Journal for Geometry and Graphics
Volume 23 (2019), No. 2, 211–220.

Geometrization of Design Flat Images or Geometric Approximation of Art Drawing

Switlana Botvinovska, Tetiana Nikolaenko, Alla Zolotova

Faculty of Architecture, Kyiv National University of Construction and Architecture
Povitroflotskyi pr., 31, Kyiv, Ukraine
email: botvinovska@ua.fm, zolotovaav1@gmail.com

Abstract. Geometrization in arts is a method for sequent simplifying pictorial forms by identifying and emphasizing their geometric structure. This article describes a process of formalization (constructing a geometric model) using the fillet of flat geometric figures developed by designers. Theoretical researches carried out in the field of the geometric description of flat curvilinear images and examples of such contours plotting will allow to engage prospective designers in studying Engineering Graphics and raising their graphic culture.

Key Words: geometric modeling, formalization, geometrization, fillet, flat shape
MSC 2010: 00A66, 00A67, 97M80

1. Introduction

Contemporary life needs for beauty. Various sciences study the laws on creating beauty, but the visualization of images is one of the main approaches in cognitive and designing activities, work of architects, and designers. Image theory answers many questions, therefore studying Descriptive Geometry, as a part of general image theory, is essential for every educated person who is engaged in architecture, design, or engineering. The distinguished physicist and philosopher David Bohm believed that division of art and science is temporary; it didn't exist in the past, and there is no reason why it should go on in the future. Bohm explained:

> *"so does science consist not in the accumulation of knowledge but in the creation of fresh modes of perception"* [1].

The current reform of higher education in Ukraine provides for introducing into the curricula the concept of competencies, where one of the main competencies is creative thinking. Therefore, it is important for each academic discipline to develop new creative challenges for students in different fields of studies.

For students of the Fine Arts course, we offer a task known as "Geometrization of flat images".

> *"Geometrization in arts is a method for sequent simplifying of pictorial forms by identifying and emphasizing their geometric structure"* [2], [3, chapter 2, p. 15].

ISSN 1433-8157/$ 2.50

Figure 1: Faculty department logo

Figure 2: Ukrainian ethnic interior style: Source https://yandex.com/collections/user/n-stadnyuk/ukrainskii-stil-v-interere/

This method of creating images can be used in geometric modeling: like a variety of toys, such as spinners; when searching for forms of logos, for example, the logo of the Descriptive Geometry and Engineering Graphics Department of KNUCA (Kyiv National University of Construction and Architecture), was developed by the Dean of the Architecture Faculty, Dr. Sci. (Eng.), Prof. O.V. Kashchenko (Figure 1); when modeling ornamental elements (Figure 2), creating stencil drawings for wall decoration. For example, such decoration was performed at the entrance to dining-hall on ground floor at school No. 53 in the city of Kyiv (Figure 3).

Designing an image of a modern flat form, outlines (contours) of its shape, is quite a creative process, but at the same time it abides by graphic and geometric principles. In designing and art modeling, besides knowing the laws, it is desirable to have a sense of style and artistic approach for obtaining the conceived form of the modeled object, keeping meanwhile its aesthetic features. Moreover, in times of mass computerization, it is essential to have skills on applying the known classical laws of graphic image designing that constitute the basis for the creation of well-constructed harmonious forms.

Figure 3: Wall decoration in Kyiv secondary school No. 53

2. Geometric analysis of flat shape elements

2.1. Fillet, as the main tool of geometrization

The shape of an object is the result of a creative process [4] that can be influenced by the environment surrounding us, by natural processes, or any other factors. A detailed elaboration of the created image, a formation of its geometric model, this is the work of architects and designers for whom a main criterion is how do observers and consumers perceive this form [4, p. 5].

