Client/server system for managing an audio and video archive for unique Bulgarian bells*

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Abstract: - In this paper, a client/server system for the management of data and its extraction from an audio and video archive for unique Bulgarian bells is proposed. The realized system provides users the possibility of accessing information about different characteristics of the bells, according to their specific interests. The architecture of the Web based system is described as well as the services offered. The authors present the structure of the created database that stores the necessary information. A client application is realized with MatLab, providing the possibility for searching the bells from the archive according to their sound.

Key-Words: - Web technologies, database, client/server system, audio/video archive, bell, sound, digital signal processing, spectral analysis, digital filter, wavelet analysis, fractal dimension

1 Introduction

The communication and information technologies have, in recent years, been introduced to all areas of public life. The development of services, which give possibilities for maintenance and dissemination of information, obtained from the examination of a national cultural – historical inheritance of the separate peoples is very important and actual.

The aim of the presented paper is to propose a Web based approach to managing an audio and video archive for unique Bulgarian bells. Currently, we are working on a project "Research and Identification of Valuable Bells of the Historic and Culture Heritage of Bulgaria and Development of Audio and Video Archive with Advanced Technologies*", whose purpose is to study and identify several dozen of the most valuable bells in our churches, monasteries and museums. An audio and video archive is developed by using advanced technologies for analysis, reservation and data protection, and it contains:

- the main bells' characteristics: design, form, type, geometric size, decorative and artistic scheme, weight, material, state, characteristics of chime, data about the producer and owner of the bell, estimation of its historical value;
- digital photos and video recordings of the bells while being tolled;
- the frequency spectrum of the bells during a stroke;
- the bells' frequency spectrum after transitive process;
- charts representing the sound fade by time, sound stream, sound pressure and other acoustic characteristics.

The developed client/server system provides users the possibility of accessing information about different characteristics of the bells according to their specific interests. We describe the architecture of the Web based system and the services, included in its realization. We also represent the structure of the created database that stores the necessary information. The data of the archive is accessible

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from [16]. In addition a client application is realized with MatLab which provides the possibility for searching bells from the archive according to their sound. Some preliminary ideas from the present paper were reported in [18, 19].

The rest of the paper is organized as follows. Section 2 contains a description of the architecture and the interface of the Web based system. In Section 3, we represent the entity-relationship model (*ER model*) of the database that stores information about the bells. We produce the relational tables obtained after the transformation of the created ER model into relational. These relations are realized by using the database management system Microsoft SQL Server. Section 4 contains a description of applied approach to searching the bells according to their sound by using the previously found partials.

2 Overview of the Web based system architecture

The architecture of the developed Web based client/server system is created on the base of the three-layer information model (fig. 1).

