Forensic land surveying: accuracy data testing through a computer-graphic model

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Abstract. The work is devoted to one of the aspects related to the resolution of disputes over the boundaries of land plots. Recently, the number of these disputes has been steadily growing, which confirms the relevance of the chosen topic. Border disputes are currently resolved only through the courts, almost always with a forensic land surveying. The aspect considered in the article concerns the accuracy of constructing models of the objects of surveying, since software products used do not have documentary evidence of the accuracy of the created models. Therefore, experts need to independently test the models for accuracy. Moreover, such tests make it possible to reveal expert errors at the modeling stage. The paper proposes the authors’ method of testing for the accuracy of a computer-graphic model of objects, studied by a forensic land surveying.

1. Introduction
Land disputes are a specific category of conflicts. The difficulty of resolving them is due to a number of factors: the nature of the object of the dispute is dual (a land plot is viewed, on the one hand, as an object, on the other hand - as a resource); lack of an established practice of resolving disputes of this category; haste and unpreparedness of the land reform of the 1990s; lack of clear regulation and detailing of the procedure for individualization of the previously registered land plot thus far; discrepancy between the accuracy of the geodetic base of the real estate cadastre and the required accuracy of the location of land plots (the geodetic base was created for completely different purposes) and many others. Land disputes are also relevant abroad [1–3].

Every year the number of land disputes on the boundaries of land plots considered by the courts, as well as the number of their varieties, is growing. In the mid-1990s, there was a transition from administrative to judicial consideration of land disputes [4]. The correct resolution of disputes about the boundaries of land plots is a complex process, therefore, at present, not a single consideration of these disputes is complete without the appointment of a forensic land surveying.

2. Results and Discussion
Forensic land surveying, as an independent type of examinations received official recognition in the Order of the Ministry of Justice of the Russian Federation of December 27, 2012 No. 237 "On approval of the List of types (varieties) of forensic examinations performed in federal budgetary forensic institutions of the Ministry of Justice of Russia, and the List of expert specialties, which are granted the right to independently conduct forensic examinations in federal budgetary forensic institutions of the Ministry of Justice of Russia ". The overwhelming majority of forensic land surveys are currently appointed by the courts when resolving disputes about the boundaries of land plots, in particular:
disputes over the establishment of a boundary, invalidation of the results of demarcation and cancellation (exclusion) of information from the USRIP (Unified State Register of Immovable Property), invalidation of the formation of a land plot, on elimination (recognition) of a register error, on the elimination of obstacles in the use of a land plot, on reclaiming a land plot from someone else's illegal possession, disputes over the transformation of land plots, and others [5].

The administration of a forensic land surveying implies, first of all, a special study in accordance with procedural legislation. The study consists of a number of stages [6], but its main substantive essence is the comparison of information about the boundaries of land plots, capital construction objects, as well as other elements contained in various sources. As a rule, this information is heterogeneous in its form, so often a head-on comparison (for example, a simple comparison of coordinate catalogs or a “visual” comparison of the configuration of objects submitted for the study) is impossible. The sources from which the information for the expert study is taken are the information contained in the Unified State Register of Immovable Property (USRIP), legal documents, documents on the formation of land plots, in the materials of technical inventory and land management materials, various urban planning documents, as well as in many others. Separately, one can single out a source associated with the conduct of expert in-situ measurements - this is the data that the expert receives directly at the facility.

Due to different forms of presenting information on land plots, a comparative study presents a certain difficulty, therefore, in the production of forensic land surveying, as well as in the performance of other kinds of examinations, not all attributes of the objects of study are identified and compared, but only those that are directly relevant for conducting expert investigation. This approach, associated with the reduction of insignificant characteristics, is essentially a modeling process. Of course, the expert is free to independently choose the type of a model (computer, electronic, electrical, mechanical model, research model presented on paper, etc.). Until the mid-2000s, research within the framework of land disputes was carried out exclusively in models on paper, and the computer was considered only as a powerful calculator and typewriter: an Excel spreadsheet processor allowed calculations and saving their history, change of calculation parameters, and Word text processor - to formulate an expert opinion in accordance with the requirements.

