

Visualization Elements in the Examination of Dangerous Production Facilities using an Unmanned Aircraft

A.E. Kozlova¹, M.Yu. Narkevich², O.S. Logunova³, K.E. Shakhmayeva⁴

Federal State Budgetary Educational Institution of Higher Education "Nosov Magnitgorsk State Technical University", Magnitogorsk, Russia

¹ ORCID: 0000-0002-3109-2185, kozlova-ann99@yandex.ru

² ORCID: 0000-0001-6608-8293, narkevich_mu@mail.ru

³ ORCID: 0000-0002-7006-8639, logunova66@mail.ru

⁴ ORCID: 0000-0001-8041-9853, kseniyashakhmaeva@yandex.ru

Abstract

The paper considers the possibility of using visualization when preparing a task for frontal surface examination of hazardous industrial facilities using unmanned aerial vehicles. The research is based on the results of an experimental survey of buildings and structures of a large metallurgical enterprise in Russia. As initial data, photographs of buildings and structures obtained using a camera of an unmanned aerial vehicle and their drawings were used. When building a 3D model, the capabilities of Autodesk AutoCAD and Autodesk Revit were used. When building a 2D information model, a combination of a 3D model and a photograph of the object was used. The resulting 3D and 2D models are included in the structure of the flight chart as part of an applied digital platform in an automated decision-making system for expert assessment of the technical condition compliance of a hazardous production facility with regulatory requirements. Violation of regulatory requirements entails the occurrence of emergencies and incidents at an industrial enterprise. Visualization elements allow increasing the reliability of information entering the database of expert information.

Keywords: automated system of expert evaluation, visualization elements, 3D object model, 2D object model, model matching, flight map structure.

1. Introduction

For the whole period of 2021, according to government statistics of the Integrated Interdepartmental Information and Statistical System (UMISS), the number of commissioned buildings of all types, namely office buildings, residential buildings, commercial buildings, industrial buildings, agricultural buildings amounted to 31252 units, with industrial buildings accounting for 5948 units, which represents 19%. Between January and July 2022, the number of commissioned buildings was 15436, of which 4113 buildings belong to the industrial sector, representing 26.6% [1]. At the same time, based on statistical data, we know that the number of buildings that have reached the end of their useful life, but are still in use, is 75% or more [2].

The widespread spread of IT technologies across economic areas has increased the use of new technical means for collecting information. The use of unmanned aerial vehicles (UAV) with subsequent visualization of real-world objects is becoming more and more popular for these purposes. A UAV is an air vehicle without a crew on board, with varying degrees of autonomy, from remotely controlled to fully automatic, with differences in design and purpose. The UAV is remotely controlled, in most cases by a personal computer or smartphone to which all data from the UAV's video devices is transmitted [3]. UAVs are used

to collect and record information in various fields: agriculture [4, 5], medicine [6, 7, 8], rescue operations [9, 10], object security [11, 12], construction [13, 14, 15], etc.

The use of UAVs in construction is worth considering in more detail. For example, UAVs equipped with motion sensors, infrared cameras or night vision cameras collect data that are used for remote control of the construction process, site mapping, data analysis and recording, thermal imaging, which is used to monitor underground and aboveground thermal communications, and building height surveys [16]. UAVs are also used to create digital twins in the mining industry. Thus, UAVs equipped with the RTK module are used to collect information. This module allows the quadcopter to determine its location in space, geo-referenced to the area and, depending on the flight altitude, get the values of land marks with a certain error. The collected information is processed in modern software complexes, such as Sarex. As a result of data processing and creation of a digital twin, the expert can see the area on which it is planned to work and determine the suitability of the area [17].

The use of UAVs in the examination of objects to monitor their technical condition is no exception. The availability of rich photo and video material obtained from UAVs opens up opportunities for post-expert examination of objects and processes, creation of 3D models for digital twins and digital shadows of objects.

The survey of hazardous industrial facilities requires quite a lot of time and human resources for its implementation. Non-compliance with industrial safety requirements results in production stoppages, economic losses, environmental damage and loss of life. For example, in Russia there were 19 major industrial accidents in 2021-2022. Each of these accidents caused victims and fatalities amongst plant employees. Therefore qualitative analysis and a correct evaluation of the expertise depend on the qualifications of experts and technology. In these cases, it is impossible to determine the danger of temporarily hidden defects that will later lead to a more complex condition of the building or structure. It is for these reasons that the inspection process has been attempted to be automated over the past few years, using 3D visualisation.