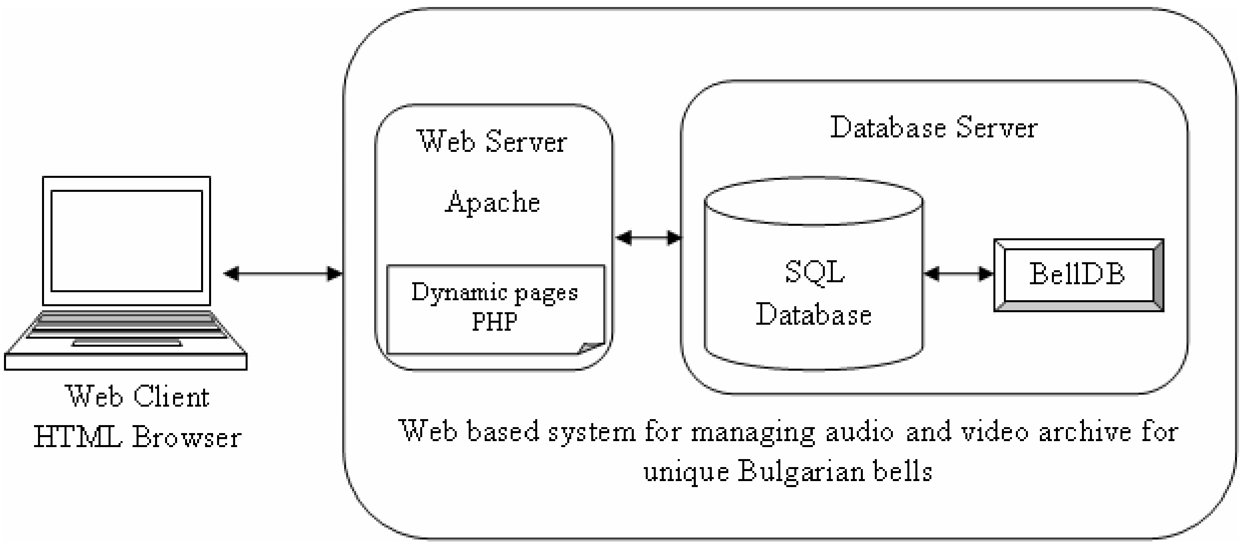

Figure 1: *The architecture of the system*

The layer for data processing is realized by using the database management system. For the present system we use Microsoft SQL Server, which allows efficient storage of large databases and provides functionality for accessing the data [1, 5, 6, 8, 9].

The `BellDB` database serves for storage and processing the data for the bells and the objects, in which they are located. Information on the name of the monastery, church, museum, castle, geographic place for the objects, etc. is maintained. In addition, description, historical notes, digital photos, sound and video files are implemented.

The application provides possibilities to insert information about bell's unique number, location, type, geometrical dimensions, weight, material, condition, creator, year or period of creation, description, estimation of its historical value, digital photos, sound and video files, spectrograms.

The basic functions of the database include:

- addition of a new object in the database;
- edition of the data about the objects;
- deletion of objects from the database;
- browsing the data for the objects;
- addition of a new bell in the database;
- edition of the data about the bells;
- deletion of bells from the database;
- browsing the data for the bells;
- searching by different criteria.

The application level is realized by using Web server. It provides the possibility for dynamic generation of the information. Apache is chosen as a Web server and PHP (*Hypertext Preprocessor*) for program modules development from the server side [11].

Forms for insertion and updating of the data are realized. Their purpose is to facilitate actualization of information. Besides this, the application allows the execution of different queries, which perform searching by an arbitrary combination of given searching criteria. Each user can search by filling in text boxes and/or list boxes which correspond to the chosen characteristics of the bells, stored in the database. The results from each query are presented in the format, convenient for the end user.

The client part of the system presents the data for users by using convenient browser (such as Internet Explorer, Mozilla Firefox, etc.). The possibility of changing the language of the interface (Bulgarian, English) is there (fig. 2).

Figure 2: *Page from the application [16]*

JavaScript function is realized. It validates the data during their insertion and modification [15, 17]. In addition, the developed system takes advantage of AJAX (*Asynchronous JavaScript and XML*) that improves the user's interface of the Internet applications. This technique provides the possibility for automatic numbering of each bell after indication of the object (monastery, museum, etc.) where the bell is located. The unique number consists of the phone code of the place, the number of the object and the serial number of the bell in the same object.

3 Modeling of data

The model of the `BellDB` database, in keeping with the entity-relationship model (*ER model*), introduced in [2], is shown in Figure 3. The objects of the ER model are depicted as rectangles, their attributes as ellipsis, and the relations as rhombus [4].

The database is realized by means of the database management system Microsoft SQL Server. The relevant relational tables are shown on Figure 4.

The structure of the database is defined to provide the best efficiency of the most frequently used operations – insertion, updating, data searching.

