Здійснено аналіз характерних особливостей проектування 3D-реклами. З'ясовано, що оскільки вхідна інформація стосовно вирішення задачі структуризації етапів створення 3D-рекламної поліграфічної продукції носить якісний характер, то для її вирішення варто використовувати експертний підхід. У якості експертів виступили технологи провідних українських видавничо-поліграфічних підприємств. За допомогою використання експертного підходу на основі цих особливостей сформовано структуризацію етапів розроблення 3D-рекламної поліграфічної продукції. Перелік і зміст параметрів такої структуризації обумовлюються конкретними видами 3D-реклами.

Для врахування окремих категорії і властивостей 3D-реклами розроблено технологію вибору варіантів реалізації 3D-рекламних інсталяцій. Ця технологія створена на основі використання інструментарію імітаційного моделювання. Вибір прийнятних альтернатив здійснюється на основі використання запропонованої базової рекурентної схеми. Запропоновано перелік оціночних параметрів, що впливають на ефективність рекламних інсталяцій і дозволяють оцінити якість створеного засобами каліграфії логотипу.

Розроблено математичну модель для створення проекції рекламного зображення. Ця модель надає такі можливості графічної обробки ілюстрацій, як спотворення початкового 3D-рекламного зображення по горизонталі, спотворення початкового 3D-рекламного зображення по вертикалі, перетворення координати пікселя в потрібному напрямку, обчислення розмірів 3D-рекламного зображення. Базуючись на розробленій математичній моделі була створена програма, яка дозволяє для будь-якого зображення формувати його спотворений вигляд, який можна наносити на поверхню. Методика створення 3D-реклами була реалізована в програмному продукті BPWin. Програмна реалізація дозволяє здійснювати оптимізацію процесу розробки 3D-реклами

Ключові слова: 3D-рекламна поліграфічна продукція, рекламна інсталяція, рекурентна схема, логотип, спотворене зображення

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DEVELOPMENT OF A METHOD FOR THE CREATION OF 3D ADVERTISING PRINTING PRODUCTS

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1. Introduction

In a post-industrial economy, advertising is an instrument that has a primary impact on public consciousness. Advertising helps consumers to make decisions regarding the need to purchase a particular type of products. Manufacturers, through advertising, make decisions regarding the expediency of switching to the production of new products, new markets, etc.

Good advertising ideas, catchy advertising campaigns are projected on the basis of accounting many factors that stimulate the sale of goods and services. One of the factors is the skillful presentation of products, which is based on the correct and unusual design of advertising. Due to the intensive informatization of society, non-standard advertising, which mainly manifests itself in the form of 3D images gives significant competitive advantages. Nonstandardity ensures the following principles of 3D advertising, such as going beyond the limits of advertising surfaces without violating the rules, the presence of three-dimensional shapes, shiny objects and moving objects, the inclusion of glowing neon elements. As a result, the most pressing challenge is to create 3D advertising printing products.

Typically, the development of 3D advertising printing products is based on the subjective preferences of engineers and designers, taking into account experience and intuition. But such a subjective approach is permissible only in small-scale orders with a limited range of potential consumers. In an attempt to go beyond these limitations, there are objective difficulties in expanding the scope of advertising installations and improving the efficiency of the process of creating 3D advertising printing products. These difficulties relate to the lack of tools, which allows you to optimize the process of developing a 3D advertising image, in particular, to correctly distort and build a visual three-dimensional illustration.

Bridging over these difficulties should be done by developing a methodology for designing 3D advertising printing

products. The central link of this methodology is a mathematical model, through which you can correctly distort and build an advertising image.

Creation of the specified methodology will provide effective tools for improvement of information provision of the publishing and printing industry. In addition, the development of a technique for creating 3D advertising printing products will create conditions for optimizing the process of designing outdoor advertising in the form of advertising installations and obtaining certain effects from the introduction into production. In particular, the productivity of the technological process of prepress preparation can be increased and its cost can be reduced.

2. Literature review and problem statement

The large-scale distribution of three-dimensional advertising installations causes the emergence of a relevant scientific interest in the problems of creating 3D advertising printing products. Thus, the research work [1] offers the choice of optimal animation technology according to the required specification for advertising products. As a practical implementation, an advertising animated video was created using the chosen methodology. But this work does not take into account the specifics of creating a printed 3D advertising product.

The research work [2] examines the possibilities of using 3D printing to create various types of advertising installations. Particular attention is paid to the main trends of 3D printing. However, this work does not provide opportunities for systematizing the entire variety of advertising installations based on the appropriate classification.

The research work is devoted to the study of the effectiveness and convincingness of stereoscopic 3D advertising [3]. In this work, cognitive and behavioral effects of 3D advertising are highlighted, and also ideas about 3D images in advertising are systematized. Five variables are proposed, which can determine the effectiveness of creating a 3D advertising product – memory, aesthetics, brand awareness, credibility and immersion. However, this research work does not include a description of the sequence of interaction with the customer during the development of 3D advertising.

In the research work [4], an approach to image segmentation in the 3D range through a gradient method was proposed. Based on this approach, you can improve the segmentation of a 3D advertising image based on edge detection techniques. But this approach lacks a mathematical model for creating an advertising image.

A detailed analysis of the spectrum of possible distribution strategies for very large algorithms for deconvolution of a three-dimensional image is proposed in the work [5]. At the same time, the consideration of the problem of deconvolution is general and is intended for the reconstruction of a three-dimensional spatial-spectral image. However, in this work there is no consideration of distortion of the original advertising image in different projections.

In the work [6], emphasis is placed on the perception of visual advertising by consumers from attention to distraction, persuasion, liking and memorization. Accordingly, certain technologies of 3D advertising product development are offered. But this work does not take into account the complexity of creating 3D advertising in the form of several stages.

The question of the use of 3D advertising products, such as digital advertising, is considered in the research [7]. In this research, the basic technologies of digital advertising production are systematized, the comparative characteristic is given, the effectiveness of digital advertising is analyzed. However, this study does not allow us to draw conclusions as to how to distort and construct a 3D advertising image correctly.

The research work [8] systematized the main trends in the design of advertising environments of expanded reality. Particular attention is paid to the effects of innovation for the development of 3D advertising installations. Possible ways of improving the technologies of 3D advertising creation are analyzed. However, the issue of determining the criteria for assessing the effectiveness of 3D advertising installation development in this study remains open.

In the work [9], an interdisciplinary literature review (marketing, information systems, and human-computer interaction) is proposed to determine the most appropriate conditions for the use of 3D visualization in advertising. However, this work does not describe the main stages of the business process of creating a 3D advertising product.

The research work [10] examines the possibilities of screen printing for the development of 3D advertising. However, this work does not take into account the complex combination of different types of printing for the creation of advertising installations.

The technology of forming color shades in the process of creating a 3D advertising product is given in the work [11]. This study proposes factors for improving the image of advertising based on the optimization of color schemes. But this work does not provide guidance on the conversion of coordinates of pixels of advertising images.

Thus, the research analysis of the problems of creating 3D advertising shows that there is no holistic, scientifically based methodology for the creation of 3D advertising printing products in the works under consideration.

3. The aim and objectives of the study

The aim of the work is to develop a methodology for creating 3D advertising printing products. This will enable the improvement of the information support of publishing activities by developing a mathematical model for creating a projection of an advertising image taking into account the mechanism of distortion of the original image.