In the field of hazardous industrial facility inspections, visualisation is used by creating 3D models. For example, one way of analysing defects on buildings and structures is to create a 3D model using laser scanning [18, 19]. At the first stage of this method laser scanning of a building is performed which results in a "point cloud" each having XYZ-coordinates. This point cloud is then converted into a high precision geometric CAD model of the building. In addition, visualisation is used for mapping terrains, locations that are difficult to access or to scale [20].

In addition to the laser scanning of a building, the Building Information Model (BIM) is used. A building information model is involved in almost the entire life cycle of a project, covering not only planning and design, but also cost management, construction process, facility operation, etc.

The general problem considered in this study is to improve the industrial safety of enterprises. The purpose of the study is to improve the reliability of information obtained using UAV to make decisions about the technical condition of hazardous production facilities in an automated system of expert evaluation.

The team of authors of the work has conducted preliminary studies in which:

- determined the challenges of using visual information in the examination of hazardous production facilities [21];
- determined the rational trajectory of the UAV in accordance with the objectives of the study [22];
- the basic algorithms for processing visual information and, depending on the problem to be solved, the use of threshold, template and neural network technologies [23].

The object of the study is an automated system for assessing the compliance of the technical condition of hazardous production facilities based on graphical information about the level of development of visually assessed damage.

One of the tasks of the automated expert assessment system is the construction of a flight map of the task, which should give a visual representation of the object under study and allow interactively setting the trajectory of the UAV flight on the image of this object.

2. Methodology for formalising real-world objects for transition to an applied digital platform

In the implementation course of the automated expert assessment system, the authors of the work designed and developed an applied digital platform (ADP), which includes 10 software modules [24]. The input data for the software modules operation are the images of the elements of hazardous production facilities, obtained by technical means, including UAV cameras, after applying the formalization methodology. The scheme of the methodology is shown in Fig. 1.

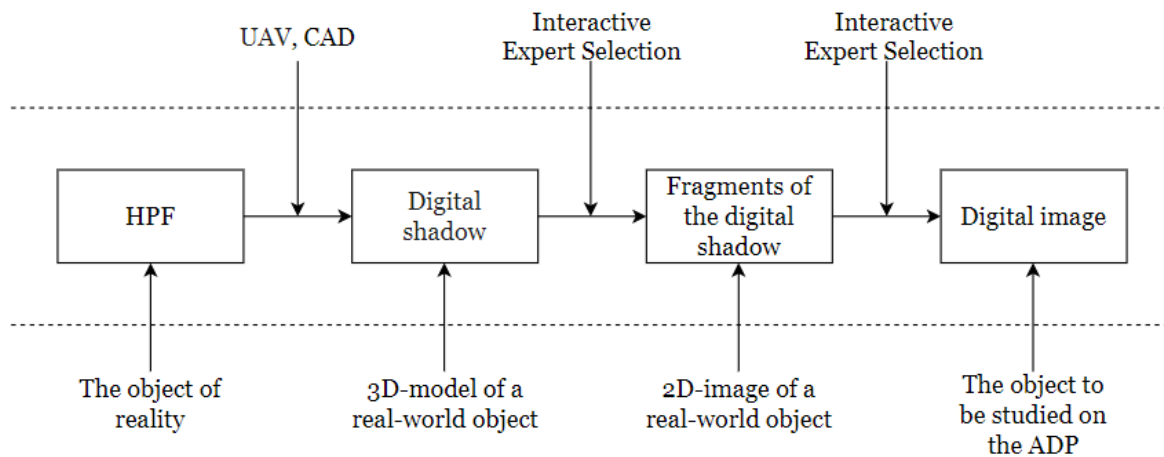


Figure 1 - Schematic diagram of the methodology for formalising the elements of hazardous production facilities to the object of the study on an applied digital platform: HPF - hazardous production facility

The essence of the methodology is to move from an actual reality object to a possible digital object, which is used by the digital application platform.

Two roles are defined in the digital application platform: technologist and expert. The technologist prepares information using the capabilities of the PCP for peer review. The technologist's role includes: obtaining information about the state of the EOP element from the UAV and transmitting it to the DDC to form a digital shadow. Using the digital shadow, the expert identifies fragments which are scrutinized and transmitted as digital images to the DDC as input data to a set of software modules.

