A Method for Wave Table Generation in Sound Synthesis Tasks Based on Two-Dimensional Wavelet Transform

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***Abstract*—**This article presents a method for wave table generation for sound synthesis based on discrete packet wavelet transform (DPWT). Wave table synthesis is an effective method of digital sound generation that utilizes pre-prepared arrays of waveforms, which can be interpolated to produce a variety of timbres and effects. Traditional methods for creating wave tables have their limitations and require significant time and technical resources. The article proposes a new approach that employs two-dimensional wavelet synthesis to generate height maps, which are then interpreted as wave tables. The algorithm of forming height maps using DPWT is described. The proposed method opens new possibilities in sound synthesis and design, allowing the creation of complex sound textures with minimal time investment and offering new control capabilities for DPWT synthesis results.

***Keywords*—** Inverse Discrete Packet Wavelet Transform; Music Computer Technologies, Wavelet Synthesis and Wave Table Synthesis.

I. Introduction

Table-wave sound synthesis (TVSZ) is a digital method of sound generation based on the cyclic reproduction of small segments of audio data known as frames, the totality of which forms wavetables [1]. The basic principle of the TVSZ is to use pre-prepared WTS, fragments of which can be interpolated during playback to obtain a variety of sounds and effects. Figure 1 shows a visualization of a W containing 64 frames. To obtain this visualization, the free WaveEdit software from Synthesis Technology was used. For example, in the figure, one frame is highlighted in bold, containing the period of a spectrum-limited rectangular signal.

This method of sound synthesis is actively used in modern synthesizers such as Access Virus, Waldorf Wave, Xfer Serum, U-he Hive 2 and others. The main advantage of the TVSZ is its flexibility and richness of timbre capabilities. Thanks to the technique of interpolation between different W frames, it is possible to obtain a significant number of sound variations without using additional processing tools.

VT creation is usually implemented in the following ways:

- Manually. Each W can be manually created by a sound designer by drawing a waveform in the time domain and/or envelopes of the frequency and phase spectra. This allows for precise control over the timbral characteristics of each VT frame. However, this approach requires considerable time and, moreover, is often fraught with technical problems.
- Sampling. The sampling technique involves analog-to-digital conversion and recording of real instruments or other sounds and their subsequent processing to create sound effects. This method requires meeting the appropriate acoustic conditions for recording and a significant amount of time to organize the recorded samples into a single volume.
- Automatic generators. Using various algorithms to create waveforms allows you to generate watts corresponding to certain timbre characteristics. In this case, the main problem is the development of the generation algorithms themselves, which would allow us to obtain a set of gradually changing waves.

Thus, there is an urgent problem of developing algorithms for generating electricity, which would:

a) reduced the time spent by the sound designer, which is especially important in the context of sound design and music production, where time and resources are limited;

b) had good manageability;

c) provided a variety of results.

Solving this problem would significantly simplify the process of creating new timbres and sounds, which led to the development of the WT generation method considered in this article based on two-dimensional wavelet synthesis of height maps.

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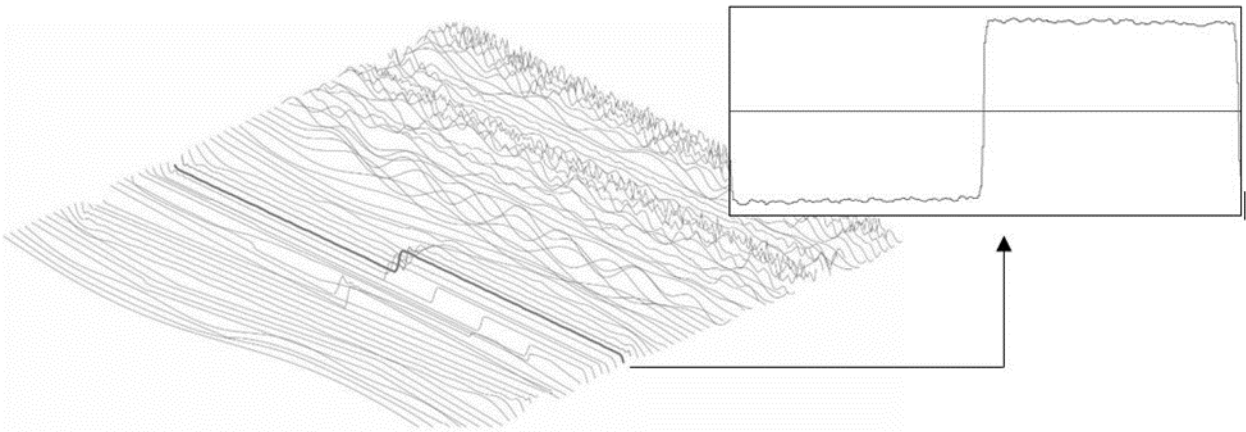