To achieve this aim, the following objectives were accomplished:

– to structure the stages of development of 3D advertising printing products;

– to develop a simulation model for choosing the options for implementation of advertising installations;

– to design the technology of creating a logo of an advertising image by means of calligraphy;

– to develop a mathematical model for creating a projection of an advertising image.

4. Development of the technique of creating 3D advertising printing products

4. 1. Structuring the stages of development of 3D advertising printing products

Designing a technique for creating a 3D advertising product involves the formation of a sequence of actions in

relation to the development of high-quality products and satisfaction of the end-user needs.

Since the input information concerning the task of structuring the stages of creation of 3D advertising printing products is of a qualitative nature, an expert approach should be used for its solution.

As experts, the technologists of such leading publishing and printing companies as Factor-Print Ltd., Folio Publishing Ltd., Balance-Print LLC (Kharkiv, Ukraine) were presented. In agreement with the experts, the main stages of creating 3D advertising were identified, which are summarized in Table 1.

Table 1

Main stages of the method of creating 3D advertising

Name of the research stages	Task of the stages	Subtasks in the context of each of the stages
Generation of the idea of an advertising project	Creating an idea	formation of the purpose of advertising; analysis of the advertised object; target audience analysis; generalization of data
	Development of the concept	creating graphic layouts; definition of the degree of conformity, the purpose of the concept of the advertising project; selection of options for the implementation of advertising installations
	Agreement with the customer	discussion of the advertising concept; making adjustments; decision making by the customer
Development of the design of an advertising project	Selection of illustrations	subject analysis; search of illustrations relevant to the subject; synthesis of illustrations; image implementation in a graphic editor
	Designing a technology for creating a logo of an advertising image by means of calligraphy	generation of ideas for creating a logo by means of calligraphy; development of a logo by means of calligraphy
Realization of the advertising project	Definition of parameters for image distortion	viewing angle analysis; analysis of basic data for image distortion; creating a graphic projection
	Selection of the place of application	discussion of the desired place with the customer; advertising effectiveness analysis
	Selection of the basis for design	definition of the type of predicted basis
	Verification of the formulated requirements to the basis	checking for cleanliness; checking for dryness; checking for smoothness; checking for anti-slip
	Cleaning of the surface	general cleaning; solvent cleaning; removal of liquid residues
	Creating a film	determination of the type of film; preparation of material; technological realization
	Sticking of the film	determination of the method of sticking; surface inspection; film sticking
	Fixing the film on the surface	treatment with protective materials
Analysis of the economic effectiveness of the advertising project	Determination of the effect of the created ad	investigation of the reaction of the target audience to the created advertising on the surface

The proposed stages of the methodology of creating 3D advertising allow you to structure the design process of advertising installations. The list and content of the parameters of such structuring are conditioned by specific options of realization of 3D advertising installations.

4. 2. Modeling the choice of options for the implementation of advertising installations

According to Table 1, at the stage of generating the idea of an advertising project within the framework of the task of developing a concept, you should make a choice of options for the implementation of 3D advertising installations. Similar to the processes of formation and selection of system options [12], the choice of options for the implementation of 3D advertising installations should be based on the use of simulation tools.

We will designate a plurality of initial options of 3D advertising installations T_0^*, a set of alternatives obtained from T_0^* by applying a set of scaling and transformation procedures, – X. As a result of scaling and transformations, the corresponding subsets $S,T \subseteq X$, are generated. Any alternative to 3D advertising from T is described by a vector of estimating parameters whose values are in the region $\Delta \subseteq E^n$, and an alternative from S – vector of the corresponding actual parameters with values from the region $\delta \subseteq E^n$. Here E^n – n-dimensional Euclidean space. Scaling goal is to convert the value of the estimating parameters from Δ so that they are in the admissible area δ.

The estimating parameters of 3D advertising installations should be as follows.

– Simplicity and brevity. That is, the absence of complex compositions, a large number of details, as well as anything that prevents fast and accurate perception, memorization and reproduction.

– Uniqueness, novelty of the idea. 3D advertising should stand out among other objects, and be original even in small details. This will ensure its distinction and recognition.

– Associativity. 3D advertising should be a riddle that allows you to imagine, understatement, which generates right associations.

– Aesthetics and emotionality. 3D advertising should not cause negative emotions. Sometimes a logo can be placed in any geometric form for this purpose. This can increase its attractiveness, provide a finished look.

Scalability and versatility. When designing 3D advertising installations, it is necessary to consider that the recognizability of letters and images varies depending on their size.

Selection of alternatives from S and T is carried out on the basis of comparison with binary relations F and G respectively,while, in the general case, F is not a constriction of G on S, namely $F \neq G \cap S$.

Formally, the model of formation of options of 3D advertising installations will be defined as a four (X, Tr, F, G), where $X = S \cup T$, and Tr – the finite set of transformations. The set of optimal alternatives with respect to F in the selection model (S, F) is denoted by Opt (S, F). The choice of acceptable alternatives is based on the use of the basic recurrence scheme, which is called a set of stages:

$$BS = (St_0, St_1, \ldots, St_L),$$

$$St_0 = T_0^* \to S_0 \to Y_0 = \mathrm{Opt}(S_0, F),$$

$$St_l = T_l^* \to S_l \to Y_l = Opt(Y_{l-1} \cup S_l, F),$$

$$T_l^* = T_l \cap Opt(T_{l-1} \cup S_{l-1} \cup T_l, G) \neq \varnothing \ldots$$

Here T_l^* – the result of the permissible transformation of the set $X_{l-1} = T_{l-1}^* \cup S_{l-1}$ when moving from stage St_{l-1} to stage St_l, $l = 1,\ldots,L$.

The base scheme is fixed if a set of mappings

$$tr_{l-1} : X_{L-1} \to Tr_{l-1},$$

is specified, where $Tr_{l-1} \subseteq Tr$, $l = 1,\ldots,L$. The core of the X^* model is called plural sets X_0 or $X_l = T_l^* \cup S_l$, for which there is no permissible transformation from Tr. Thus, in the fixed scheme with the stage St_{l-1} is connected with the subset $Tr_{l-1} \subseteq Tr$ of permissible transformations, and with the scheme as a whole – the corresponding sequence Tr_0, Tr_1,..., Tr_{L-1}... Generation and selection of options are performed recurrently until the core is selected that exists if and only if $X_0 \neq O$. At the same time, alternatives are selected at each stage on the basis of the comparison with respect to F, taking into account the results of the previous stages.

In the context of each of the selected types of advertising installations of the above classification, the creation of the logo of the advertising image should be created. The most vivid and visually three-dimensional logo for 3D advertising can be created by the art of calligraphy. The proposed estimating parameters that influence the effectiveness of advertising installations, allow us to evaluate the quality of the logo created by means of calligraphy.

4. 3. Designing the technology of creating a logo of the advertising image by means of calligraphy

According to the proposed structuring of the process of development of 3D advertising printing products (Table 1), at the stage of "Development of the design of an advertising project", it is necessary to create a logo by means of calligraphy.

Designing the technology for creating a logo for an advertising image by means of calligraphy should be carried out in two main stages, each of which contains several specific tasks and subtasks. They are summarized in Table 2.