Among the parameters used to describe a shape, there is a very important factor such as the dimensional ratios of shape elements, in just the same way as it happens in nature when natural beauty is determined by a diversity of, not only, forms [5] but their dimensional ratios, as well [4, p. 76]. Exactly this approach constitutes the basis of architectural bionics [6], [7, chapter 3, Sect. 3.1], where at each stage of geometric modeling objects' shape problems are being solved for the creation of a shape similar to one that is found in nature [6, p. 58–65].

More young designers are concerned with ethnic themes. An important task is to revive traditional craft practices, artistic and creative works in the field of decorative art. Nowadays this work is impossible without applying the latest computer technology, which in turn requires developing a database of ornaments' basic elements. Some of the Ukrainian ornaments can be made not only with a brush but graphically constructed following all the laws of graphic drawing as well. Therefore we face a question: is it possible to describe algorithmically the geometric design of the simplest elements of Ukrainian ornaments? In [8], it is specified that the well-known mathematician H. Weyl termed ornamental art *"the oldest aspect of higher mathematics expressed in an implicit form"*.

The analysis of geometric forms in elements of Ukrainian ornaments in [9, 10] has shown that the majority of curvilinear contours can be obtained by using simple geometric plotting.

> *"Visual expression and imagination belong more to arts, while strict logic is the privilege of science. Geometrization combines these two contrasted approaches that reciprocally permeate, arrange, and manage each other"* [11, p. 1–2]

In [9], the authors analyzed the geometric possibilities for plotting curvilinear elements in ornaments based on fillets and they developed a method of accurate contouring curvilinear elements while keeping mathematical accuracy, geometric rigor, and simplicity of construction.

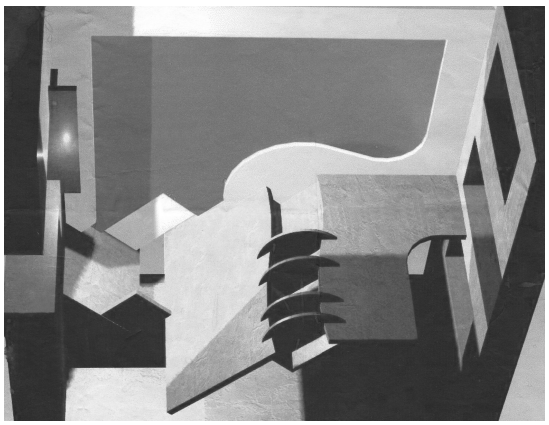
2.2. Modeling of second-order curves by arcs

Among the great number of various forms and laws on creating flat curvilinear outlines, there can be marked out the classical approach for modeling with arcs of second-order curves, which is convenient to use at early stages of designers' training. A complex decorative element is always easier to plot with simple geometric shapes, known from a school geometry course. The harmonious existence of shape elements consisting of arcs of second-order curves, namely *fillets*, gives integrity of perception and an aesthetic look to flat outline.

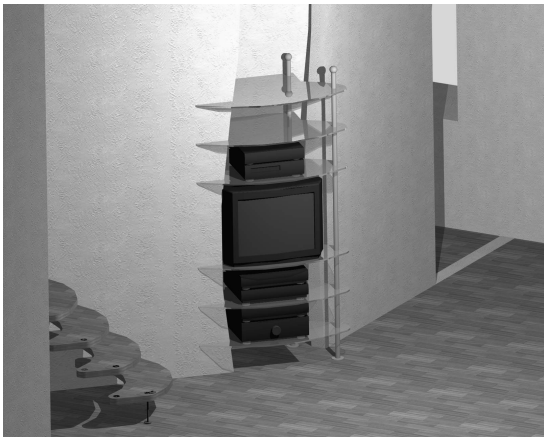
Fillets are widely applied within geometric drafting of decorative elements. Various ornaments that can be described by both a simple geometric plotting and a smooth combination of lines, circles, and arcs of second-order curves.

Fillets, as a common tool for plotting flat design shapes, allow to perform drawings under which you can later implement all required elements of a future design, and you can manufacture it directly at site.