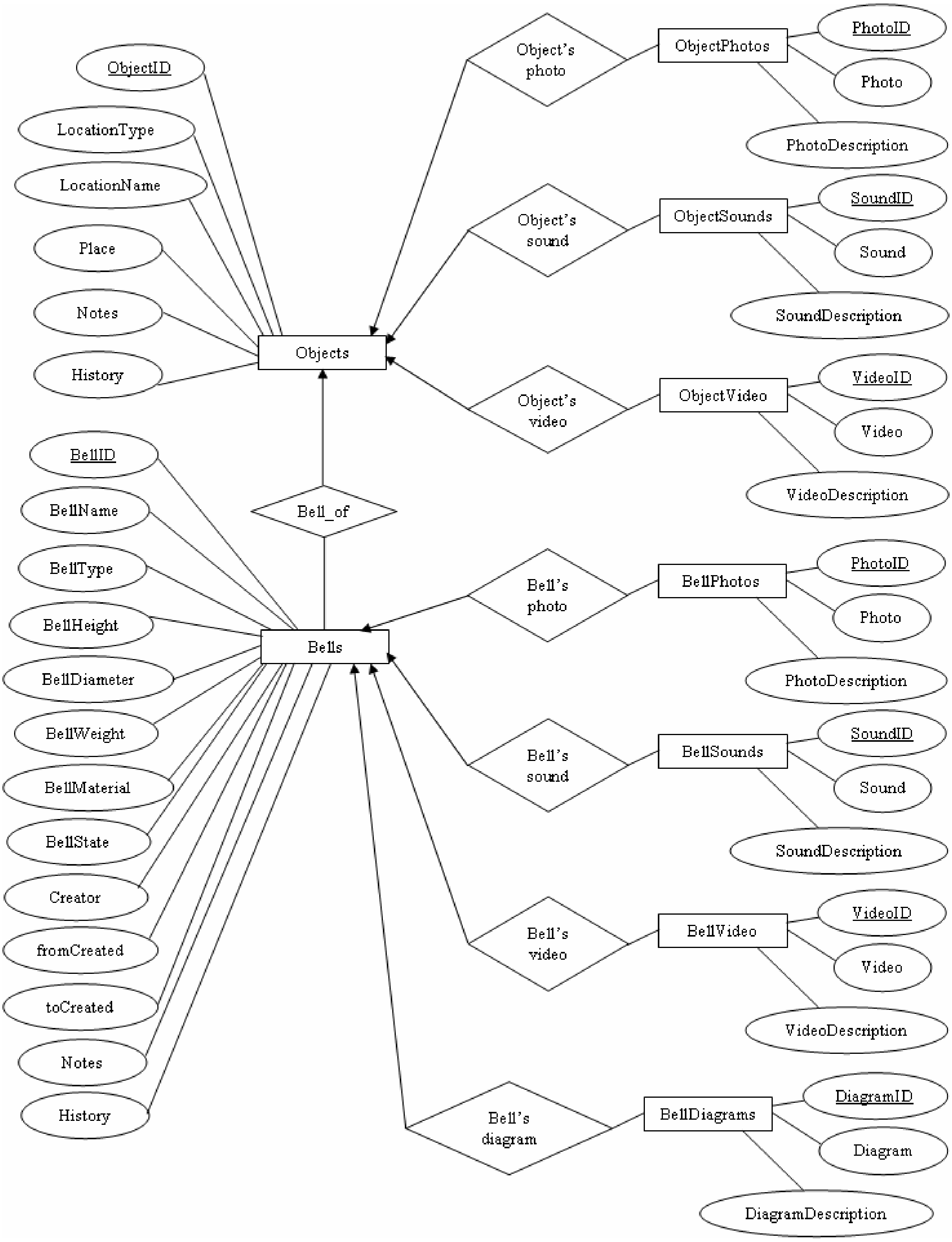

Figure 3: *ER diagram of* `BellDB` *database*

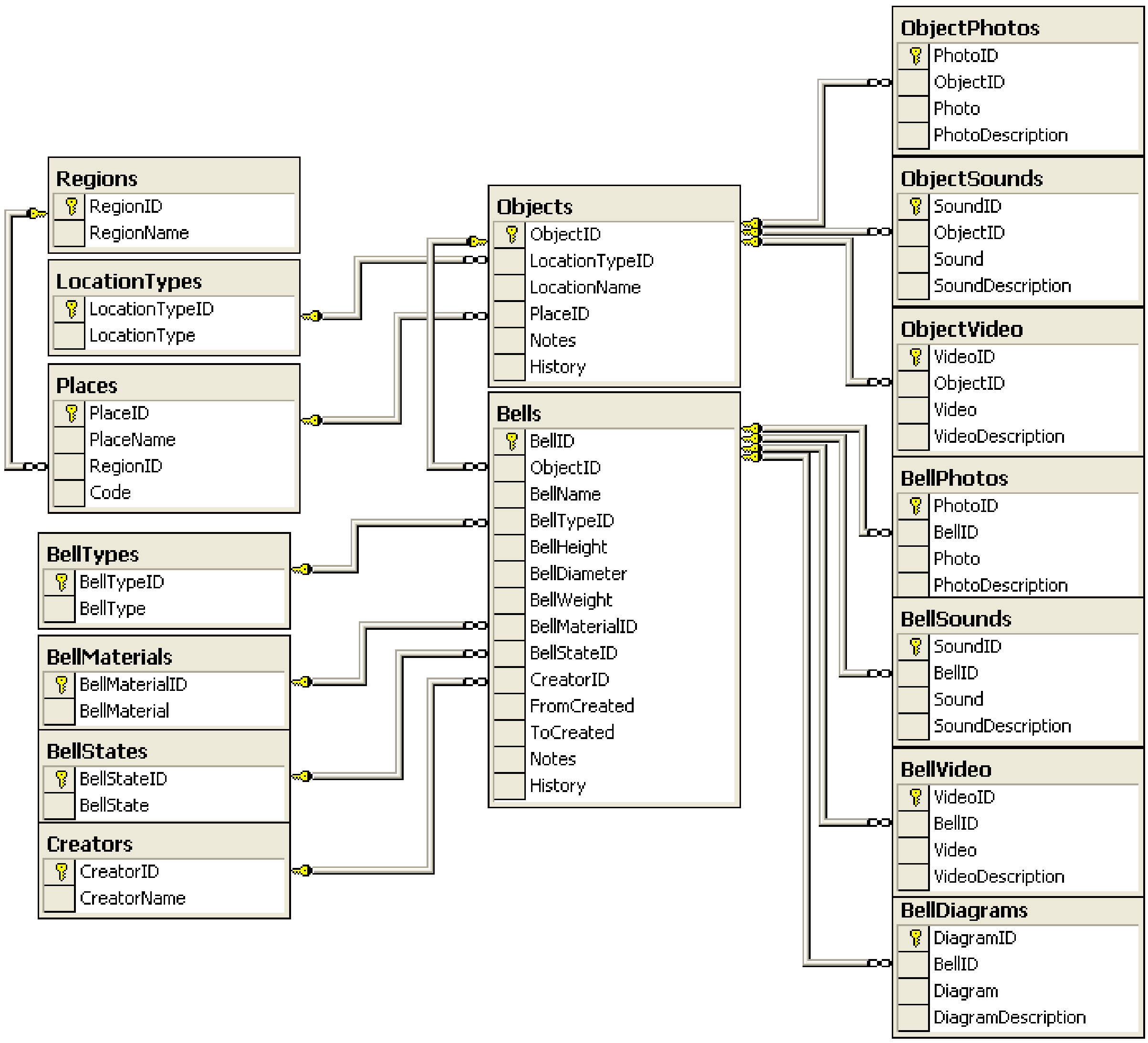

Figure 4: *Relational model of `BellDB` database*

4 Client application for analysis of bell sounds

A client application is realized with MatLab [10, 20] for analysis of the sounds of the bells by using various methods for digital signal processing (DSP) – spectral analysis by means of the Discrete Fourier Transform (DFT), digital filtering, wavelet analysis. The partials of the sounds of the bells are found by applying the digital filter. The data are visualized by using spectrogram, 3D spectrogram, etc.

4.1 Methods for digital signal processing, used in the application for analysis of bell sounds

In the next subsections of the paper, the different methods for digital signal processing used in the application for analysis of bell sounds, are represented.

4.1.1 Spectral analysis by means of the Discrete Fourier Transform

The Discrete Fourier Transform of the signal x is defined by the following way [12, 13, 14]:

$$X(w_k) = \sum_{n=0}^{N-1} x(t_n) e^{-j w_k t_n}, \; k = 0, 1, \ldots, N-1,$$

where

$x(t_n)$ is the input signal amplitude at time t_n (in seconds);

t_n is the n-th sampling instant in seconds, $t_n = nT$, n is an integer, for which $n \geq 0$;

T is the sampling interval (in seconds);

$X(w_k)$ is the spectrum of x at frequency w_k;

w_k is the k-th frequency sample (in radians per second), $w_k = k\Omega$;

Ω is the radian-frequency sampling interval, $\Omega = \frac{2\pi}{NT}$;

f_s is the sampling rate (in samples per second or Hertz (Hz)), $f_s = \frac{1}{T}$;

N is the number of the time samples or the number of the frequency samples.