Table 2

Stages of creation of the logo of 3D images by means of calligraphy

Name of the research stage	Task of the stages	Subtasks in the context of each of the stages
Generating ideas for creating a logo by means of calligraphy	Creating an idea	forming the goal of creating a logo by means of calligraphy; target audience analysis; data generalization
	Agreement with the customer (if it is an order)	discussion of the logo concept by means of calligraphy; making adjustments; decision making by the customer
Logo design by means of calligraphy	Selection of materials	selection of paper for work; selection of tools for creating a logo by means of calligraphy; selection of ink; use of methods for hand warming
	Development of the concept	subject analysis; definition of the degree of conformity, the purpose of the logo concept by means of calligraphy; selection of phrase/word; selection of style; trial deposition; selection of technology for storing, processing and distributing 3D content; definition of the general composition
	Creating a logo	drawing of the first sketch; development of a modular grid; setting the placement of the inscription on a given surface format; preparation of the writing tool; checking each letter for its grapheme; selection of a glyph form for each letter; stylistic experiments; search for letters to create ligatures
	Digitization	selection of shooting style; shooting; processing photos in Adobe Photoshop; transfer into different color profiles and selection of colors that are as close as possible; saving files in different graphic and vector formats

At the stage of generating ideas for the logo creation by means of calligraphy within the framework of the task of creating the idea (Table 2), it is necessary to select the appropriate variation of the 3D logo image by means of calligraphy, which is given in Table 3.

At the stage of development of the logo by means of calligraphy within the framework of the task of developing the concept (Table 2), it is necessary to choose a technology for storing, processing and distributing the 3D content. It is necessary to distinguish between technologies that use various standardized markup web server language extensions (VRML, X3D, WebGL) and technologies that use different non-standard and proprietary add-ins (for example, Java 3D).

Here is an example of using WebGL to fill the 3D content of an advertising installation (Fig. 1).

Table 3

Variations of the use of modern calligraphy

Variations	Realization	Result
Thicker stroke	This is the simplest variation. To create a calligraphy in this variation, you need to write a word, then draw the strokes thicker, adding another to the right of the original stroke. Make sure that the new stroke perfectly merges with the original.	
Reducing the size of the letters and lengthening the connecting lines	Another way to diversify the calligraphic style is to merge the lowercase letters with long light strokes by reducing the letters and emphasizing the connecting lines. The standard style can not contain long connecting lines, because the size of the letters and the length of the lines should be balanced.	
Changing the angle of inclination	The angle of inclination of the original style is rather small. You can change the calligraphy style by simply increasing the slope. The easiest way to reach the right angle is to turn a piece of paper at an unusual angle. For example, when you create an original style, the paper is usually rotated about 20 degrees. For a stronger inclination, you need to rotate the paper so that it reaches an angle of 45–90 degrees.	
"Bubble" effect	Almost any calligraphy can be made more fun and with the effect of "bubbles". For this, you must skip inclined and too big loops, the letters should not have to be exactly in series and not the same size.	
Exclusion of loops and roundings	This variation is quite complicated, since it is difficult to convince your hand not to make smooth loops to which it is accustomed. You need to replace everything that even remotely resembles a circle, straight lines and angles. This means that all the letters will be joined together by awkward and sharp lines.	

Further, at the stage of developing the logo by means of calligraphy within the framework of the task of creating a logo (Table 2), the graphic design of the logo of the 3D advertising product should be made on the basis of the development of a modular grid. In order to clearly configure the modular grid, you should use the Ruled Calligraphy Paper script, in which you can specify the width of the pen in millimeters, the width and height of the letters both uppercase and lowercase; adjust the paper size, set the color to different directions (Fig. 2).

```
<script id="2d-fragment-shader" type="notjs">
precision mediump float;

uniform vec4 u_color;

void main() {
gl_FragColor = u_color;
}
</script>
var colorUniformLocation = gl.getUniformLocation (program,
"u_color");  ...
// we create 50 rectangles in random places with random color
for (var ii = 0; ii <50; ++ ii) {
// define a random rectangle
// The recording will take place in positionBuffer,
// communication point ARRAY_BUFFER    setRectangle (      gl,
randomInt (300), randomInt (300), randomInt (300), randomInt
(300));
// give a random color    gl.uniform4f (colorUniformLocation,
Math.random (), Math.random (), Math.random (), 1);
// draw a rectangle
gl.drawArrays (gl.TRIANGLES, 0, 6);  }} // return random integer
values from 0 to range-1function randomInt (range) {  return
Math.floor (Math.random () * range);}
// fill the buffer values that define the rectangle
function setRectangle (gl, x, y, width, height) {  var x1 = x;
var x2 = x + width;
var y1 = y;  var y2 = y + height;
gl.bufferData (gl.ARRAY_BUFFER, ...)
// affects the buffer that is tied to the point of
attachment`ARRAY_BUFFER`,
// but so we will have one buffer. If we needed it
// several buffers, we would have to tie them first to
gl.bufferData (gl.ARRAY_BUFFER, new Float32Array ([    x1,
y1,    x2, y1,    x1, y2,    x1, y2,    x2, y1,    x2, y2]),
gl.STATIC_DRAW);}
```

Fig. 1. Filling the 3D content of the advertising installation

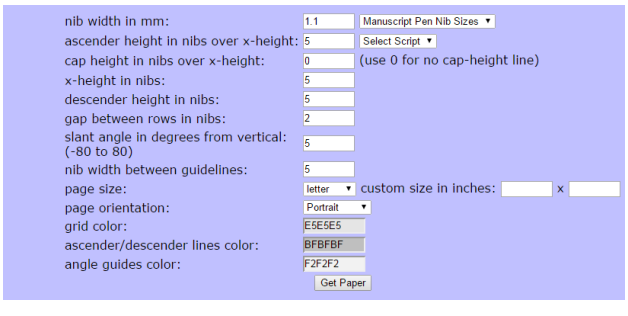

Fig. 2. Script for developing a modular grid

The result of the Ruled Calligraphy Paper script is shown in Fig. 3.

Fig. 3. A modular grid is developed

At the stage of development of the logo by means of calligraphy in the framework of the task of digitizing (Table 2), it is necessary to make shooting and photo processing for the future 3D advertising installation. For qualitative photographing of the logo of a 3D advertising product by means of calligraphy, first of all, it is necessary to consider a number of factors and the necessary elements, which are given in Table 4.

Table 4

Components for a high-quality shooting of the logo of a 3D advertising product by means of calligraphy

Parameter	Description
Natural light	As a rule, it is easier to achieve the best results during daytime shooting. Not only the total amount of light is important, but also its uniform distribution.
Tripod	With the slightest camera shake, the picture may be fuzzy and blurry. Moreover, the smaller the distance between the camera and the object, the higher the degree of blurring.
Scale	For the visibility of the magnitude of the inscription on a photograph, it is desirable to give the right sense of the work scale. For this, we include the familiar object (for example, any coin or large object) in the frame, in comparison with which, it is possible to easily determine the size of the inscription
Situation	Try to put different pieces on the paper with the inscription. For example, the feather was depicted as an inscription or what subjects inspired to create the work
Details	If you want to emphasize this or that part of the logo by means of calligraphy, you need to use a function for close-up shooting. This mode is called "macro" and in most modern cameras it is indicated by an icon of a flower resembling a tulip.