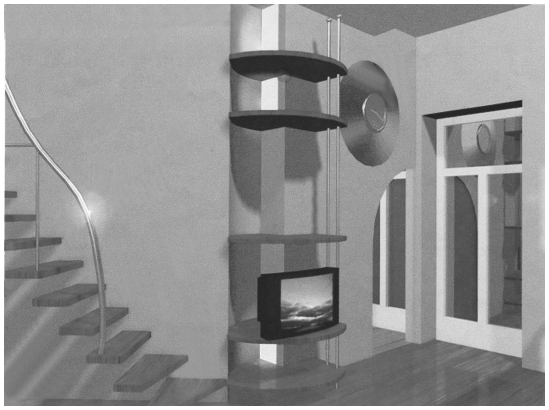
The decoration of a living room may serve as a case of fillets' use. For example (see Figure 4), the said apartment is located in a house with 4 m ceiling height. That is why it has been necessary to perform a correct and precise measurement of the interior space. In course of the apartment styling at the drafting stage, there have been made sketches of future shapes of the living room niche ceiling cornice and decorative elements; shapes of each stair have been elaborated and chosen. Then, using elementary fillets, geometric models of flat



(a) Draft sketch of future design for a living room



(b) One of shelf design options for the main niche



(c) Example of implemented niche in the living room

(d) Image of the curved cornice in the living room (final design)

(e) View of final stairs and metal handrails

Figure 4: Example of apartment design

curvilinear outlines of all curved elements have been worked out. To implement the project at the last designing stage, all the required drawings have been performed in AutoCAD, under which the patterns for working with plasterboard have been made thereafter. The final room design is shown in Figures 4d and 4e.

Such a creative design solution leaves a good impression. Curvilinear shapes of stairs, cornice ceiling, and niches remain being interior elements in trend, with focusing on them and giving the room a unique look.

2.3. Synthesis of designer's creative process and laws of geometric designs

Using computer graphics elements in implementing shape's final option, as well as applying standardized components allow the design of a great diversity of flat figures. While performing such a work, there is a need to transfer images to any surface. The best way is to use a stencil. Stencils are a universal tool for creating images on different surfaces. Due to the appearance of such images, while finishing works of premises, the authors' interior design is sure to become identifiable and memorable, cozy, and interesting.

For example, if there is required to adorn a kids' room and to decorate walls with the image of a cat, a person who has no special training and education, may choose any picture he/she likes, and afterwards perform its drawing using various geometric drafts or use a certain available drawing and scale it to the appropriate dimensions. We proposed to consider a model for plotting a curvilinear outline of the *"Cat"* (Figure 5), which can be drawn by designers for further execution of a template and for a decoration of the kids' room.

In order to develop a geometric model, it is required to determine all the centers and fillet radii that enable a complete reproduction of the given outline. By changing the outline shape

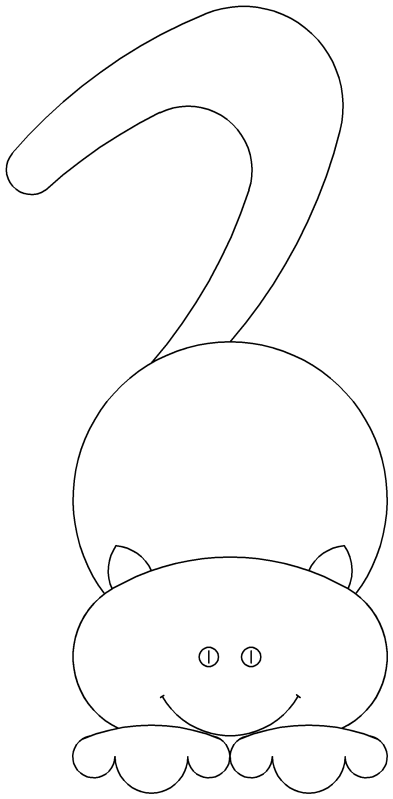


Figure 5: Picture of *Cat*

a little to make plotting more convenient, we created a geometric model. A plot of the fillet outlines is shown in Figure 6.

