Development of an algorithm for creating an insolation solution for a building within the construction area

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Abstract. The work is devoted to the issues related to the development of the insolation solution for the building within the construction area. It is worth noting that these aspects are regulated normatively in most of the countries. The paper presents one of the possible approaches to the development of a script that makes it possible to automate the process of developing an insolation solution for a building in the construction area redistribution according to the criterion of the insolation duration. The introduction of this algorithm in urban planning practice will give the architect a tool that will allow, at the initial conceptual stage of designing a new building, to find the optimal shape and location for the building from the point of view of the insolation duration, as well as to obtain a parameterized BIM model of the building, to create the apartments’ layout, providing the conditions comfortable for the people to live, or during the additional calculations of the “passive house” project development. At the same time, there is a significant reduction in time and labor costs.

1. Introduction
Currently, in the countries that have the cities with a limited number of sunshine hours, many aspects are normatively regulated related to the development of an insolation solution for a building within the construction area. An example of such documents may be the following [1]:
- Regulation № 620/2002 of the Ministry of Infrastructure on the technical requirements of Poland, which establish the requirements for insolation standards in schools and childcare buildings;
- Standard EVS 894: 2008 / A1: 2010 Daylight in residential buildings and offices in Estonia, which establishes the rules for the design of residential and office buildings with regard to natural daylight;
- The environmental sustainability assessment protocol for the adoption of building regulations by the regions sets the standards for insolation in Italy;
- DIN 5034 Standards “Daylight Indoor” and the VDI 6011 Series of Guidelines “Optimization of Daylight and Artificial Lighting” in Germany, which contain the general requirements for the residential and industrial premises’ insolation, as well as the principles, rules, methods and criteria for calculating insolation, the requirements to lighting brightness and acceptable glare;
- Regional regulations prohibiting the construction of high fences (Spite fence) in the United States, etc.

In Slovakia, the rules governing the requirements for providing natural lighting are contained in a number of documents and establish that the solar (natural) lighting should be provided in all types of spaces with constant employment (schools, offices, residential buildings, hospitals, kindergartens, etc.):
- Decree of the Ministry of Health of the Slovak Republic № 259/2008;
- Decree of the Ministry of Environmental Protection of the Slovak Republic № 532/2002;
- Standard STN 73 4301:2005 Residential buildings, etc.

In Russia, the requirements for insolation and sun protection of premises in the residential and public buildings and territories are established by the Sanitary rules and regulations 2.2.1 / 2.1.1.1076-01 “Hygienic requirements for natural, artificial and combined lighting of residential and public buildings”. The standardized duration of continuous insolation for the premises of residential and public buildings is set differentially depending on the type of apartments, the functional purpose of the premises, planning zones of the city, and geographical latitude.

However, the calculations of insolation by automatic methods in Russia are not yet accepted for consideration during the examination, nevertheless, for the internal audits and for the coordination with the customer, such tools can be widely used. Much attention is paid to the improvement of methods for calculating insolation, the development of automated systems for calculating insolation, etc. [2-7].

At the same time, the analysis of scientific works showed that the process of developing an insolation solution for a building is very time-consuming and requires considerable time, in this regard, the goal of this work is to develop an approach to automate the process of creating an insolation solution for a building within the construction area, taking into account the existing experience.

2. Methods and methodology
Despite the fact that in 2008 the Decree of the Government of the Russian Federation No. 87 dated February 16, 2008 “On the composition of the project documentation sections” abolished the mandatory section with a calculation for insolation in the project documentation, the task remains relevant and very important to ensure a comfortable living environment for a person. However, the calculation of insolation is necessary to solve the practical problems specified in BC 42.13330, BC 54.13330, BC 160.1325800, and aimed at fulfilling the hygiene requirements of Sanitary rules and regulations 2.2.1 / 2.1.1.1076, Sanitary rules and regulations 2.1.2.2645, Sanitary rules and regulations 2.4.1.3049, SanPiN 2.4.2.2821 on the duration of premises’ insolation in the designed, under construction and existing buildings, as well as in the territories adjacent to these buildings.

To calculate insolation in Russia, the provisions of GOST R 57795-2017 “Buildings and structures. Methods for calculating the insolation duration” are applied.

The calculation of the insolation duration of the residential, public buildings and territories premises is carried out using the solar maps and insolation graphs, which are a combination of hourly radial lines and shadow line on the day of the beginning (end) of the insolation period.