At the final stage of the development of the logo by means of calligraphy within the framework of the digitization task (Table 2), the choice of the degree of "handwriting" should be made (see Table 5). At this stage, the logo is vectorized with calligraphy tools in Adobe Illustrator.

Table 5

Vectorization of the logo of a 3D advertising product by means of calligraphy

Degree of "handwriting"	Method of work	Work recommendations
Brush or pen tracks	Image tracing	The easiest way to trace a graphic document is to open or place a file in Illustrator and apply an automatic trace. The user has the ability to control the level of detail and fill the tracing results and save these parameters as their own style.
Smooth lines	Bézier curves	The curve is created by adding a reference point at the point where its direction changes, with subsequent dragging of control lines. The shape of the curve is determined by the length and inclination of the control lines.

After the logo is mapped by means of calligraphy, it is necessary to make a selection of corporate colors for the calligraphic logo. Corporate colors can be used as backgrounds, substrates, dies, etc. It should be noted that the colors in the RGB, CMYK and Pantone color schemes are visually identical, so in case of use there is no need of manual correction.

Vectorizing the logo of a 3D advertising product and selecting colors create favorable conditions for the transformation and calculation of the size of a 3D advertising image with the help of mathematical modeling tools.

5. Results of the study on the development of a method for creating 3D advertising printing products

According to Table 1, the stage of realization of the advertising project, distortion of the image for the advertising installation should be carried out. In order to create a toolkit that would correctly distort an image that appears visually three-dimensional from a certain point of view, it is necessary to calculate and display the formulas for the proper partition of the image, the distortion of each part. All this also depends on the size of the image, the distance from the viewing point to the image, etc.

First, you should calculate the breakdown of the original 3D advertising image.

We introduce the following notation:

R – image viewing point height (human eye level) (m);

D – distance to the image (m);

L_0 – distance from the viewing point to the edge of the image (m);

H_0 – height of the image in the viewing plane (m);

W_0 – width of the image in the viewing plane (m);

H_1 – height of the image (m);

$W_1 = W\max$ – maximum image width (m);

N – number of parts of the image partition;

m_i – true size of the i-th part of the image (m), $1 \le i \le N$;

$M_i = \sum_{j=1}^{i} m_j$ – total length of the i-parts of the image (m);

d – distance from the viewing point to the image plane (m);

The general view of the 3D advertising image viewing scheme is shown in Fig. 4.

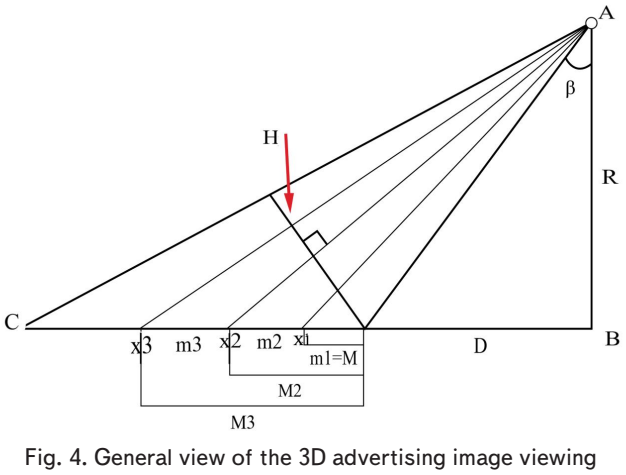

Fig. 4. General view of the 3D advertising image viewing scheme

In Fig. 4, β – the angle at the viewing point between the perpendicular to the base and the beam directed toward the base of the image plane.

$\alpha_j, 1 \le i \le k$ – the angle from the point of view on the i-th part of the image in the viewing plane.

Converting a 3D advertising image vertically should be based on the use of the following formulas:

$$L_0 = \sqrt{R^2 + D^2}:$$

$$d=\sqrt{L_0^2+\left(\frac{H}{2}\right)^2};$$

$$tg\beta=\frac{D}{R};\ \ \beta=\text{arctg}\left(\frac{D}{R}\right).$$

Here is a part of the drawing from the point of view to the viewing plane in this way (Fig. 5).

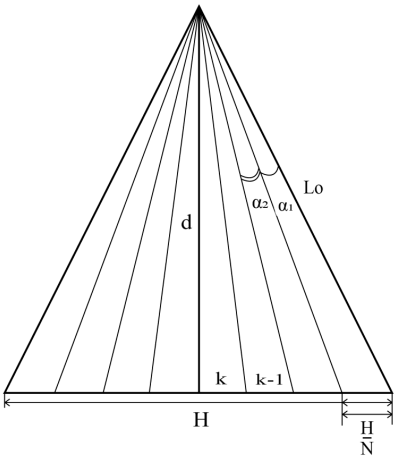

Fig. 5. View of the image from the point of view to the viewing plane

We divide the viewing plane into N equal parts (N – even) and denote

$$K=\frac{N}{2}.$$

Then:

$$\text{tg}\alpha_k=\frac{H/N}{d}=\frac{H}{Nd},\ \ \alpha_k=\text{arctg}\left(\frac{H}{Nd}\right);$$

$$\text{tg}(\alpha_k+\alpha_{k-1})=\frac{2H}{dN};\ \ \alpha_k+\alpha_{k-1}=\text{arctg}\left(\frac{2H}{dN}\right);=\rangle$$

$$\alpha_{k-1}=\text{arctg}\left(\frac{2H}{dN}\right)-\text{arctg}\left(\frac{H}{dN}\right);$$

$$\alpha_j=\text{arctg}\left(\frac{(k-j+1)H}{dN}\right)-\text{arctg}\left(\frac{(k-j)H}{dN}\right);\ \ 1\le j\le k;$$

$$\alpha_k=\alpha_{k+1};\ \ \alpha_1=\alpha_{2k}=\alpha_N.$$

Let's denote

$$\sum_{j=1}^{i}\alpha_j=A_i,$$

then

$$\text{tg}(\beta+\alpha_1)=\frac{D+M_1}{R};$$

$$M_1=m_1=Rtg(\beta+\alpha)-D=Rtg(\beta+A_1)-D;$$

$$tg(\beta+\alpha_2)=\frac{D+M_2}{R};$$

$$M_2=Rtg(\beta+A_2)-D.$$

In general:

$$M_j=Rtg(\beta+A_j)-D;\ \ m_j=M_j-M_{j-1}.$$

Converting a 3D advertising image horizontally should be based on the following formulas:

$$\frac{W_0}{d}=\frac{W_{\max}}{d+H_1};\ \ H_1=M_N,$$

$$W_{\max}=\frac{W_0(d+H_1)}{d}.$$

Fig. 6 shows distortion of the original 3D advertising image horizontally.