But in recent decades, the exponential growth of the calculating power of computers, the global expansion of the scope of their use made it possible to fill with a new, deeper meaning the words of the ancient Greek thinker Pythagoras. He argued, two and a half thousand years ago, that number is the essence and meaning of everything in the world. Today, when everything used by man has been digitized, number as the only and universal characteristic of everything that exists has become its basis. Therefore, when we talk about a model within the process of producing a forensic land survey, we mean a computer-graphic research model created with the help of certain software. The name “computer-graphic” indicates two of its fundamental properties: it is a model capable of performing calculations, as well as graphically displaying objects, their relative position, their characteristics and calculation results.

That is, in other words, an expert-land surveyor first builds a computer-graphic model, and then proceeds to study the objects reflected in the model in order to obtain answers to the questions posed. Based on the logic of the study, the computer-graphic model should ensure the fulfillment of the following research tasks: construction of models of real estate objects and other objects of forensic land surveying in the form of flat geometric figures with the preservation of proportions along the given spatial geodesic coordinates; construction of various geometric objects of various shapes relative to the points already available in the model using various resection methods and obtaining the values of their coordinates; determination of line lengths and distances between lines and points in the model; determination of the areas of closed contours; presentation of research results in an acceptable form.

When performing any operations in a computer-graphic model, an important parameter is the accuracy of both the constructions and the calculations carried out in it, therefore the expert needs guarantees that the model is built correctly, and the actions carried out in it have the proper accuracy. In addition, determining the accuracy of the model would help the expert himself (especially a beginner or insufficiently attentive expert) to avoid some of the mistakes that are made during modeling.
It should be noted that when modeling objects investigated in land surveying, the requirements for modeling accuracy are relatively weak: as a rule, the maximum accuracy in the documents under study and regulatory requirements are limited to the second decimal place, i.e. the accuracy is 0.01 m.

In the course of litigation, it often happens that the parties, disagreeing with the results presented by the expert in the opinion, ask the expert to justify the accuracy of the modeling results, i.e. evidence that the aforementioned research problems in the model are solved with appropriate accuracy. Here, the disagreeing parties draw an analogy with geodesic equipment, which, in accordance with regulatory enactments, must be verified and have an appropriate certificate. Therefore, the software product must also have confirmation of the accuracy of its constructions. The participants in the process and the court have the right to demand detailed justifications for the accuracy of the studies carried out in the model from the expert, and this is substantiated in the legislation. Thus, Articles 4 and 8 of the Federal Law "On State Forensic Expert Activity in the Russian Federation" establish a requirement for the objectivity of expert research, i.e. its results should not depend on the subject of expert activity, as well as on the model used.

These circumstances, repeatedly appearing in litigation, prompted us to conduct research on the software that experts use to create computer-graphic models. A survey of 255 land surveyor experts showed that all interviewed experts conduct research in computer-graphic models, while mainly using AutoCAD and MapInfo software, as well as Credo Dialog and ARGO - a software package for cadastral engineers.

A detailed study of the software products documentation on the websites of the companies-developers the above mentioned software products, as well as materials about these products on the Internet for information about the accuracy of modeling in them, did not bring any results. Therefore, letters were sent to the companies responsible for the development and support of the above mentioned software, asking whether the developer had documents confirming the accuracy of the models created by its software. Such documents could be, for example, testimonials of certification of a software product (voluntary or mandatory), or some other procedure confirming these provisions. None of the companies surveyed provided evidence that their software product was certified for modeling accuracy, although it is worth noting that the software products are certified to meet various other requirements. In response to our question, company representatives indicated that there was no statutory need for such certification.

In addition, we searched for software products for spatial modeling on the website of the State Register of Measuring Instruments (https://info.metrologu.ru/grsi/). There are no such programs in this register. And this is quite natural, since the programs do not make measurements (to measure some value means to compare it with a homogeneous value taken as a unit), and the required values are calculated mathematically in them.

Thus, not a single software product, even if it is legally acquired, does guarantee that the model built in it and the values determined in it are calculated correctly, although many experts, due to the high cost of original software products, use their unlicensed hacked copies.

In this situation, an expert must independently test each model he has built, since this will ensure the accuracy of constructions, the accuracy of determining the coordinates and other characteristics of objects, will point out the expert's errors (explicit and implicit), as well as errors in calculation methods, limitations in the use of mathematical apparatus, if these took place during the study. In this case, by testing a model, we propose to understand a set of operations performed in order to confirm the compliance of a model with the established requirements for accuracy.