Key stages of plotting (Figure 6):

• We draw three circles of arbitrary radius R_1 with centers O_1, O_2, O_3, to construct the first oval formed by arcs with centers O_2, O_3, O_4, and O_5.

• The segment O_1A is extended from point O_1 along the vertical axis; thus we obtain the center B of the circle with radius $O_1B = O_1A$.

• Through the point C of intersection of the circles with radius R_1, we draw a horizontal line l, where we choose points D and E under the centers O_2 and O_3.

• Through the lower point K of the first oval, we draw a horizontal line l', where we choose points L under A and O_6 under O_2. On the segments O_6D and O_6L as well as on the semi-axes, we plot the upper half of the second oval LDK.

• The same curve is drawn through the points K, E, L'. When plotting, there have been defined the centers O_7 (arcs LM) and O_9 (arcs MD). A similar plotting has been performed on the segment KEL'.

• On the line l' between points L, L', and K, there have been selected centers O_6 (O_11), which are symmetric towards its centers O_7 and O_8 (and O_10 and O_12), so that halves of R_2 and R_3 radii circles are to be tangential to vertical lines at points L, K, L', 1, 2. At the same time the values of radii R_2 and R_3 may be arbitrary.

• The centers N and $N_\prime$ are chosen on the line AA' over the points O_8 or O_1O.

• The points 3 and 4 on first oval outline are to be taken as arcs centers, and the distance between them as radius R_4. Plot the arcs to the cross-section at point F.

• Through the points P and 5, we draw a straight line f, and through T the straight line h parallel to f. On the straight line f, we draw segments $PS = SG = 1.25\,R_1$. Through the point S, we draw a straight line j perpendicular to f.

• Continue the vertical line BT until its intersection with j at the point Q. Plot a half of the third oval with the center S and the vertices P, Q, and G. The sequence of plotting is marked by appropriate points $6, \ldots, 10$. Among them, there are the points 8, 9, and $9'$ as the centers of arcs $10 - Q - 10'$, $G - 10$, and $10' - P$.

• The fourth oval has a center at point V, a small axis TR, which size is determined by plotting of segments $TV = VR$ and half of the large axis VH.

3. Creative process and its practical visualization

Very often, designers get the opportunity to perform individual projects with elements, the shape of which combines different curves and fillets. It can be a variety of decorative stickers, cornice elements, et cetera. The best design concepts can be obtained when specialists have available and use stencils or templates by sketches and drawings executed with proper quality.

For students of Kyiv National University of Civil Engineering and Architecture who are studying "Fine Arts" or "Industrial Design", our department offers one of the graphic works by its own technique (Figure 7), similar algorithms of action as in the example displayed in Figure 6.

It is well known that all people are capable of drawing from their childhood on. Someone makes it better, someone worse. Almost all students that enter the Civil Engineering University to take specified courses, can draw very well. But, in order to master this qualification, in