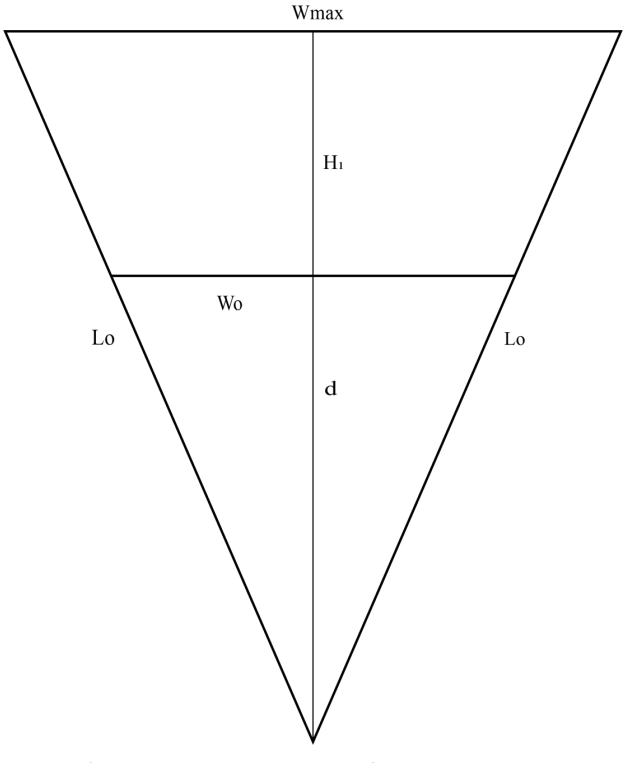

Fig. 6. Distortion of the original 3D advertising image horizontally

We find out the match of the pixel of the original image to each pixel of the converted 3D advertising image.

Denote:

h_0 – the value of the current point of the image in height (m);

y_0 – the value of the current point of the image in height (pixels);

x_0 – the value of the current point of the image in width (pixels);

h_1 – the value of the current point of the converted image in height (m);

y_1 – the value of the current point of the converted image in height (pixels);

x_1 – the value of the current point of the converted image in width (pixels);

HP_0 – image height in the viewing plane (pixels);

WP_0 – image width in the viewing plane (pixels);

$KH_0 = \frac{H_0}{HP_0}$ – the conversion factor of the image in the viewing plane in height (m/pixels);

$KW_0 = \frac{W_0}{WP_0}$ – the conversion factor of the image in width (x-axis) (m/pixels);

$KH_1 = \frac{H_1}{HP_1}$ – the conversion factor of the image in the plane of the figure itself in height (y-axis) (m/pixels);

HP_1 – the height of the converted image (pixels);

F – the size of the plot without the image (pixels);

Lx_1 – the line length of the image with the coordinate y_1 (pixels);

$Kx_1 = \frac{Lx_1}{WP_0}$ – the coefficient of proportion at the point y_1;

$$tg(\beta + A) = \frac{D + h_1}{R};$$

$$\angle A = \operatorname{arctg}\left(\frac{D + h_1}{R}\right) - \beta;$$

$$tgC = \left(\frac{d}{\frac{H_0}{2}}\right);$$

$$\angle B = \pi - A - C;$$

$$\frac{h_0}{\sin A} = \frac{L_0}{\sin B}; => h_0 = \frac{L_0 \sin A}{\sin B}.$$

Converting the coordinate of the pixel vertically lies in the sequence of the following transformations:

$$y_1 \to h_1 \to h_0 \to y_0; \quad h_1 = KH_1(HP_1 - y_1);$$

$$h_0 = \frac{L_0 \sin A}{\sin B},$$

where

$$A = \operatorname{arctg}\left(\frac{D + h_1}{R}\right) - \beta; \quad \beta = \operatorname{arctg}\left(\frac{D}{R}\right);$$

$$C = \operatorname{arctg}\left(\frac{2d}{H_0}\right); \quad B = \frac{\pi}{2} - A - B; \quad y_0 = HP_0 - \frac{h_0}{KH_0}.$$

Converting the coordinate of the pixel horizontally consists in the sequence of the following transformations:

$$F = \frac{(WP_1 - WP_0)x_1}{2HP_1}; \quad Lx_1 = WP_1 - 2F;$$

$$x_0 = \frac{x_1 - F}{Kx_1}, \text{ if } F < x_1 < WP_1 - F.$$

The developed mathematical model allows us to calculate the size of a 3D advertising image, which should be applied to the surface so that the image in the viewing plane corresponds to the given size. Based on the developed mathematical model, a program was created that allows forming the distorted appearance for any image, which can be applied to the surface.

The method of creating 3D advertising was implemented in the BPWin software product. The choice of BPWin as an implementation environment has been made due to the fact that this product is the most convenient and affordable system for business process modeling. The IDEF0 diagrams contained in the program are vivid and easy to understand, while they formalize the notion of work.

Fig. 7, 8 show the diagram of the steps for creating a 3D advertising product.

Each of the stages using IDEF0 was decomposed into more detailed steps that are part of the previous one. Fig. 9–11 show the decomposition of each stage of creating 3D advertising.

