ALGORITHMS FOR VECTORIZING DRAWINGS OF THE UPPERS SHOES

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Abstract: *Perfection of methods of footwear production technology through the use of computer-aided design systems allows to develop production technology, to supply consumers with high-quality and comfortable footwear. At the stage of development of design and design documentation for a new model of footwear, there are a number of difficulties, the formalization of which using computer graphics tools would significantly reduce the subjectivity of the designer's design decisions or free it from performing the same procedures. In the framework of the research known algorithms for vectorizing the drawing were considered, on the basis of which a new method using a set of apertures appropriate for the drawings of the upper parts of the shoe was proposed.*

The results of the research were – formulated requirements for the "Digitization" module; its structural and logical scheme, allowing automated input of information about drawings of designs of the uppers shoes in CAD; structural and logical scheme of a topological algorithm that allows vectorizing drawings of the uppers shoe in accordance with the set of apertures.

The calculation of material costs for the design of footwear was also carried out, which showed the economic efficiency from the introduction of the proposed method into production.

Keywords: CAD, TOPOLOGICAL ALGORITHM, STRUCTURAL AND LOGICAL SCHEME, ECONOMIC EFFICIENCY, QUALITY OF FOOTWEAR

1. Introduction

The footwear industry delivers millions of goods a year. The expansion of international trade, the development of Internet commerce, and the development of information technology - all these factors make manufacturers supply, comfortable and fashionable shoes in a short period of time. This can help improve the methods of footwear the technology. Thus use of computer-aided design remains the main tool.

The scientific novelty of the research is the concept of the automated design system for the contours of the part templates and for the drawings of the footwear uppers using technical visual tools.

The theoretical significance lies in the development of the mathematical model and algorithms for vectorizing drawings of the upper structure of shoes and template outlines. Practical significance consists in expanding the capabilities of known CAD systems, which allows reducing the time of information input and the process of designing shoes.

At the first stage of the investigation, modern CAD systems for shoes were analyzed, table 1 was compiled, in which the well-known CAD systems are sorted according to the principle of the design device and the design method. Analysis of this table showed that domestic CAD systems are oriented to 2D design and use mainly manual input method, with the help of digitizers. Therefore, the research was focused on the domestic manufacturer, in particular, on the "Shoes Model" and "ASKO-2D".

2.Analysis of input devices for graphic information in the CAD of the footwear industry.

Next, the stages of designing shoes were analyzed, difficulties were identified: input of information, design and detailing stages, as well as layouts and assembly technologies (Fig. 1). As a result of the research, the structural-logical scheme of the "Digitization" module was proposed and the following requirements for this module were formulated: support of inexpensive and common input devices; ensuring integration with domestic CAD shoes. Analysis of input devices showed that the best is the scanner, but in the long term, a digital camera, a web camera or a tablet was chosen for 3D design.

The analysis of the scanner as a device revealed that all the necessary infor-mation stored in the graphic file can be read through the API function. Thus, a table was formed, the necessary data were read out of it, and a transition to values-such as inches, centimeters and millimeters-was made using a proportion.

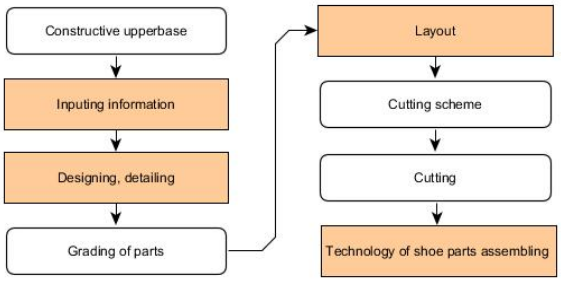


Fig. 1 *Structural-logical scheme of designing shoes.*

Table 1: *Comparison of CAD software for footwear according to the type of design and input of information.*

CAD	Country of origin	Type of design	Input device	Form of initial information
ASKO-2D	Russian Federation	2D	digitizer (H*)	drawing
ShoesModel	Russian Federation	2D	digitizer (H)	drawing
Assol	Russian Federation	2D	digitizer (H), сканер (HA), digital camera (HA)	drawing (H), patterns (HA)
Naxos	Italy	2D,3D	3D-digitizer (H), digitizer (H)	last
ClassiCAD	Czech Republic	2D	digitizer (H)	drawing
Crispin	Great Britain	3D	3D scanner (A)	last
Shoemaster	Great Britain	3D	3D scanner (H,A)	last
Rhinoceros	USA	3D	3D scanner (A)	last

* Information input mode: H - handloading, A - automatic, PA - half-automatic.