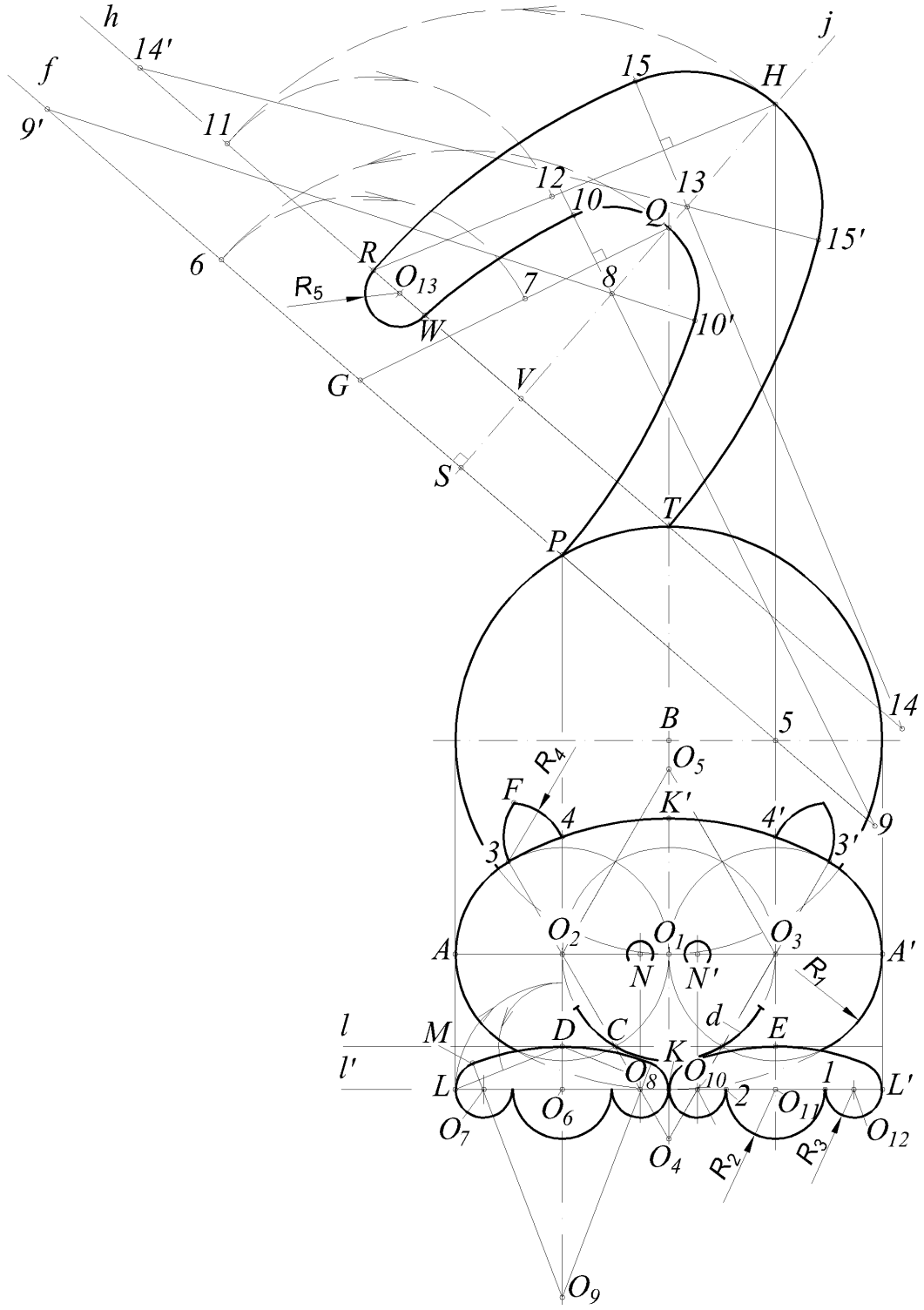


Figure 6: Geometric model of the picture *"Cat"*

addition to drawing, it is important to educate a graphic culture as well. That is why there is a goal to teach students to perform drawing of flat curvilinear outlines or flat figure outlines that they have imaged.

On the one hand, this is not a difficult task, but on the other hand, its implementation requires students to master knowledge and skills, while attending an Engineering Graphics

course. Properly selected algorithms of actions for performing fillets allow to gain the desired result.

One task for students is submitted with source data, when the student should reproduce a given drawing. Figure 7 shows a finished view of the drawing after its geometrization. For this drawing, a geometric model consisting of circular arcs and fillets of different lines has already been created.

To perform the second task, the student must find by himself a drawing of a given object and create its geometric model. It is known that the geometrization of different outlines using circular arcs is available in any CAD-systems.