Since AutoCAD is the most common tool for creating models in the production of forensic land surveying among private experts, and is also used in the Russian Federal Center for Forensic Science under the Ministry of Justice of the Russian Federation [7], we will consider testing a model using this software product.

We propose to test the model as follows. First, the very computer-graphic model of the objects of study of the forensic land surveying is created. As a rule, such a model is created based on the results of expert field measurements or according to the information on the spatial position of the research objects...
contained in the USRIP. Then, a test frame is built in the model, for this it is necessary to select five points from the available in the model, four of which should form a quadrilateral that maximally covers the points of the model. The fifth point must be selected in the center of the quadrilateral, but not at the point of intersection of its diagonals. After that, it is necessary to use a polyline to connect all the selected points to each other according to the following scheme: 1-2-4-1-3-2-5-4-3-5-1. An approximate selection of points and the polyline connecting them are shown in Figure 1.

Next, from the obtained polyline, using the "_list" command, get the coordinates of the vertices of the test frame and import the coordinate catalog into the Excel spreadsheet processor. In Excel, using a well-known formula, determine the distances between all points of the frame. Then, in the model, use the Dimension tool to define and display those same distances. The results are shown in Figure 2.

The data obtained must be entered into a table; an example is presented in Table 1.

In addition to controlling the distances when testing the model, it is necessary to control the areas. To do this, using Excel tools, for example, using the VLOOKUP command, generate tables containing the coordinates of the vertices of nine shapes, according to the following schemes: 1-2-3-4-1, 1-2-5-1, 2-5-3-2, 3-5-4-3, 4-5-1-4, 1-2-4-1, 2-4-3-2, 1-2-3-1 and 1-4-3-1. The calculation of the areas of figures by the coordinates of their vertices is carried out using the Gauss formula. Then the areas of these shapes are determined in AutoCAD and compared with the results of calculations. The data obtained must be presented in tabular form, an example is presented in table 2.
Table 1. Distances control

| Point No. | Coordinates      | Distances, m | Divergences |
|-----------|------------------|--------------|-------------|
|           | X                | Y            | Calculated  | By AutoCAD |            |
| 1         | 1 290 707.92     | 359 831.58   | 93.36       | 93.36      | 0.00       |
| 2         | 1 290 799.23     | 359 812.11   | 46.95       | 46.95      | 0.00       |
| 4         | 1 290 759.41     | 359 787.24   | 67.95       | 67.95      | 0.00       |
| 1         | 1 290 707.92     | 359 831.58   | 105.70      | 105.70     | 0.00       |
| 3         | 1 290 780.00     | 359 754.27   | 60.95       | 60.95      | 0.00       |
| 2         | 1 290 799.23     | 359 812.11   | 108.52      | 108.52     | 0.00       |
| 5         | 1 290 696.72     | 359 776.50   | 63.60       | 63.60      | 0.00       |
| 4         | 1 290 759.41     | 359 787.24   | 38.87       | 38.87      | 0.00       |
| 3         | 1 290 780.00     | 359 754.27   | 86.20       | 86.20      | 0.00       |
| 5         | 1 290 696.72     | 359 776.50   | 56.21       | 56.21      | 0.00       |

Table 2. Areas control

| Point No. | Coordinates      | Area, sq. m. | Divergences |
|-----------|------------------|--------------|-------------|
|           | X                | Y            | Calculated  | By AutoCAD |            |
| 1         | 1 290 707.92     | 359 831.58   | 5 245.91    | 5 245.91   | 0.00       |
| 2         | 1 290 799.23     | 359 812.11   | 1 523.09    | 1 523.09   | 0.00       |
| 3         | 1 290 780.00     | 359 754.27   | 1 523.09    | 1 523.09   | 0.00       |
| 4         | 1 290 759.41     | 359 787.24   | 1 523.09    | 1 523.09   | 0.00       |
| 1         | 1 290 707.92     | 359 831.58   | And so on for each figure | 5

3. Conclusion
Since the norm contained in Article 8 of the Federal Law "On State Forensic Activity in the Russian Federation" requires the inclusion in the expert's opinion of provisions that make it possible to verify the validity and reliability of the conclusions drawn on the basis of generally accepted scientific and practical data, the results of model testing should be placed in the conclusion. Thus, in the research part of the conclusion, it is necessary to place diagrams and calculation results in tabular form, examples of which are given in this article, with a description of the operations performed.
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