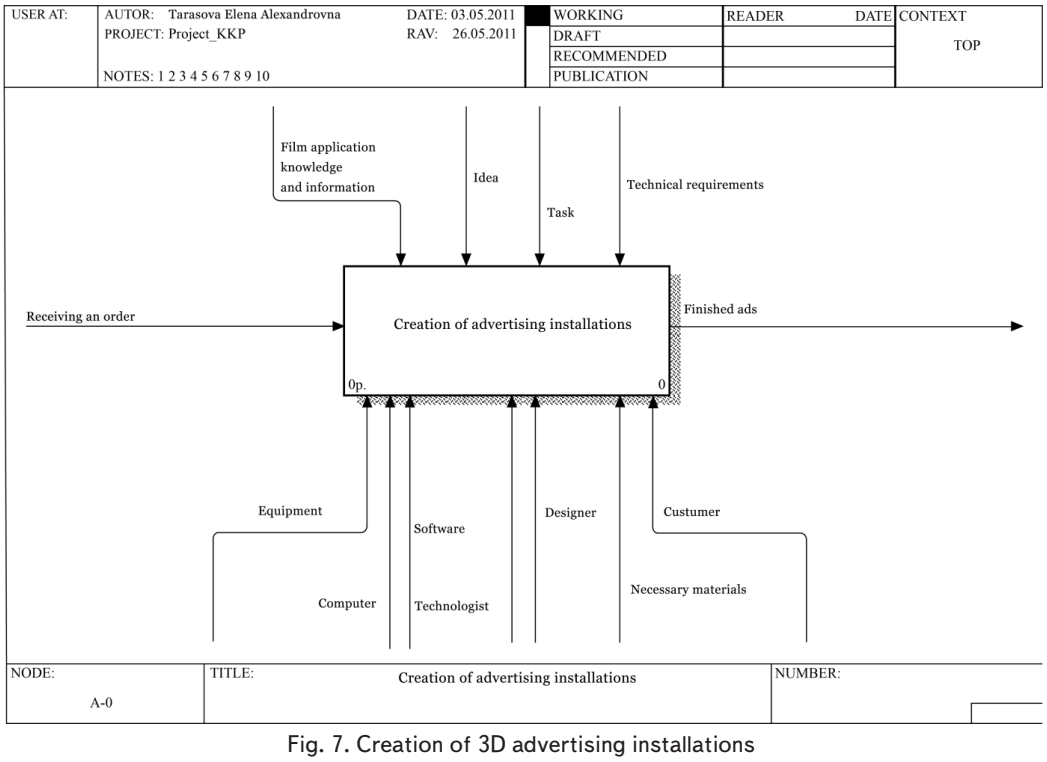

Fig. 7. Creation of 3D advertising installations

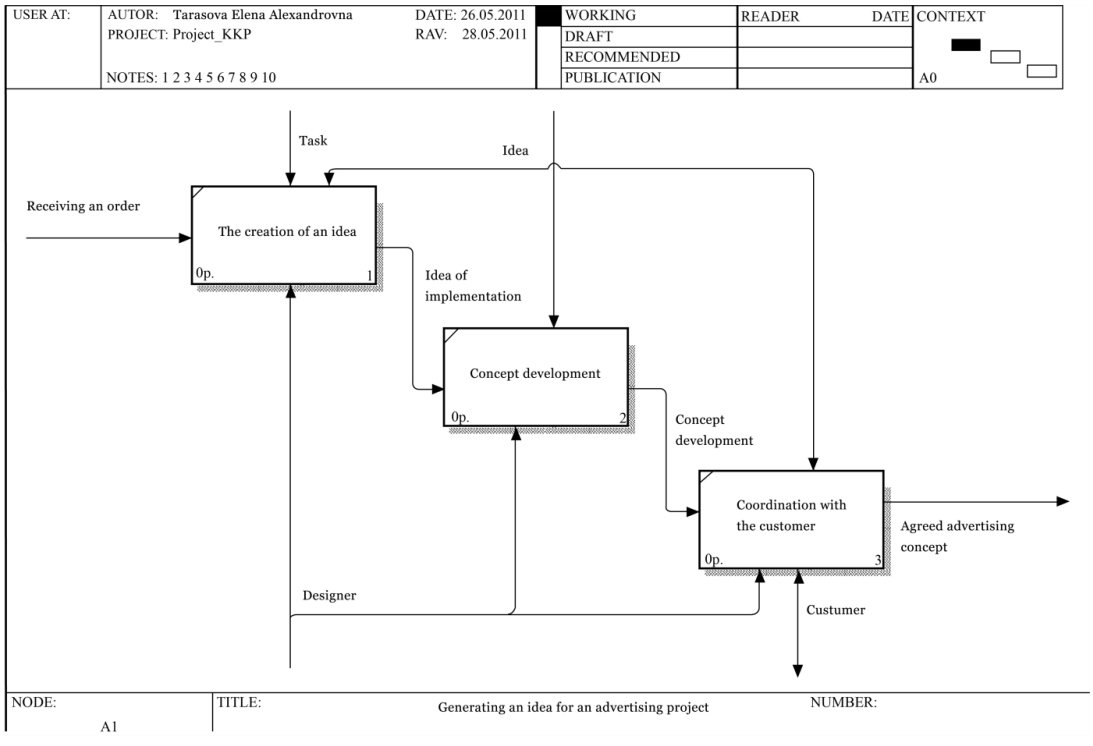

Fig. 8. Main stages of the business process of 3D advertising product design

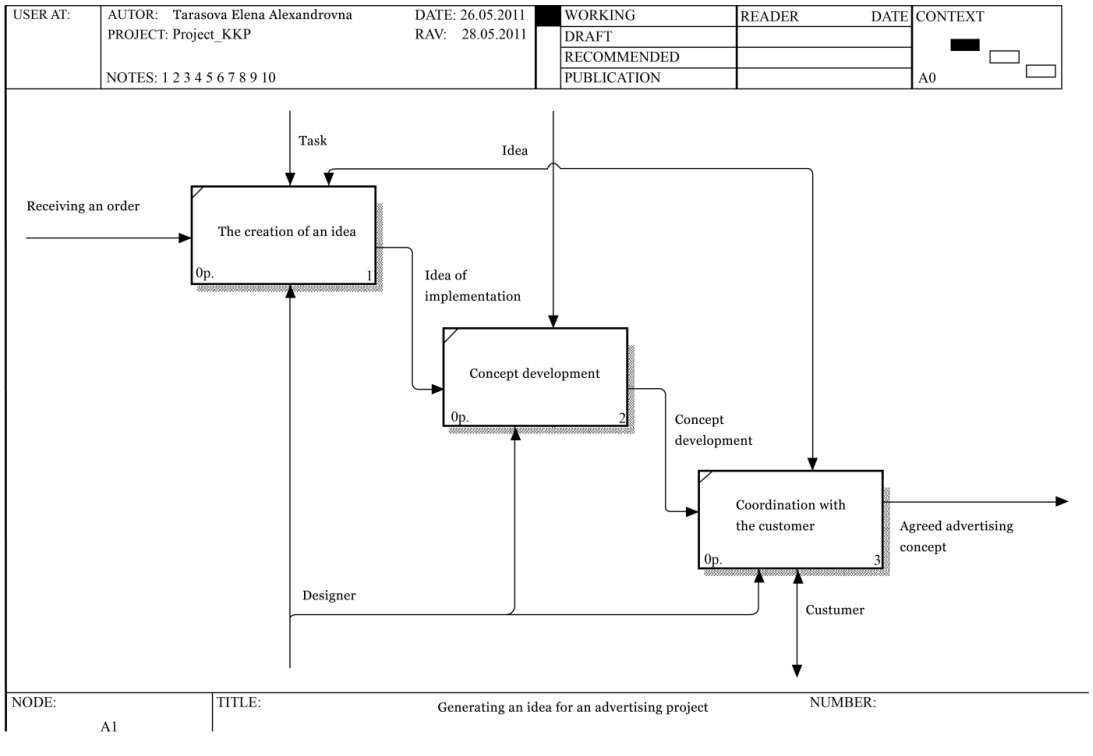

Fig. 9. Decomposition of the "Generation of the stage of the idea of an advertising project" stage

By means of the C# language, a program was developed that calculates and distorts the advertising image.

Initial data for the program implementation of the methodology for creating 3D advertising are:

1) the height of the viewing point;
2) the viewing height of the picture;
3) the viewing width of the picture;
4) the number of partition parts.

The height of the viewing point is the point at which a person looks at the image (human eye level).

The viewing height of the picture is the height of the picture in an imaginary (viewed) plane.

The viewing width of the picture is the width of the picture in the imaginary (viewed) plane.

The number of partition parts is the number of individual sections of the image for which the conversion is made.

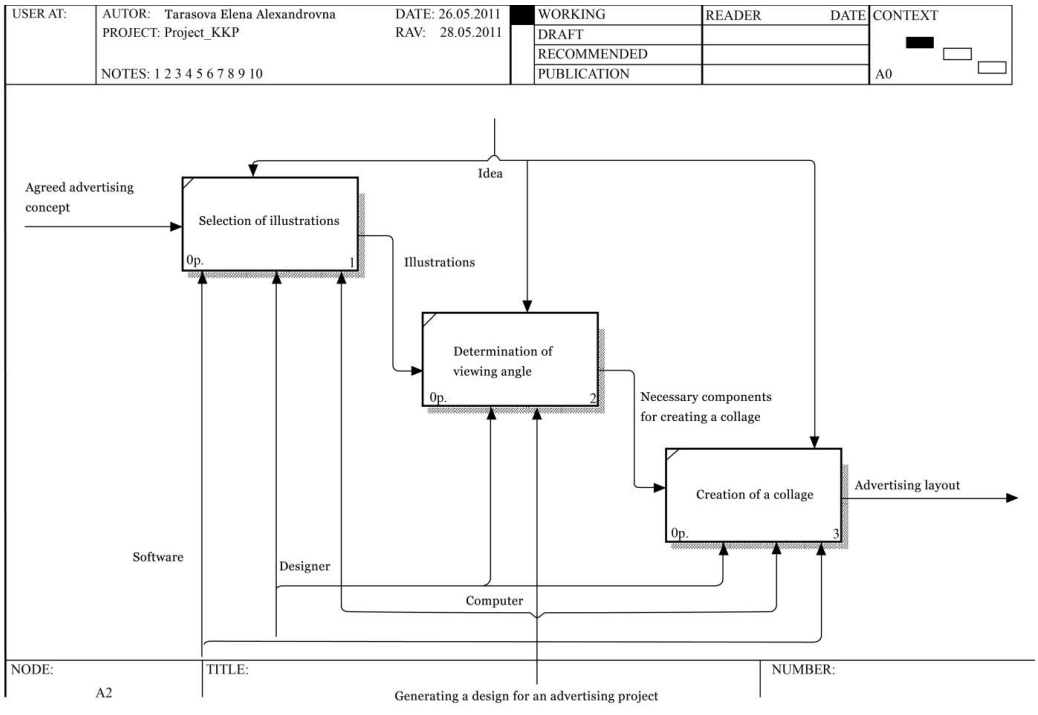

Fig. 10. Decomposition of the "Development of the design of an advertising project" stage

