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The Use of Combinatorial Methods for Sound Scanning of Objects

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Abstract. In article considers application of combinatorial methods for research of sound images scan by the medium of integer sequences – ideal ring bundles as comfortable mathematical models for synthesis and optimization of systems with non-uniform structure. By using combinatorial approaches quality of methods based on the passage of sound signals through the tissues can be significantly improved. Studies show that the use of integer sequences based on the ideal ring bundles in information conversion tasks ensures simplicity of hardware application.

Key words: ideal ring bundle; non-uniform structure, sound diagnostic; sound generator; sound scanning.

INTRODUCTION

In recent years, more and more attention is paid to various methods of diagnostics in medicine: iridodiagnosis, nuclear magnetic resonance, echolocation, and others. First of all, you need to develop methods that do not affect the status of the object under investigation.

The value of each method depends on many parameters: objectivity, speed, accuracy. Secondary but also important parameters are the cost, mobility, independence of the method from the raw materials [1, 2, 5].

By using combinatorial approaches quality of methods based on the passage of sound signals through the tissues can be significantly improved. From our point of view, methods of sound probing are valuable also because they can be used not only in the field of medicine, but also in geology, construction, robotics and other industries [3, 4, 6].

FORMULATION OF THE PROBLEM

Let's consider the object, through which a sound wave is transmitted (Fig. 1). At point A it receives an audio signal that is represented as adding waves received from the acoustic conductor that is connected with sound generator. Since some cyclic pulse sequence arrives from the generator, then at the point A will be obtained the sum of these sequences, shifted by one time step [7, 10, 11].

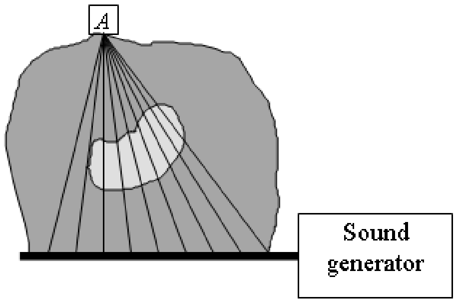

Fig. 1. Acoustic sounding scheme

In this case, if the damping of each wave path is different, and there is some sign on which at point A it is possible to distinguish the passage of the wave in each of the paths, then you can get information on the size of the acoustic noise that has encountered in each path.

Here, in this place, most of the existing algorithms assume a big mistake. The reliability of such implementation strongly depends on the nature of the distribution of the smallest significant bit in the container and in the message. And in the vast majority of cases, these distributions are different in different bits. And in pictures built using binary codes in the younger bits there will be roughly even distribution of "0" and "1", and such an introduction will be noticeable even to the eye. Therefore, an important task is the choice of distribution of the smallest significant bit [8, 9, 12].

To solve the problem, it is first necessary to synthesize such a signal of the generator, which would differ in the shift [13, 15]. If you imagine a wave as $\{1, 0\}$ -sequence, then there are many such signals. If you select an arbitrary random signal length *N* of time steps, which, when shifting to step dt is not repeated, then the problem is reduced to the solution of the linear equation:

$$S \times X = F \ , \tag{1}$$

where S – is a matrix of size $N \times N$ signal $\{1, 0\}$, which is written in its first column. Each next column j of this matrix is cyclically shifted on j stacks down relative to the first column. X – matrix of attenuation size N, which characterizes the size of the acoustic noise in each direction of sound propagation, F is the matrix of the received signal at point A the size of N. If the reflection and external interference are not taken into account, then the signal received by the sensor, fixed in matrix F, should also be repeated cyclically.

Since equation (1) should be done for different points of the investigated object, the solutions of (1) must be present in the form of:

$$X = S^{-1} \times F, \tag{2}$$

where S is an inverse matrix. In this case if the problem is in the size of 1000 time steps (very few), the inverse matrix should be 1000×1000, which firstly lead to unnecessarily high loss of memory, and the secondly will lose accuracy of calculations, since numerical methods require at least $N(N-1)$ multiplication and division operations.

Therefore, it is necessary to find such a kind of probing signal, which will allow to get analytical elements of the matrix S^{-1} and in addition, this expression for each of its elements should not be too complicated [16, 18].

SOLVING THE PROBLEM KEY

If, for the distance between the impulses of the probe signal, the ideal ring bundles of order M are chosen, then the value of $N = M(M-1)+1$ [19, 20, 29]. Ideal ring bundle is the set of positive integers, arranged as divisions on the ruler in the way that the distance between any two divisions is unique.

In other words, along the whole line, we cannot find two numbers with difference between them repeated twice [14, 23, 26].

The ideal ring bundle (IRB) is a sequence of $K_N = (k_1, k_2, ..., k_N)$ numbers in which all possible circular sums exhaust the value from the row of natural numbers $1, 2, ..., S_N$, where [14]:

$$S_N = N(N-1). \tag{3}$$

A binary code constructed in accordance with the ideal ring ratio $r(M)$ with a shift to any number of steps in the range from $[1, N(N-1)]$ has exactly one matching of units between the shifted and the initial combination [23, 24].