Figure 6 shows the spectral plot of the sound of the bell in the Kilifarevo Monastery "St. Nativity of Virgin Mary", Kilifarevo, Bulgaria. The waveform of this sound is presented on Figure 5.

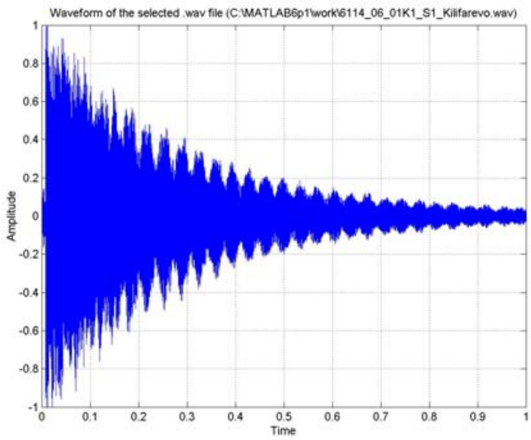

Figure 5: *Waveform*

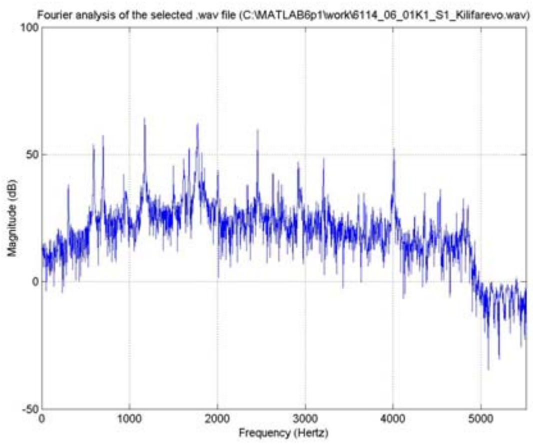

Figure 6: *Spectral plot*

The intensity of the partials over time is shown on the spectrogram (sonogram) on Figure 7.

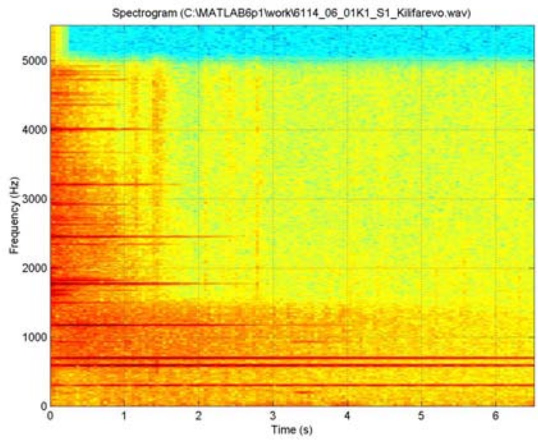

Figure 7: *Spectrogram*

The three-dimensional graph provides a clearer view of the change of the amplitude of the various partials of the sound (fig. 8).

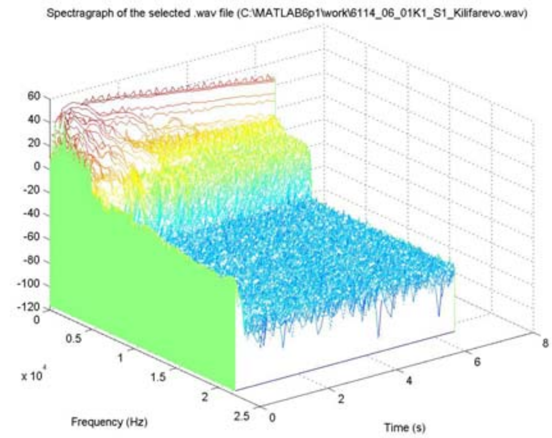

Figure 8: *3D spectrogram*

4.1.2. Digital filter

An autoregressive filter transfer function is defined by the following way:

$$H(z) = \frac{1}{1 + \sum_{k=1}^{p} a_k z^{-k}},$$

where p is the order of the filter;

a_k are the coefficients of the filter.

