**Real-time Identification of Common and Extended Musical Chords using Artificial Neural Networks**

**R2-B09**

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1. **Musical chords are the basis of harmony in music (Chord, 2004, p. 147).**
   1. According to the The Concise Oxford Dictionary of Music, a chord is “any simultaneous combination of notes, but usually of not fewer than 3” (Chord, 2004, p. 147).
   2. A chord name is dictated by two significant parameters.
      1. The root note is a “note from which a chord originates” (Root, 2004, p. 615).
      2. The chord type is determined by the distances between the notes that comprise it.
2. **The identification of musical chords is significant.**
   1. Humphrey, Bello, and Cho (n.d.) state that “the general music learning public places a high demand on chord-based representations of popular music” (par. 1).
   2. Websites on the Internet that provide chords for many popular songs exist, but these are generated by a user base and are not guaranteed to be correct or accurate.
3. **Identification of musical chords depends on absolute pitch.**
   1. Absolute pitch is expressed when one can identify a musical note by hearing it (Zatorre, Perry, Beckett, Westbury, & Evans, 1998).
   2. Absolute pitch is expressed in a low percentage of the human population and acquired through a combination of favorable genes and music training at a young age (Baharloo, Service, Risch, Gitschier, & Freimer, 2000).
   3. Complete and accurate determination of these chords by hearing requires the use of absolute pitch, because chords are based on an absolute reference point, the root note (Root, 2004, p. 615).
4. **Previous attempts have been made at chord identification, but there is still an unexplored area in this research.**
   1. Fujishima (1999) and Stark & Plumbley (2009) independently made classical algorithms for identifying musical chords from audio inputs in real-time.
   2. Implementations using neural networks have also been attempted before, but they do not aim to run in real-time and do not include chords outside major and minor chords (Osmalskyj, Embrechts, Piérard, & Van Droogenbroeck, 2012; Perera & Kodithuwakku, 2005; Zhou & Lerch, 2015).
   3. None of these researches explore the use of neural networks to identify more complex or extended chords in real-time.
5. **Artificial Neural Networks (ANNs) are computational models.**
   1. Machine learning modeled through Artificial Neural Networks are designed to be adaptable and simple through self-organization (Daniel, 2013).
   2. The machine learns a given input dataset through by mapping an input through a probability distribution into its most probable class (Colina, Perez, & Paraan, 2017).
   3. In the case of chord identification, individual neurons are assigned the task of identifying a specific chord, with each neuron being trained with the same input data set, but is constrained to having a designated chord to output (Perera & Kodithuwakku, 2005).
6. **Various pieces of hardware and software will be utilized in this research.**
   1. A GPU or graphics processing unit is a parallel processor (Nickolls, Buck, Garland, & Skadron, 2008) useful for parallel computing applications such as artificial neural network (ANN) simulations and training and is empirically found to be approximately 30 times faster than a regular CPU in these tasks (Colina, Perez & Paraan, 2017).
   2. Certain pieces of software will be necessary to define the structure of, train, and test the neural network.
      1. The neural network libraries necessary include Keras, a library that allows for the prototyping of the neural network on python, and Theano, which allows GPU-parallelization and on which Keras operates on (Colina, Perez, & Paraan, 2017).
      2. Use of the GPU depends on NVIDIA CUDA which will be necessary for GPU computations and NVIDIA cuDNN which will allow the neural network to be simulated on the GPU (Nickolls, Buck, Garland, & Skadron, 2008).
      3. Anaconda is a specific distribution of the Python and R programming languages for scientific computing and data processing.
      4. PyCharm is a piece of software known as an independent development environment or IDE, which allows the user to write and run code.
      5. The *pyrtmidi* library (Kidd, 2017) will be installed as it allows real-time MIDI signal input to be interpreted by Python code and fed to the neural network for chord identification.

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