SIMULATION OF MUSICAL CONTENT BY 3-D VISUALISATION

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ABSTRACT

Audio information we receive is a complicated phenomenon. Consequently, an extensive analysis of a piece of music is a complex task due to the sheer number of data attributes such as tempo, rhythm, pitch, consonance, harmony, dynamics. That is the reason why all the research conducted to date in this field has concentrated solely on selected parameters, and that fact determined the aim of the experiments as well as their results. This paper presents a totally new approach to creating 3-D images to the analysis and simulation of musical content. As the main criterion for the synthesis of the 3-D images we have chosen harmonic content, which has close relation to the musical content of a piece. Additionally, the graphic display of its main components in shape of 3-D figures is a crucial aspect in the presented approach. The figures, which were named AKWETs, are applicable in simulation and analyse musical content. The paper also states that the the order of AKWETs identified in a given phrase forms a meaningful visual sequence, connected with its musical original.

INTRODUCTION

The following questions have been asked for a long time: why do people admire a particular piece of music, whilst are not attracted to another? What criteria need to be fulfilled for the listener to accept or reject a given performance? By what means do people's hearing and brain analyse the information carried by sound? Only recently academic papers have emerged that study the musical content with application of computer techniques.

Audio information we receive is a complicated phenomenon. Consequently, an extensive analysis of a piece of music is a complex task due to the sheer number of data attributes such as tempo, rhythm, pitch, consonance, harmony, dynamics. That is the reason why all the research conducted to date in this field has concentrated solely on selected parameters and that fact determined the aim of the experiments as well as their results. Some authors analyse different performances of one piece of music, restricting their attention to two expressive dimensions: tempo and loudness (Dixon et al. 2002). Typical example, where musical and spatial parameters are related one to another and form an interactive visual tool are also served (Graves et al. 1997).

This paper presents a an entirely new approach to creating 3-D images to the analysis and simulation of musical content. As the main criterion for the synthesis of the 3-D images we have chosen harmonic content, which has close relation to the musical content of a piece. Additionally, the graphic display of its main components in shape of 3-D figures is a crucial aspect in the presented approach. The figures, which were named AKWETs, are used to simulation and analyse musical content. The paper also states that the the order of AKWETs identified in a given phrase forms a meaningful visual sequence, connected with its musical original.

Visualisation is often used in academic research to illustrate relation between various parameters. Applied to analysis of musical content, visualisation reveals its aesthetical value, as it combines two independent human senses. What is more, it helps obtain information that is not always clearly perceived when considerable amount of data is given. We can assume that we obtain information of a different level and our cognitive potential extends. Consequently, the presented AKWETs enable us to:

- demonstrate correlation between 3-D images and music
- obtain additional information about chords - their type, internal consonance and dissonance etc.
- draw conclusions about how chords follow in succession
- get a new look at the overall structure of a piece of music

This area is still open for further research.

METHOD OF CREATING 3-D IMAGES

Harmonic content of a piece of music consists of chords that are related to its consecutive segments, and that relation depends on the sounds of a chord as well as other principles of musical theory (Sikorski 1965).

The main idea of the method presented is based on chords. As mentioned above, chords divide the analysed musical content into segments, the length of which is not equal. It is determined by the mentioned principles (Sikorski 1965). The segments may include a part of a bar or several bars, so that the difference in length between particular segments may be considerable. Our method of audio analysis is completely different in comparison with the traditional ones (Czyżewski 2001).

The fact that most chords contain three notes or it is possible to choose three crucial components from a

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multi-note chord was taken into account (Sikorski 1965).

Every musical note can be represented in a simplified form as a sine curve of frequency f. Consequently, each component of chord A is described by means of sine function $S_i(t)$ of frequency f_i.

Each function obtained is associated with one of the axes (X, Y or Z) of Cartesian coordinates {U}, and a 3-D figure Φ_A assigned to chord A is formed.

$$A \rightarrow \Phi_A \tag{1}$$

We name figure "**AKWET**" = **AK**ord**W**izualny**ET**alon.

The forming of each AKWET may be described as the result of the movement of point P, spatial position of which is determined by function $S_i(t)$ values put on X, Y and Z axes respectively (Figure.1).

