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Guilloche rosette as an element of building complex geometric structures

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Abstract:

Geometry as one of the tools of cognition is widely in demand in various fields and directions. One application of this use is the construction of complex geometric structures. In particular, this is possible based on the guilloche technology, which allows the formation of patterned curves. Based on this, the work discusses some approaches to constructing guilloche rosettes. Complex geometric designs using guilloche are presented. The results are presented in the form of separate figures. Some problematic issues are also discussed.

Key words: Patterned curves, Design, Guilloche technology, Rosette, Geometric structures

Introduction

Geometric structures can be considered as one of the elements that are used in solving various applied problems [1], [2]. The scope of use of such structures is very extensive and their application is possible in any field of knowledge. These elements help either to understand what we are studying, or to ensure the protection of information in some applications of their use. Also geometric structures are a design element [3].

We can find geometric structures in pattern recognition problems [4]-[6], in the construction of security elements in securities printing [7], [8], in economics [9]-[11], in solving complex technical problems to describe the topology or connection elements of certain devices [12]-[14]. Such a variety of directions of geometric structures allows us to talk about the possibility of using various methods and algorithms to justify their application.

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One of the tools for using geometric designs is patterned curves. These curves can be constructed based on guilloche rosettes. The ability to construct various guilloche rosettes is an excellent tool for forming complex geometric structures and expanding the possibilities of their application. Based on this, the purpose of this work is to consider guilloche rosettes as a tool for forming various structures. To do this, the work provides a brief analysis of related works, and considers some for constructing patterned curves based on guilloche patterns.

Related works

Among the various studies on the design of geometric structures, let us pay attention to patterned curves and guilloche technologies.

First of all, we note that patterned curves are widely used in physics. For example, W. Gong, Y. Zu, S. Chen and Y. Yan study the transition energy curves of droplet wetting [15]. This study is important for understanding the properties of various liquid surfaces. In particular, transient-based energy transfers properties.

M. Winklhofer, R. K. Dumas and K. Liu study magnetization properties using first and second order reversal curves [16]. This is important in the study of nanomagnets, which are used as magnetic recording media with ultra-high density patterns. Such a study is based on the measurement of several families of second-order turn curves along selected profiles on a first-order turn curve diagram [16].

At the same time, N. R. Chaganty is studying the possibility of using growth curves using template correlation matrices for various applications in social, biological and medical research [17]. The paper discusses the estimation of regression, correlation and scale parameters in the respective models. The issues of assessing the structure in these models are also considered.

K. Izumi, Y. Yoshida, and S. Tokito consider patterned curves in a study of soft offset gravure printing to create finely patterned conductive layers [18]. This allows printing on a variety of curved, non-flat surfaces as well as flat surfaces using silver ink. The authors emphasize, that this method is the basis in three-dimensional printed electronics.

H. C. Lee, E. Y. Hsieh, K. Yong, and S. Nam use patterned curves to inform the design of graphene sensing devices [19]. This is important when creating a new platform for wearable devices. The authors note that they were able to develop a

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dimensionless geometric parameter that makes it possible to predict the tensile strength of a structure with high accuracy [19].

However, patterned curves have also found widespread use in the printing industry to protect documents and designs. This is based on the use of guilloche technology.

M. Al-Ghadi, Z. Ming, P. Gomez-Krämer and J. C. Burie use guilloche technology to authenticate identity documents based on counterfeit detection [20]. This is achieved by detecting counterfeit guilloche patterns. To do this, the guilloche features are first extracted and then compared with the standard. As a result, the work notes the ability to extract the corresponding characteristics of guilloche patterns and, thus, correctly compare them with the standard.

R. Tomescu, C. Parvulescu, D. Cristea, B. Comanescu and M. Pelteacu are exploring the possibility of creating micro-tags based on guilloche technology [21]. This approach can be used to protect your products from counterfeiting. The article presents the technology of forming engraved protective elements in the form of geometric structures. This makes it possible to combine different types of protective elements.

S. J. Simske studies the capabilities of guilloche technology in defining different printing strategies [22]. In particular, the article discusses applications for secure printing and additive manufacturing [22]. The basis of such applications is guilloche technology.

The study [23] considered the issues of frosting glass based on the creation of guilloche patterns using low-temperature plasma.

Thus, we see various directions for the use of patterned curves and guilloche technologies, and the features of their application. This suggests the need to more carefully consider the capabilities of guilloche technology. This is exactly what is discussed below.

Guilloche as a way to construct complex geometric structures

Guilloche – a special pattern on the surface and the method of its application [24]. Guilloche elements are a drawing made of a large number of patterned lacy thin lines, given, among other things, by mathematical formulas. Such elements can be protective nets, rosettes, borders, vignettes and corners. The guilloche design can be

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both symmetrical and asymmetrical. Currently, most guilloche elements are created on the basis of complex computer programs based on special mathematical formulas. The construction of guilloche elements is based on the use and superimposition of standard functions such as sine and cosine [25].

Guilloche elements are created in stages. First, the foundation is set, on which all subsequent steps will be built. Any geometric figure that forms a coordinate system, within which the guilloche pattern will be created, can act as a basis.