Fig. 1. Visualization of the wave table

II. Application of two-dimensional wavelet synthesis to generate height maps

Two-dimensional HDPE is most often used as a tool for analyzing and processing signals and images [2, 3]. Nevertheless, HDPE can be used to synthesize various signals [4]. Using a two-dimensional DFT to generate elevation maps provides a new approach to creating a VT. The generated height map can be interpreted as W, where each slice is a W frame. In [5], an algorithm for the synthesis of wavelet coefficients was proposed for the first time to solve the problem of estimating the noise of quantization of the DPVP coefficients, which was then adapted for the two-dimensional case [6]. Below, the authors provide **an algorithm for generating a height map by applying a wavelet transform**:

1. Creating an array of zero values P of size n x n, where $n = 2^k$, $k \in Z$.

2. Creating a seed array I with arbitrary values. Experiments have shown that 4x4, 8x8 and 16x16 arrays are the most convenient in terms of interaction through a graphical interface. At the same time, each element $i \in I$ could take the values $i \in \{0,1\}$.

3. The implementation of a two-dimensional FFT array P up to the decomposition level L, at which the size of each node of the batch tree would be equal to the size of the seed array I.

4. In one of the available nodes N (the number of possible nodes is determined by the formula $N = 4^L$), an array I is loaded at the L level and the reverse PRT is performed. The resulting reconstruction result is written to the R array.

5. The R array is normalized by the maximum value (optional). $\tilde{R} = R / \max(R)$.

6. A filtering operation is applied to the final result (for example, using a Gaussian filter), for smoothing (optional).

All available nodes belong to one of four types of coefficients of two-dimensional FIBERBOARD: approximating, horizontal, vertical and diagonal. This aspect affects the features of the formation of the final result. The seed array itself also affects the generation result. If the selected node does not belong to the approximating coefficients, the final result of the algorithm becomes chaotic, without obvious trends. In such cases, optional algorithm operations can be applied, including filtering. The use of the Gauss filter ($\sigma = 2$) is ineffective for detailing coefficients. In this regard, before applying it, a cut–off operation is used - all negative values are set to zero.

III. A Using elevation maps as a VT for the TVSZ

Modern software synthesizers use the PCM wav format of uncompressed sound to store watts. The frames are sequentially written to file B (see Fig. 2). For use in an internal combustion engine, the file with VT is opened, segmented into frames in the memory of the computing device, between which interpolation occurs during the sound generation process.

Thus, the coefficients of the resulting height map R are recorded line by line in a wav file. Since the array R is square, it can be constructed not only with respect to rows, but also with respect to columns. It should also be noted that in order to avoid an edge effect, each row of R should be weighted in the window

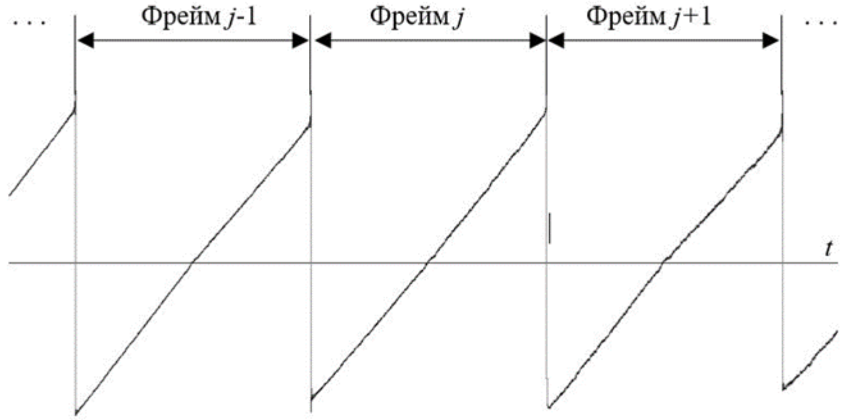

Fig. 2. Example of the arrangement of frames in a file VT

For the experimental part with sound synthesis, the authors used the resources of the Research and Methods Laboratory *Music Computer Technologists* of the Herzen State Pedagogical University of Russia [7; 8]. In the course of the experiments, software models obtained by the authors using the Csound language and various hardware MIDI controllers were used. Some of the synthesizer models were obtained during practical training in the framework of the specialized course *Sound Timbral Programming*, the elements of which are taught during the preparation of bachelors and masters studying in the field of *Information Systems and Technologies* as part of the development of educational profiles *Information Technologies in Music and Sound Design* and *Digital Technologies in Music and Sound Design.*

IV. Conclusion

Using two-dimensional wavelet synthesis, it becomes possible to automate the creation of VTS, while ensuring controllability through the use of a seed array. The user gets the opportunity to select nodes of the wavelet synthesis tree, as well as set the dynamics of noise filling, which opens up wide opportunities for creating unusual and complex sound textures. Two-dimensional DFT provides new methods and approaches to sound synthesis, opening up new horizons for composers and sound designers to experiment and create original timbres.

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