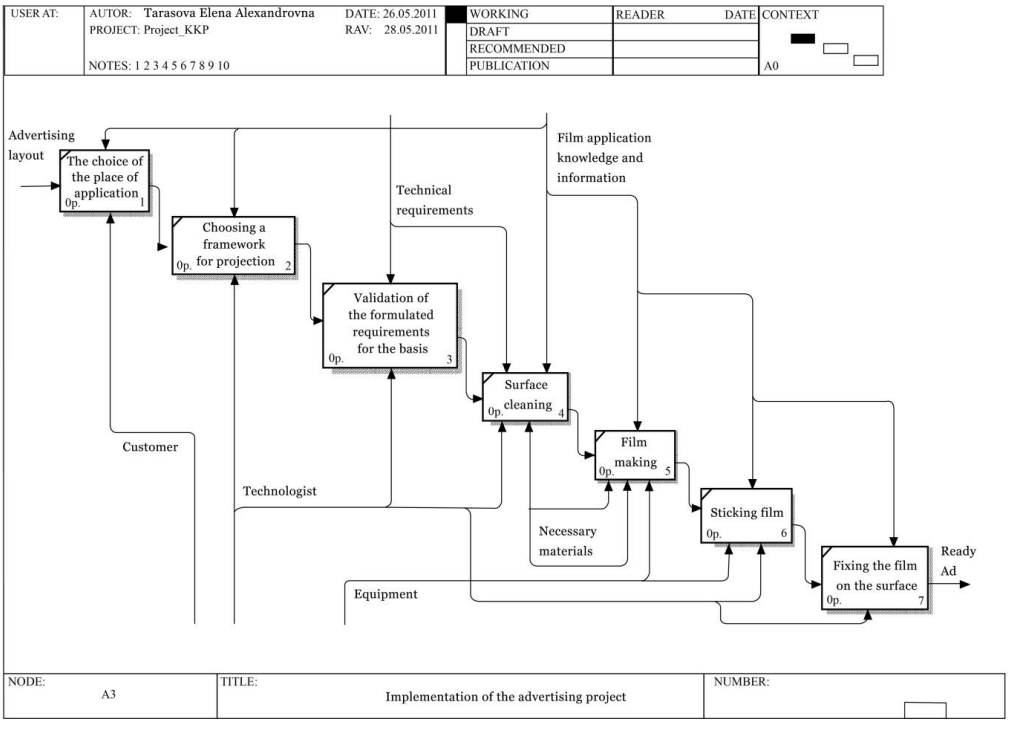

Fig. 11. Decomposition of the "Realization of the advertising project" stage

The result of the work of the created code is the table with the calculation of the length of each part of the distorted image (Fig. 12).

Left button "Очистить" (Clear) allows you to cancel the calculation and clear the fields for entering the initial data. Right button "Очистить" (Clear) removes the image from the form.

To create the overall appearance of the distorted image, you must select the "Просмотр изображения" (View Image) tab. As a result, the uploaded image will be distorted in accordance with the calculation, according to the developed mathematical model and will appear on the tab (Fig. 13). If, however, it is premature to go to the "Просмотр изображения" (View Image) tab, a warning will be issued that the image parameters were not calculated (Fig. 14).

The described implementation allows automating the development of 3D advertising.