From the point of view of applied geometry, students are requested to perform an approximation of planar curves. The problem of approximation for a preset curvilinear outline of a flat figure consists of two stages. At the first stage, it is proposed to discretize a given curve, i.e., to represent it as a group of nodal points. Students are required to determine the coordinates of these points by selecting them at a certain interval. At the second stage, it is required to interpolate these points. Since students have to choose the nodal points on the outline of a drawn image by themselves, their number may be sufficient for plotting circles and performing fillets, and there will even be more than they will need. So then, for executing the drawing, a variety of splines may be used.

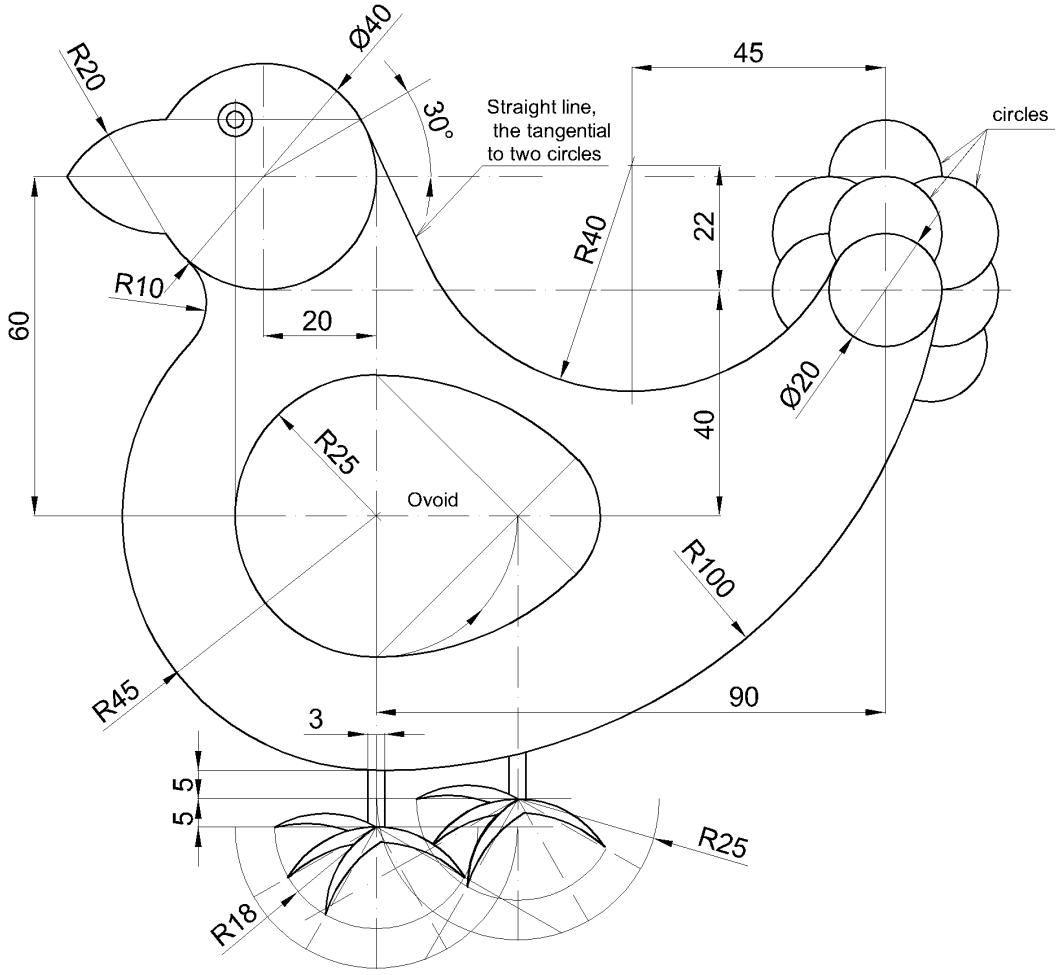


Figure 7: Geometric model of a picture *" Bird"*

4. Conclusion

In order to decorate walls or perform style design of rooms according to a selected concept, it is necessary to depict a most unique individual image. This can be achieved by whatever methods, but nowadays the most popular is wall decoration which can be performed by fixing pre-made elements on walls or by using stencils and paints. This approach will give the project an exceptional, exquisite style. Select certain segments and give them a special feeling. To achieve this goal, it is very important to perform stencils or templates of due quality.