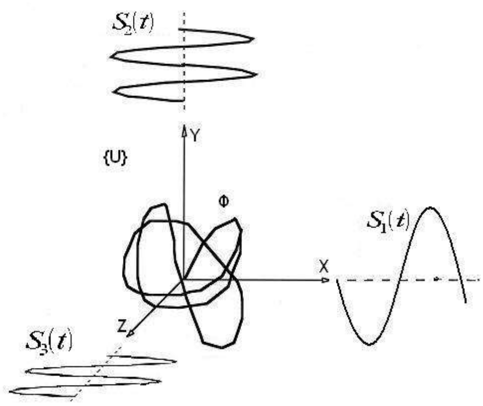


Figure 1: Forming of an AKWET

Each axis of the {U} coordinates is related to a sinusoidal signal $S_i(t)$ of frequency f_i where i = 1,2,3. The signals illustrate consecutive components of the AKWET. When digitised with frequency F >> f_i, the signals $S_i(t)$ form a sequence of samples s_{ji}. Each element of the sequence is a three-dimensional vector that determines position of point P_j.

The coordinates of a single point P_j (P_{jx}, P_{jy}, P_{jz}) , which are calculated on the basis on common time t, and the signal function $S_i(t)$ may be recorded as follows:

$$\begin{aligned} P_j &= (P_{jx}, P_{jy}, P_{jz}) \\ P_{jx} &= S_1(t_j) = A\sin\omega_1 t_j \\ P_{jy} &= S_2(t_j) = A\sin\omega_2 t_j \\ P_{jz} &= S_3(t_j) = A\sin\omega_3 t_j \end{aligned} \tag{2}$$

Since all the components taken into account are equally important in an AKWET's structure, we investigate three functions of identical amplitude A.

AKWET Φ is a spatial and periodic figure (Figure 1) and its period depends on the values of component signals.

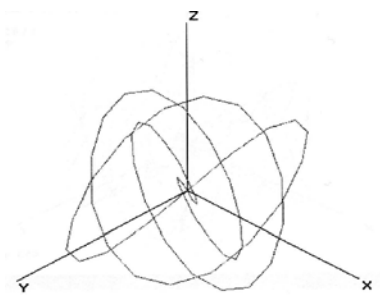
ACHIEVEMENTS TO DATE AND FUTURE WORK

AKWET's structure is similar to Lissajous figures (Szczeniowski 1972). Significant difference lies, however, in the fact that we achieve 3-D figures, which are then used to visualise and analyse sophisticated musical content.

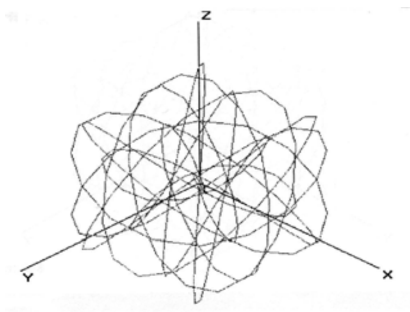
Correlation between AKWET's shape and the sound of chords

Classical music theory uses two basic keys – minor and major, to describe the scale of a particular piece. The keys are represented by minor and major chords, the sound of which substantially differs; simplifying the matter we can state that a minor key is "sad", while a major – "cheerful" (Sikorski 1965). We can consider keys basic AKWETs.

It results that the figures representing major and minor chords respectively differ significantly (see Figure.2). The major chord's shape is simpler and clearer. The minor chord, on the other hand, is denoted with a more complex, multidimensional figure, which cannot, despite its regular shape, be associated with peace.



a)



b)

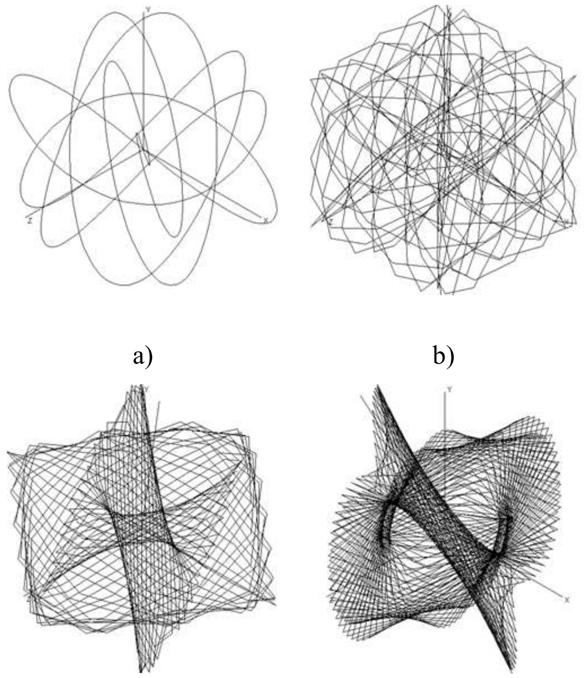
Figure 2: Model patterns a) major AKWET b) minor AKWET