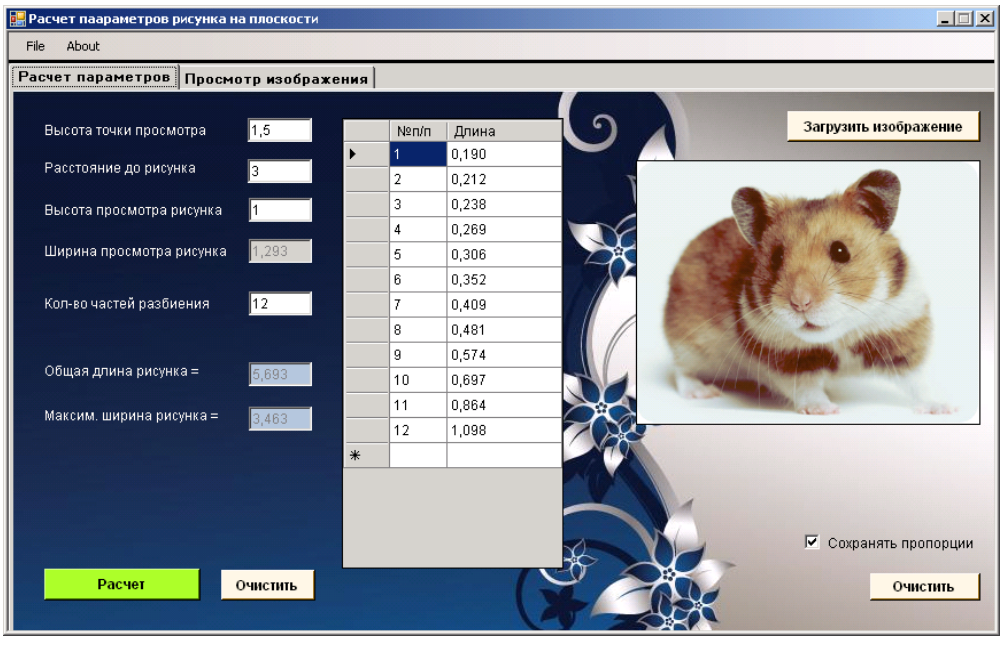

Fig. 12. Table for calculating the length of parts of the distorted image

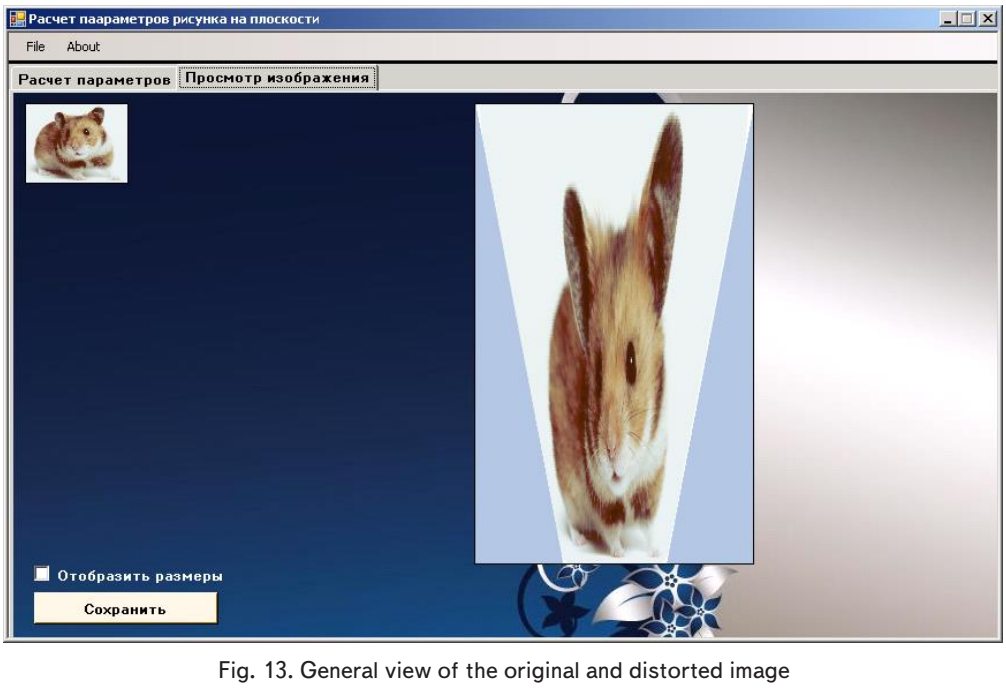

Fig. 13. General view of the original and distorted image

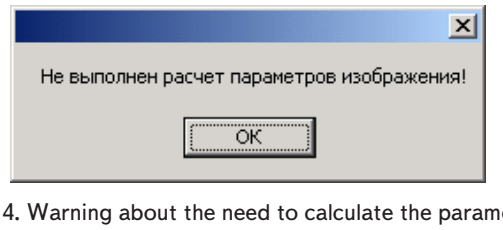

Fig. 14. Warning about the need to calculate the parameters of the image

6. Discussion of the development results of a methodology for creating 3D advertising printing products

As part of this research, a technique for creating 3D advertising printing products taking into account the mechanism of conversion of a 3D advertising image was developed. The proposed methodology is a continuation of the authors' research on the development of a methodology for informational support of publishing activities. Possible areas of practical application of the proposed methodology are:

– management of the processes of production of advertising printing products;

– marketing of printing production;

– informational support of publishing activity;

– prepress preparation and design of advertising printing products.

Based on the results of the development, the following conclusions can be made regarding the possible practical application of the technique of creating 3D advertising printing products.

1) Dynamic development and distribution of 3D advertising create conditions for the expansion of the range of advertising installations, as a result of which the created classification of 3D advertising images must be adapted to the specific conditions of marketing of printing production.

2) The design of an advertising logo based on calligraphy, as well as through the use of design techniques of typography, composition and stylistics, will allow the development of creative 3D advertising tools.

3) According to the proposed method, the 3D advertising image contains rich content. Therefore, it is important to analyze the graphic design products used to match them with the principles of harmonic composition and ergonomic requirements. Also, graphic design products should be checked for their emotional impact on the viewer.

4) In the process of using the proposed mathematical model of distortion of a 3D advertising image, it should be kept in mind that advertising installations modify and complicate the object. This is fair even in the case of a simple increase and hypertrophy. Such a structure, on the one hand, loses its functional qualities in comparison with traditional forms of advertising media, on the other hand, it affects the consumer much sharper.

5) In order to provide a strong emotional color associated with the brand, the proposed method of creating 3D advertising printing products should be realized on the basis of non-standard advertising. This approach will lead to the creation of acute sensations and impressions of consumers and will promote their interest in advertising installations.

The advantages of the proposed method of creating 3D advertising printing products are:

– taking into account the opinions of leading technologists and directors of the leading publishing and printing enterprises of Kharkiv concerning the creation of 3D printed advertising;

– accounting of a wide range of publishing and printing materials, parameters and methods of printing, as well as individual characteristics of consumers, interpreted in the developed method into the classification features of 3D advertising and the corresponding elements of the criterial basis, affecting the effectiveness of advertising installations;

– the presence of a mathematical model that allows you to calculate the size of a 3D advertising image.

The shortcomings of the developed methodology for the development of publishing and printing web portals include the fact that the use of expert survey methods to form the basic set of the main stages of creating 3D advertising (Table 1) can lead to the subjectivity of the results. Also in the program implementation of the transformation of the advertising image there is no option to display the horizontal lines in the distorted image, which correspond to the proportional parts of the original image.

In the process of using the proposed results, the following restrictions of subjective nature may be imposed:

– personal preferences of designers and consumers of 3D advertising may lead to a change in the configuration of possible variations of the advertising logo of the 3D image by means of calligraphy (Table 3);

– in the process of program realization of the mathematical model of 3D advertising image distortion, the proportions of the image can be changed and integrity of the data within the program can be violated. To overcome this difficulty, you should use Visual C#.

Further research areas may include:

– assessment of the effectiveness of creating 3D advertising printing products;

– design of means of optimization of a 3D advertising image;

– development of a methodology for assessing the quality of an advertising installation based on the use of calligraphy tools.

In the process of realization of these further research directions, such difficulties may arise.

– During the evaluation of the effectiveness of creating 3D advertising printing products, there may be difficulties in the determination of the integral indicator of such efficiency and quantitative determination of each component of this indicator.

– Designing 3D advertising image optimization tools may face the challenge of selecting color gamut parameters and color and tonal image correction tools.

– In the process of developing a methodology for assessing the quality of an advertising installation based on the use of calligraphy tools, it may be difficult to identify the factors of usefulness of various calligraphic tools and variations for the practice of 3D advertising.

7. Conclusions

1. The structuring of the development process of 3D advertising printing products was conducted. Accordingly, the main stages of 3D advertising creation are highlighted. A characteristic feature of this structuring was the formation of a sequence of actions in relation to the development of a high-quality 3D advertising product in order to meet the needs of the end user.

2. The simulation model of choice of options of realization of advertising installations is offered. This model describes the process of creating acceptable alternatives to 3D advertising by comparing the corresponding binary relations with the proposed estimating parameters. The result of the model is the choice of acceptable alternatives, which is based on the use of the proposed base recurrent scheme.

3. According to the proposed structuring of the development process of 3D advertising printing products, the technology of creation of the logo of the advertising image by means of calligraphy was designed. The indicated technology is realized by generating an idea for the creation of a logo by means of calligraphy and the actual development of the logo by means of calligraphy. In this, at the stage of the idea generation, the choice of the appropriate option of the advertising logo of the 3D image by means of calligraphy is carried out. At the stage of developing the logo by means of calligraphy, there should be a choice of technology for storing, processing and distributing the 3D content. As a result, a list of variations of the use of modern calligraphy for the design of 3D advertising printing products was formed.

4. A mathematical model for creating a projection of a 3D advertising image is developed. This mathematical model contains formulas for the proper partitioning of the image and distortion of each part. The proposed mathematical model allows us to calculate the size of a 3D advertising image that should be applied to the surface so that the image in the viewing plane corresponds to the given dimensions. Based on the use of hypothetical input data as a result of software implementation of the model, the values of the length of 12 parts of the distorted image were obtained – 0.19; 0.21; 0.23; 0.27; 0.3; 0.35; 0.4; 0.48; 0.57; 0.7; 0.9; 1.1.

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