The proposed model of flat outline geometrization that has a series of interconnected second-order curves, can become a contemporary tool for educating the graphic culture of prospective designers, and that must be taught at the first years of studies at higher education institutions in Ukraine.

The specified technique along with innate logic and intuition of students, enhanced with laws and rules of precise geometric plotting, will allow prospective designers and architects to find new creative forms for elements of design concepts. These curvilinear outlines will remain unique, harmonious, and distinguished by the aesthetics of their form.

The creation of similar flat shapes or outlines can be quite a promising trend of artistic designing of decorative elements. In our opinion, the geometrization of any two-dimensional or three-dimensional objects is an important component of creative thinking, an expressive approach to solving the tasks.

References

[1] D.J. Bohm: *Unfolding Meaning. A Weekend of Dialogue with David Bohm.* Emissary Foundation International, 1985; translated from English: M. Nemtsov, 1992. Electronic publication: Center for Humanitarian Technologies. 14.02.2019. available at: `https://gtmarket.ru/laboratory/basis/5119` [in Russian].

[2] *Geometry and Art* [in Russian]. Available at: `http://geometry-and-art.ru/geometrization.html`

[3] M.I. Yakovlev: *Composition + Geometry* [in Ukrainian]. Caravel Publ., Kyiv 2007, p. 243.

[4] Y.I. Kurbatov: *Essays on the theory of shaping: a course of lectures* [in Russian]. SPbGASU Publ., Saint Petersburg 2015, p. 132.

[5] V.Y. Mikhailenko, M.I. Yakovlev: *Geometric Prerequisites for the Creation and Aesthetiziation of Trademark Shapes in Graphic Design.* Geometry Graphics **2**/(2), 133–139 (1998).

[6] V.Y. Mikhailenko, M.I. Yakovlev: *Nature "geometry" architecture* [in Russian]. Budivelnyk Publ., Kyiv 1988, p. 184.

[7] V.Y. Mikhailenko, O.V. Kaschenko: *Fundamentals of Bio-Design* [in Ukrainian]. Karavela Publ., Kyiv 2011, p. 224.

[8] Y.Y. Simakov: *Ornaments on the plane* [in Russian]. Young scientist **5**/(1), 129–133 (2011). Available at: `https://moluch.ru/archive/28/3054/`

[9] S. Botvinovska, N. Nikolaenko, A. Piven: *Geometric modeling elements in the Ukrainian Ornaments.* The industrial Art and Design: Interdepartmental Collection of Proceeding **13**, 141–146 (2017).

[10] I.O. Kuznetsova, O.V. Loboda: *Techniques for using Ukrainian ornament in a modern interior* [in Ukrainian]. Theory and practice of design **1**, 68–74 (2012). Available at http://er.nau.edu.ua/bitstream/NAU/11965/1/19.pdf.

[11] N.L. Mayorova, G.V. Shabarshina: *Some arguments about teaching mathematics at school as a result of writing a report on the conduct of the unified state exam in mathematics* [in Russian]. VII International scientific practical conference "Mathematical education at school and university: theory and practice" (MATHEDU 2017). Publishing House of the Kazan University **1**, 180–185 (2017). Available at: http://dspace.kpfu.ru/xmlui/bitstream/handle/net/117650/F_IFME_2017_1_180_185.pdf

[12] A.A. Savelov: *Flat curves* [in Russian]. Publishing House LIBROKOM, Moscow 2010), p. 296.

Received March 12, 2019; final form September 27, 2019