This example is the first evidence that the AKWET is based on the right criterion.

Further development of AKWETs might make use of another criterion – aesthetic qualities of a 3-D image.

Additional information about chords that might be extracted from the figures' shape

An AKWET simulator has been designed and built for further experiments and all the basic, according to the musical laws (Sikorski 1965), chords have been tested. Furthermore, simulator-generated graphics originated ideas of new AKWETs. Figure 3 shows several model patterns depicting internal consonance (a) and dissonance (b) as well as two additional AKWETs (c) and (d), not subjected to musical laws, but interesting for further research.



a) b) c) d)

Figure 3: Several model AKWETs: a) consonance, b) dissonance, c) new 1, d) new 2.

Simulation of musical content

The sequence of appearance of static 3-D images is an equally interesting field of research. One of the basic patterns of development of a musical piece is called cadence (Sikorski 1965). Figure 4 enables us to visually track the development of a major cadence K_d (T S D^7 T). This cadence is a common harmonic description of the ending of a musical piece. Consecutive AKWETs form a visual sequence that is temporally connected with the musical original.

Each chord from the sequence K_d has meaningful content reflected in a visual sequence: introduction, development, climax and denouement. A developed AKWET simulator can play the sequences of chords and simultaneously draw figures, creating the videoclip of a musical piece. The order of AKWETs identified in a given phrase forms a meaningful visual sequence, connected with its musical original.

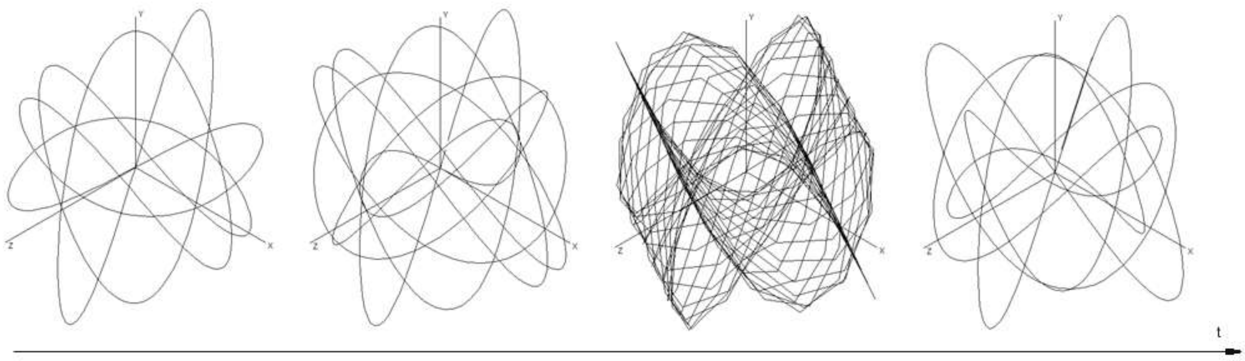
CONCLUSIONS

The method presented in this paper is an innovative approach to simulation and analyse pieces of music. It is based on combining two human senses: hearing and vision, which results in mutually linked abstract figures that illustrate music and to analyse musical content (AKWETs).

The AKWET method may be applied in:

- visualising music;
- studies and prediction of the impact of music on listeners;
- supporting composer's work in evaluating combination of chords in a composition by visual simulation

We are certain that continuation of this research may bring, especially when the computer programmes are developed, new discoveries in the area that combines music with technology.



a) b) c) d)

Figure 4: Visualisation of a model cadence K_d (T S D^7 T): a) T (I), b) Subdominant (IV), c) Dominant^7 (V^7), d) T (I_1).

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