3.Development of the concept of the module "Digitalization".

Next, we considered image processing algorithms. It was revealed that the drawing must be submitted in black and white, ie

to perform binarization of the image. However, for this, it is necessary to calculate the binarization threshold. The studies for the drawings of the shoe parts for two methods were carried out an image in shades of gray and with a uniform brightness distribution or an equalization. It was found out that on the equalisation the drawing contains artifacts, superfluous details and noise, and in shades of gray, on the contrary, all the extra details are missing. Thus, it was decided to use the transformation to shades of gray in the algorithm and in the module.

Since the scanner was selected as part of the MFD, its scanning area is limited to A4, so it is necessary to glue parts of the drawings into a single view. Within the framework of the study, several algorithms were considered. The best according to the results of the experiment is the SURF method, which allows the image to be glued together quickly and in the most acceptable way.

And the final stage of the transformation of the drawings of the tops of the footwear from the raster representation to the vector one is vectorization. Several algorithms were considered: algorithms for "turtle" and "tracking" algorithms; watershed, skeletonization, and boundary detector Canny. However, theoretical studies have shown that the "tortoise" and "tracking" algorithms do not allow recognition of the designs of the shoe uppers, since they can not record complex structure information. The other two methods - the watershed and the wave one - are good at recognizing the forks, but they require large amounts of memory, and are also time-consuming. Experiments for skeletonization methods and the Kenny boundary detector have not given good results. So, the result of the work of the first method, contains lines of forks that complicate the process of further editing this drawing. In addition, the information is presented in a raster format, i.e. an additional pass through the image is required in order to convert it into a vector form. The Canny algorithm recognizes all lines of the drawing, but vectorizes each of them from two sides, i.e. if you need to edit the lines there will be difficulties (Fig. 2).

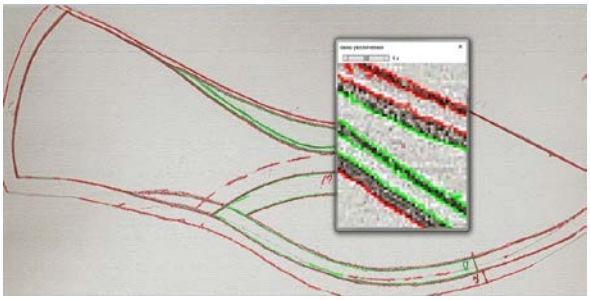
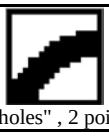
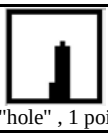


Fig. 2 *Implementation of the Kenny algorithm.*

Thus, the task of developing a new method that could recognize forks and form lines of a given thickness is obvious. To do this, the analysis of the design drawings of the shoe uppers was made, a common set of elementary zones of the drawing was formed. Table 2 presents the apertures arranged in descending order, i.e. the most common aperture is "two holes and two points", it is about 80% of the drawing. The next three represent the lines of allowances and are about 20%. The aperture “e” characterizes the connection of key points. And the least common aperture is "one hole - one point".

Table 2. A characteristic set of apertures for drawings of the uppers of footwear

 2 "holes" , 2 points	 2 "holes" , 3 points	 3 "holes" , 3 points
a	b	c
 3 "holes" , 4 points	 4 "holes" , 4 points	 1 "hole" , 1 point
d	e	f

Thus, a topological algorithm was formulated, its essence is as follows: pass through the drawing with a variable-sized aperture and, depending on the information that is in it, a drawing is recognized (Fig. 3).