This property makes it possible to construct an inverse matrix based on such an algorithm:

the matrix S is transposed;

symbols $\{1\}$ are replaced by $1/M$;

symbols $\{0\}$ are replaced by $(-1)/(M(M-1))$.

Consider, for example, the ideal ring bundle: $1, 3, 2, 7$ [16, 17, 18]. With such parameters, the size of the matrix S will be: $N = 4 \times (4-1)+1 = 13$. The cyclic signal generated by the generator should be: {1100101000000}, where the distance between impulses corresponds to the ideal ring ratio of $1, 3, 2, 7$. By the given algorithm, the form of the matrices S and S^{-1} will be the following:

S =

1	0	0	0	0	0	0	1	0	1	0	0	1
1	1	0	0	0	0	0	0	1	0	1	0	0
0	1	1	0	0	0	0	0	0	1	0	1	0
0	0	1	1	0	0	0	0	0	0	1	0	1
1	0	0	1	1	0	0	0	0	0	0	1	0
0	1	0	0	1	1	0	0	0	0	0	0	1
1	0	1	0	0	1	1	0	0	0	0	0	0
0	1	0	1	0	0	1	1	0	0	0	0	0
0	0	1	0	1	0	0	1	1	0	0	0	0
0	0	0	1	0	1	0	0	1	1	0	0	0
0	0	0	0	1	0	1	0	0	1	1	0	0
0	0	0	0	0	1	0	1	0	0	1	1	0
0	0	0	0	0	0	1	0	1	0	0	1	1

In the following symbols $p = 1/4$, $k = -1/12$.

S^{-1} =

p	p	k	k	p	k	p	k	k	k	k	k	k
k	p	p	k	k	p	k	p	k	k	k	k	k
k	k	p	p	k	k	p	k	p	k	k	k	k
k	k	k	p	p	k	k	p	k	p	k	k	k
k	k	k	k	p	p	k	k	p	k	p	k	k
k	k	k	k	k	p	p	k	k	p	k	p	k
k	k	k	k	k	k	p	p	k	k	p	k	p
p	k	k	k	k	k	k	p	p	k	k	p	k
k	p	k	k	k	k	k	k	p	p	k	k	p
p	k	p	k	k	k	k	k	k	p	p	k	k
k	p	k	p	k	k	k	k	k	k	p	p	k
k	k	p	k	p	k	k	k	k	k	k	p	p
p	k	k	p	k	p	k	k	k	k	k	k	p

Each element of the inverse matrix can be calculated from the cyclic sequence q, which is obtained from the sequence of the sound generator according to the above algorithm:

$$S_{ij}^{-1} = q_l, \tag{4}$$

where $q = p, p, k, k, p, k, p, k, k, k, k, k, k$ and $l = \mathrm{mod}\, N(N+j-i)$.

Formally, the combinatorial properties of the codes underlying the matrices S and S^{-1} can be expressed as predicates over the lists in terms of logic of the 1st order.

The reproduction of the sound image, from our point of view, must take several steps:

– using the Figure 1 scheme, the fixation of audio signals at points located on the surface of the object is performed. This can be done by using the laws of laser wave interference, as it is done in holography;
– the received and recorded signals must be translated into the form of attenuation matrices in each direction of the propagation of acoustic waves. This step is reduced to the operation of

multiplication of matrices, (3) whose elements are calculated by the formula (4);

- matrix of attenuation must be transformed into a matrix $\{x_{ijk}\}$ of the structure of the object itself. This step is the most time-consuming and requires some assumptions which will be discussed further;
- the last step is the visualization of the image on the screen of your computer, which in itself is a separate engineering problem that we won't investigate.

For transformation of sound signal attenuation matrices in a matrix structure against of the object let's consider the scheme of sound waves routing, shown in Fig. 2.

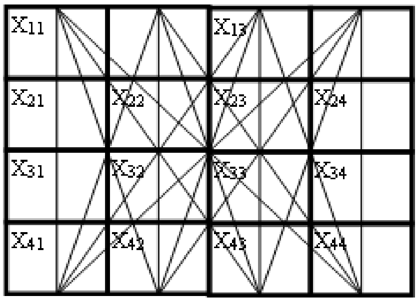

Fig. 2. A chart of passing of acoustic waves is through the object of cellular structure

To solve the problem, one must make the following assumptions:

- the object has a cell structure;
- fading factor $\{x_{ijk}\}$ of acoustic signals in the cell (i, j, k) is constant for the whole cell;
- each cell is a parallelepiped.

According to the latest assumption, the attenuation of the energy of each beam passing through the cell at an arbitrary angle is proportional to the length of the segment that is cut off at the beam by the edges of the cell.

Thus, if each cell is a parallelepiped, then the measuring scheme "automatically" sets the matrix of the lengths of the rays L in the middle of each cell [27, 28, 30].

As can be seen from Fig. 2, the number of cells should be equal to the number of equations. Only in this case one can find the absorption factor of each cell [21, 22, 25].

CONCLUSIONS

During implementation works were the collected and studied materials about technologies of voice scan-out of objects by means of ideal ring bundles.

A practical value the got results will allow optimally to choose the signal of voice generator which will provide more effective work of devices of voice scan-out.

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