There exist several methods to compute the coefficients a_k as: autocorrelation method, Burg method, modified covariance method.

In order to find the frequencies of the partials from the filter, we consider the coefficients of the filter as coefficients of a polynomial and we compute the roots of the polynomial.

Figure 9 depicts the found partials of the sound (fig. 5) of the bell in the Kilifarevo Monastery "St. Nativity of Virgin Mary", Kilifarevo, Bulgaria.

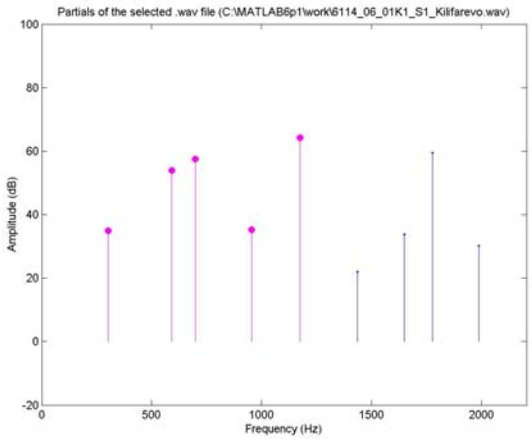

Figure 9: *Partials*

The opportunities of MatLab for building the convenient graphical interface are utilized (fig. 10).

4.1.3 Wavelet analysis

In order to determine the pitches of the sound of a bell over the time, we apply the method described in [7]. The fast lifting wavelet transform (FLWT) is employed, by using the Haar wavelet, where the approximation signal $a_k(t_n)$ and the detail signal $d_k(t_n)$ are obtained by the following way:

$$d_0(t_n) = x(t_{2n+1}),$$
$$a_0(t_n) = x(t_{2n}),$$
$$d_k(t_n) = d_{k-1}(t_n) - a_{k-1}(t_n),$$
$$a_k(t_n) = a_{k-1}(t_n) + \frac{d_k(t_n)}{2}.$$

Performing the FLWT with the Haar wavelet on the signal is mathematically equivalent to performing a low-pass operation followed by down-sampling on the signal to generate the approximation signal, and performing a high-pass operation followed by down-sampling on the signal to generate the detail signal. The repeated low-pass operations reduce the noise levels in the signal being analysed, thus supporting determine the pitches. The peaks of the successive wavelet approximations are detected and by this way the pitches of the signal are determined.

