are combined to extract the tonal profile of musical compositions and evaluate music similarity.

Music signal processing can be used also for the preservation of the cultural heritage. In this sense, we have developed a complete system with an interactive

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graphical user interface for Optical Music Recognition (OMR), specially adapted for scores written in white mensural notation. Color photographies of Ancient Scores taken at the *Archivo de la Catedral de Málaga* have been used as input to the system. A series of pre-processing steps are aimed to improve their quality and return binary images to be processed. The music symbols are extracted and classified, so that the system is able to transcribe the ancient music notation into modern notation and make it sound.

Music signal processing can also be focused in developing tools for technology-enhanced learning and revolutionary learning appliances. In this sense, we present different applications we have developed to help learning different instruments: piano, violin and guitar. The graphical tool for piano learning we have developed, is able to detect if a person is playing the proper piano chord. The graphical tool shows to the user the time and frequency response of each frame of piano sound under analysis and a piano keyboard in which the played notes are highlighted as well as the name of the played notes. The core of the designed tool is a polyphonic transcription system able to detect the played notes, based on the use of spectral patterns of the piano notes. The designed tool is useful both for users with knowledge of music and users without these knowledge. The violin learning tool is based on a transcription system able to detect the pitch and duration of the violin notes and to identify the different expressiveness techniques: *détaché* with and without *vibrato*, *pizzicato*, *tremolo*, *spiccato*, *flageolett-töne*. The interface is a pedagogical tools to aid in violin learning. For the guitar, we have developed a system able to perform in real time string and fret estimation of guitar notes. The system works in three modes: it is able to estimate the string and fret of a single note played on a guitar, strummed chords from a predefined list and it is also able to make a free estimation if no information of what is being played is given. Also, we have developed a lightweight pitch detector for embedded systems to be used in toys. The detector is based on neural networks in which the signal preprocessing is a frequency analysis. The selected neural network is a perceptron-type network. For the preprocessing, the Goertzel Algorithm is the selected technique for the frequency analysis because it is a light alternative to FFT computing and it is very well suited when only few spectral points are enough to extract the relevant information.

Therefore, the outline of the paper is as follows. In Section 2, musical content management related tools are presented. Section 3 is devoted to the presentation of the tool directly related to the preservation of the cultural heritage. Section 4 will present the different tools developed for technology-enhanced music learning. Finally, the conclusions are presented in Section 5.

2 Music Content Management

The huge amount of digital musical content available through different databases makes necessary to have intelligent music signal processing tools that help us managing all this information.

In subsection 2.1 a novel tool for navigating through the music content is presented. This 3D navigation environment makes easier to look for inter-related