Examples of functions that are used to build a guilloche include:

$$x = (R + r)\cos(mt) + (r + p)\cos(\frac{m(R + r)}{r}t) + Q\cos(mt),$$
$$y = (R + r)\sin(mt) - (r + p)\sin(\frac{m(R + r)}{r}t) + Q\sin(mt), \quad (1)$$

where t – is a parameter, and other marks are "secret" parameters affecting the geometric shape of the socket.

You can use other functions to create guilloche. We will focus on the functions of sine and cosine, as they are the simplest. However, even these functions allow the construction of complex geometric structures.

Some examples of constructing geometric structures

Let us consider as a basic function for constructing a geometric structure a function of the form:

$$x = a\cos(t) + \frac{1}{2}\cos(bt) + \frac{1}{3}\sin(ct),$$
$$y = a\sin(t) + \frac{1}{2}\sin(bt) + \frac{1}{3}\cos(ct), \quad (2)$$

t – some parameter that determines the boundaries of the pattern change,

other parameters determine the geometric shape of the outlet.

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By changing parameters a, b, c we can get different types of guilloche rosettes (see Figure 1).

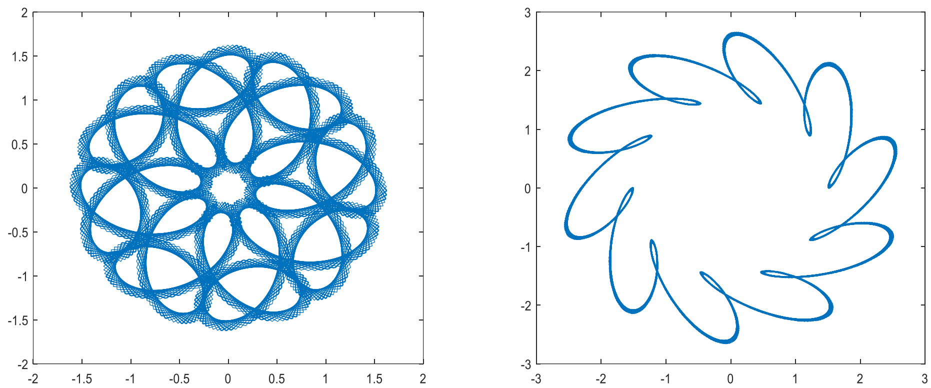

Figure 1: Examples of guilloche rosettes with different input parameters

To change the shape of the rosette, and accordingly the geometric design, we can also change the analytical expression of the basic function for constructing a guilloche. For example, for the basic function below we have the image shown in Figure 2.

$$
\begin{aligned}
x &= (2 + \frac{1}{2}\sin(at))\cos(t + \frac{\sin(bt)}{c}), \\
y &= (2 + \frac{1}{2}\sin(at))\sin(t + \frac{\sin(bt)}{c}).
\end{aligned} \tag{3}
$$

Comparing Figure 1 and Figure 2, we note different forms of constructing geometric structures.

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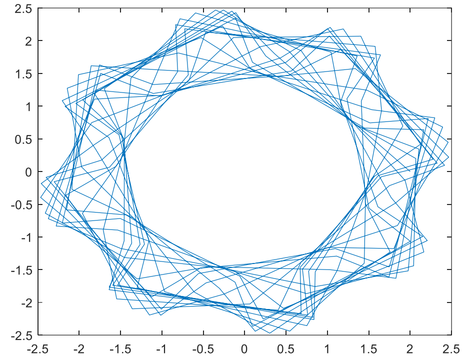

Figure 2: Guilloche rosette for formula (3)

We can also combine some guilloche rosettes into one design. This will help to obtain new images of such forms of structures. Consider this basic formula:

$$x = (2 + \sin(a1 * t1)/2) * (\cos(t1 + \sin(b1)/c1)),$$
$$y = (2 + \sin(a1 * t1)/2) * (\cos(t1 + \sin(b1 * t1)/c1)), \quad (4)$$

t1 – some parameter that determines the boundaries of the pattern change,

other parameters determine the geometric shape of the outlet.

Let's combine the form with equation (2) and equation (4) on one graph. As a result, we get a new geometric structure (Figure 3).

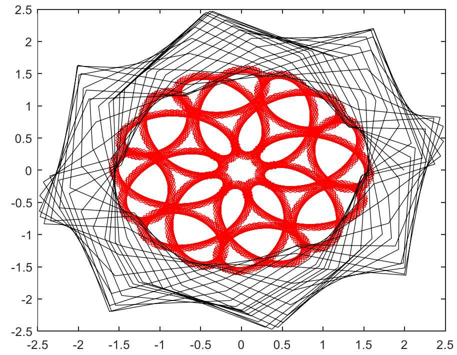

Figure 3: Example of a complex geometric structure as a combination of shapes (2) and (4)

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We also note the possibility of forming different colors when constructing individual geometric structures. This expands the possibilities of using guilloche technology. As a consequence, we can build different geometric structures with separate colored components.

Conclusion

The article discusses the main points of using geometric approaches in various fields and areas of research. Among these approaches, special attention is paid to patterned curves and guilloche technologies. These approaches can be used to protect information and add graphic design to printed products. It is shown that using the example of simple basic functions in constructing such curves, complex geometric structures can be obtained. Moreover, such designs can have a separate color component, which increases the degree of information security and improves the design of the perception of possible products.

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