The insolation duration calculation can also be carried out using the solar charts, which are a horizontal plane in the form of a circle with drawing on it the trajectory of the sun from sunrise to sunset at a certain point in time, depending on the azimuth and the sun height, it is also necessary to have a shadow goniometer, which drawn in the same projection and scale as the solar map, and is a horizontal projection of the firmament half, onto which the coordinate grid is projected, consisting of the curved and radial line systems. The system of curved lines represents the equal vertical shadow angles, and the system of radial lines represents the equal horizontal shadow angles. On the other hand, the equal vertical shadow angles’ curve can be interpreted as the perspective of the unlimited length buildings located at the equal angular distances. Each line from the radial line system in this case will depict the building length limitation in the angular measurement.

At the same time, due to the building density and irrational placement increase in the buildings, the insolation duration is reduced, which leads to a decrease in the people’s life comfort. Therefore, one of the main tasks of architects and builders is finding the ways to increase the residential premises’ insolation duration. However, the initial way to increase the building’s insolation is to choose the right insolation solution for the building within the construction area. At the same time, the above-mentioned methods are very laborious and take a considerable amount of time. Automation of this process using the information modeling technologies can solve this problem.

2
In the study, to achieve the set goal - designing free forms to the set criterion, the Grasshopper visual editor was used, which was originally conceived in order to reduce the amount of routine work in Rhino - a three-dimensional modeling program.

Let us consider, for example, the process of creating an insolation analysis algorithm in the Revit computer-aided design software package using the Dynamo visual programming platform in general in accordance with [7]:

1) The shapes of several adjacent buildings are created;
2) A family of the facade panels is being created, the southern facades in front of the buildings are not separated to speed up the calculation process, since they will have the same insolation;
3) Next, the “Solar” parameter is created, which indicates the insolation time and a filter is set to sort the stained glass panels; the panels with insolation of an hour or less are highlighted in black, dark gray - up to 1.5 hours, light gray - up to 2 hours, white - from 4 hours or more;
4) Next, the transition to the Dynamo program, which sets the shading geometry, by selecting all panels, is in progress;
5) Then, the location of the buildings, the analysis periods are set, and the solar path with the necessary density is constructed, that is, the number of sun positions per hour is taken into account;
6) The panels are divided into planes, and the outer face is selected, then the center point is found, the normal is drawn from it and the duration of the sun shining on each panel is calculated and converted to hours;
7) At the end, the panels are set to the “Solar” mode according to the calculated time.

The result of the analysis is a color display of the panels’ insolation time. Insolation time data can also be automatically entered into the specification.

3. Results
As a result of the studies, the algorithm presented in Figure 1 was developed to create an insolation solution for the building within the construction area, the main criterion of which is the insolation duration.

![Algorithm for creating an insolation solution for a building within the construction area](image)

Figure 1. Algorithm for creating an insolation solution for a building within the construction area
The result of this step is shown in Figure 2. Similarly, the geometry of the environment is created.

**Figure 2.** Creating a parameter for each floor rotation and the main building model formation

Then, on each floor, the geometry of the windows is created, observing their height, width and number of sectors, also considering the height relative to the floor (Figure 3).

**Figure 3.** Creating window geometry and setting the parameters to change their properties

Next, using the built-in nodes, we obtain the data on the object’s location. Based on the location data and the specified time data (day and month), the trajectory of the sun is constructed. Based on the obtained trajectory of the sun, the geometry of the main building and the shading building, the insolation duration for each window is calculated and a vertical ruler is created that correlates the insolation duration with the corresponding color.
4. Summary

Insolation is one of the most important factors affecting the life of each person. Compliance with the regulatory requirements of insolation standards can guarantee the creation of a favorable lighting environment, both in a single apartment, and in everything in a city or village.

For convenience, the results can be uploaded to PO ArchiCAD software.
The paper presents an algorithm for creating a script to automate the process of developing an insolation solution for a building in the construction area redistribution according to the insolation duration criterion.

The introduction of this algorithm in urban planning practice will give the architect a tool that will allow, at the initial conceptual stage of designing a new building, to find the optimal shape and location of the building from the point of view of the insolation duration, as well as to obtain a parameterized BIM model of the building, to create the apartments’ layout, providing the conditions comfortable for people to live in, or during the additional calculations of the “passive house” project’s development. At the same time, there is a significant reduction in time and labor costs.

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