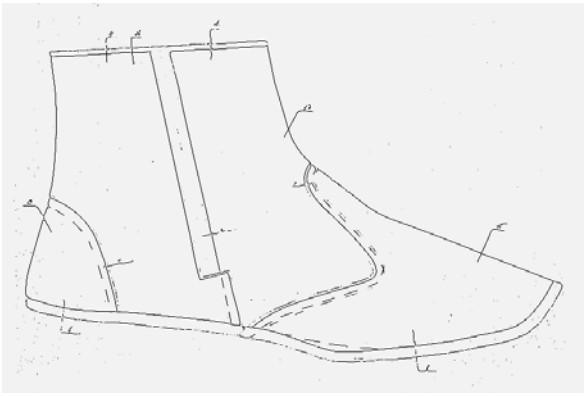


Fig. 3 *Experimental approbation of the module "Digitization" in the drawing.*

The method of integration with known CAD shoes was considered. A format was created, a bunch, by transferring from SVG to DFX, since this format is the most common. Figure 4 shows the final structural-logical scheme of the digitization module, i.e. taking into account all the studies that have been presented previously.

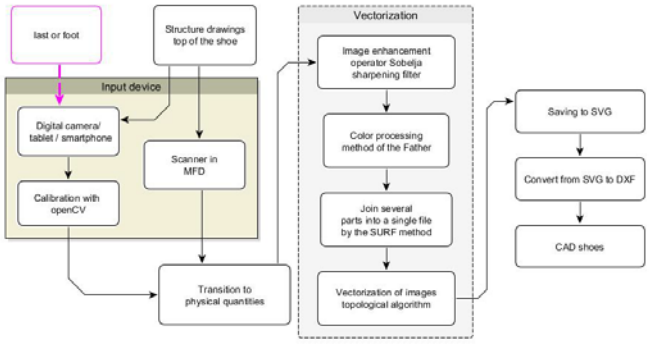


Fig. 4 *Structural-logic diagram of the vectorization block.*

4. Material costs

In conclusion, we would like to say about material costs. Table 4 shows that the cost is reduced several times by using common equipment. I want to emphasize that 2D-design uses a scanner in the MFB, i.e.it can be used at the enterprise for printing documents and copying.

Table 4 Material costs of designing shoes

The concept of designing	2D known	2D redesigned concept
The program for designing	Autodesk AutoCAD (local license for 1 year)	FreeCad/LibreCad
The price [(thousand RUB)]	71,3	0
The device	Digitizer 2D (CalComp DrawingBoard VI)	Flatbed scanner with MFD (Brother MFC-J2320)
The price [(thousand RUB)]	30	12
Total [(thousand RUB)]	**101,3**	**12**

5. Conclusions

1. The considered modules of CAD configurations for footwear industry, the analysis of packages of programs of well-known companies (ASKO-2D, ShoesModel, Assol, Naxos) and their functionality showed that the input of information in the domestic CAD of footwear is carried out mainly manually using digitizers. Modern software can not completely solve the problem of transforming the raster representation of the drawings of the footwear uppers into a vector, and the automation of the process is constrained by the high cost of the equipment.

2. The possibility of introducing technical vision in CAD shoes for integration with different modules has been identified. The scanner turns out to be the preferred device for inputting information about drawings of the shoe uppers. Cameras of a digital camera, smartphone or tablet are the perspective device for designing in 3D-space.

3. Requirements for the module "Digitization" are formulated, its structural-logical scheme is developed, which allows automated input of information on drawings of designs of the shoes uppers in CAD. The need to develop the method for converting raster information about drawings of the footwear uppers into a vector with the help of binary image is revealed. The value of the threshold value of the binarization of the drawings of the structures of the shoe uppers is calculated.

4. The structural-logical scheme of the topological algorithm that allows vectorizing the drawings of the footwear uppers in accordance with the set of apertures is developed.

5. The need to develop a mathematical description for the patterns of the upper shoe parts that preserves the second derivatives and the operatively building contours is revealed.

6. The calculation of material costs for the design of footwear showed the economic efficiency of technical vision systems, expressed in reducing the time re-quired of developing a new model when designing in 2D; expansion of electronic database and automation processes; a significant reduction in the cost of the equipment and software used.