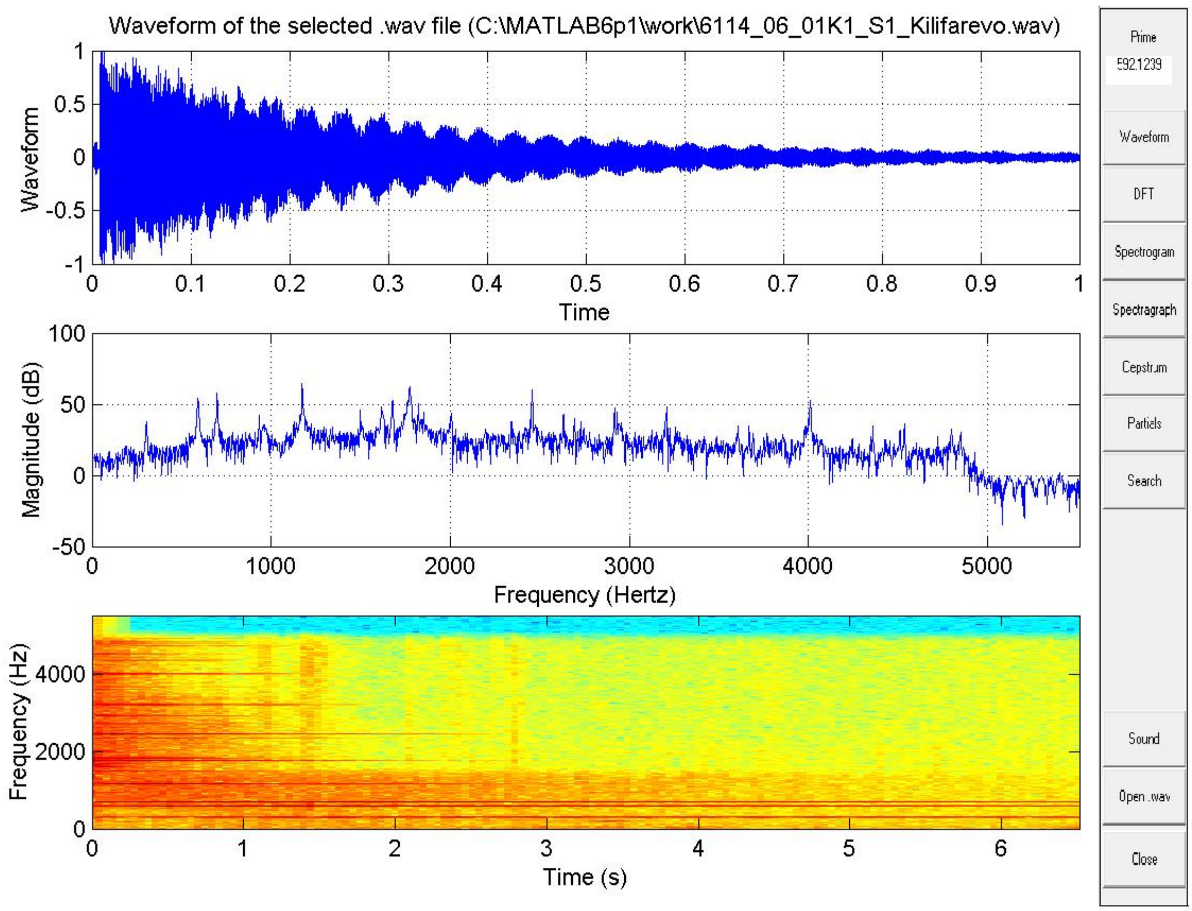

Figure 10: *Graphical interface of the application*

Figure 11 depicts the found pitches of the sound (fig. 5) of the bell in the Kilifarevo Monastery "St. Nativity of Virgin Mary", Kilifarevo, Bulgaria.

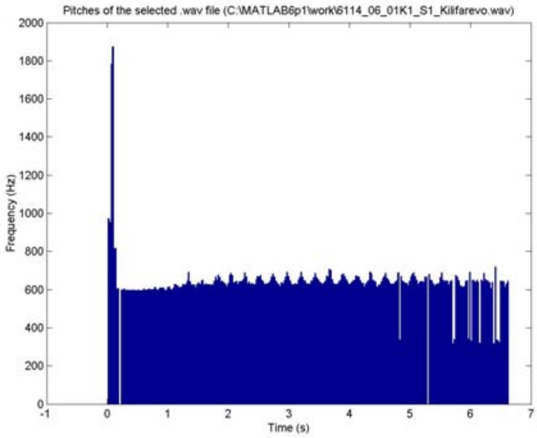

Figure 11: *Pitches*

4.2 Searching the bells according to their sound by using the partials

The MatLab application provides the possibility for searching the bells according to their sound. The comparison is performed on the base of the found partials. The information about the previously calculated partials of the sounds of the bells is stored in the archive.

During the searching process the difference between the frequencies of the corresponding partials is verified whether it exceeds a value, previously given from the user (fig. 12). For comparison seven parameters are applied: first five partials; the fractal dimension [3] of the frequency spectrum graph (fig. 13) and the fractal dimension of the 3D spectrogram of the sound of the searched bell. On the one hand the last two parameters provide the possibility to differentiate between the sounds of bells with close values of the partials and on the other hand to retrieve bells, which sound similar.

The realization of searching includes creation of a stored procedure, by using Transact-SQL [9] to increase the performance.

Tables 1 and 2 illustrate a comparison between samples of two strikes of one bell (6114_06_01) of the Kilifarevo Monastery "St. Nativity of Virgin Mary", Kilifarevo, Bulgaria.

Partial	Frequency	Amplitude	Ratio fi/f1
1	302.243	34.948	1.000
2	592.124	53.895	1.959
3	698.080	57.539	2.310
4	954.829	35.236	3.159
5	1174.523	64.233	3.886
6	1435.637	22.072	4.750
7	1648.431	33.699	5.454
8	1775.977	59.507	5.876
9	1987.498	30.218	6.576
10	2267.458	24.582	7.502

Table 1: *Partials, obtained from the first strike of the bell in the Kilifarevo Monastery "St. Nativity of Virgin Mary", Kilifarevo, Bulgaria*

Partial	Frequency	Amplitude	Ratio fi/f1
1	301.743	31.024	1.000
2	592.466	48.769	1.963
3	698.090	57.217	2.314
4	950.793	25.261	3.151
5	1174.435	60.931	3.892
6	1453.213	23.821	4.816
7	1648.266	28.519	5.462
8	1774.781	65.925	5.882
9	2001.135	32.750	6.632
10	2287.602	26.836	7.581

Table 2: *Partials, obtained from the second strike of the bell in the Kilifarevo Monastery "St. Nativity of Virgin Mary", Kilifarevo, Bulgaria*

Figure 12: *Searching the bell according to its sound*

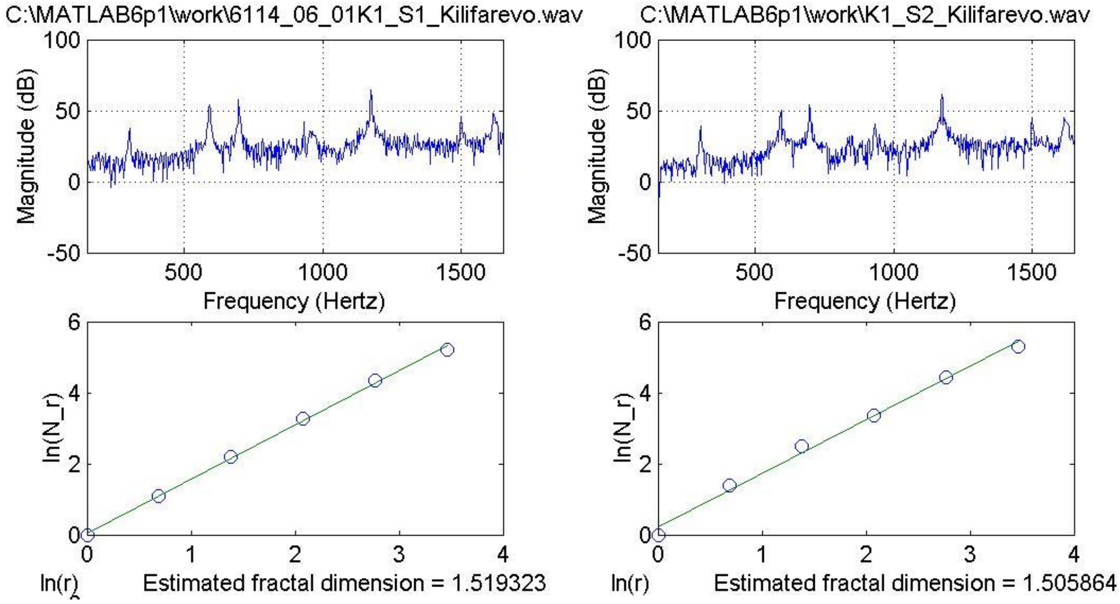

Figure 13: *Two strikes of the same bell in the Kilifarevo Monastery "St. Nativity of Virgin Mary", Kilifarevo, Bulgaria*

5 Conclusion

In this paper, the automated system is proposed. It explores a Web based approach to managing an audio and video archive for unique Bulgarian bells. The created database contains information about different characteristics of the investigated bells and it is realized on Microsoft SQL Server. The interface is developed by means that allow establishing a connection with the database of standard Web browsers. This gives users the possibility of easily accessing detailed information about unique bells from our national culture-historical heritage.

Various methods for digital signal processing are applied. Searching the bells from the archive according to their sound by using the found partials is realized.

Our future work includes development of an application for mining the constraint-based association rules, which allows the association analysis of the different characteristics of the bells.

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