To build and visualize a 3D-model of a hazardous industrial facility we chose methods that allow joint use of drawings of objects and their photographs. For realization of methods applied software was used:

- Autodesk AutoCAD to correct the drawing, to calculate numerical characteristics (height, length and width) of objects such as walls, windows and doors, stairwells;
- Autodesk Revit for creating a 3D model of an object;
- Adobe Photoshop for creating digital shadows.

2.1 Description of the raw data for the visualisation of the survey results

The input data for the visualisation of the results of a drone survey of industrial buildings and structures are photographs and drawings of objects.

The object drawing was obtained using Autodesk AutoCAD software. All major numerical features (building height, door opening dimensions, dimensions of supporting and non-

supporting walls) were defined on the drawing. In addition to the main features, the main axes have been marked on the drawing. These axes are called coordinate or breakout axes. They are indicated by a dashed line that runs through the entire building (plan, facade, section), component or element. In the drawing used for the trial operation, 55 dividing axes were constructed, dividing the drawing horizontally and vertically, as shown in figure 3. 3. These axes are marked alphabetically (B-H) and numerically (1-44).

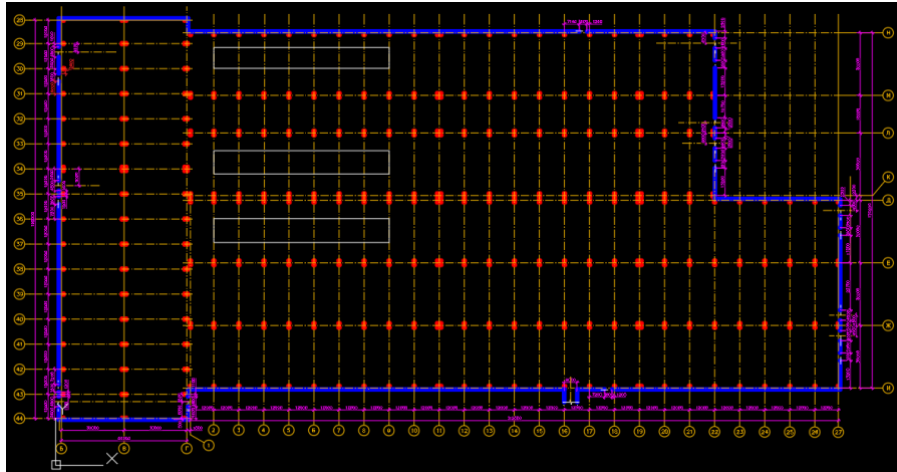


Figure 2 - Plan of MMK SLS-8 building

Photos of the building are used to achieve the adequacy of the 3D model. The adequacy of the model refers to the matching of the appearance, parameters and characteristics with the original structure. Photographs are grouped in accordance with the breakdown axes for the correct positioning of windows, doors and production staircases. Examples of photos are shown in Fig. 3 and Fig. 4.



Figure 3 - Front of SLS-8 building (I-D axes)



Figure 4 - Front of SLS -8 building (H-axis)

2.2 Methodology for 3D visualisation of industrial buildings and structures according to design/technical documentation

Autodesk Revit software was used for 3D visualisation of the object. After editing the drawing, the drawing file was imported into Revit for the model design process.

The process of creating a 3D model includes the following steps:

- 1) constructing the main Y and X axes, which are the basis for the walls;
- 2) Creating templates for load-bearing and non-bearing walls, and adjusting the corresponding thicknesses;
- 3) connection of libraries that include objects (doors, windows, stairways, columns) needed to create a 3D model of the building or structure that approximates the original building;

4) design of walls, placement of windows and doors according to the drawing and photographs of the building or structure.

5) Designing the ceiling and roof. First the ceiling is designed on the basis of the external walls. Then the roof is superimposed on top of it and its shape and type of covering is specified;

6) designing stairwells that are part of the building façade and are outside the building itself;

7) Transition of the workspace from 2D to 3D view and its adjustment: possibility to change the location of the model relative to the central axis and adjust the surroundings.

The digital shadow of a building or structure is a virtual 2D digital model of a building or structure used to integrate the operation of various engineering systems, e.g. lighting, climatic conditions, security and fire systems, etc. A digital shadow uses 3D models with specified parameters, but is not able to predict what may happen to the product under certain operating conditions. Thus a digital shadow must be able to predict the behavior of the real object only under the conditions in which the data is collected, without affecting the data.

In general, a digital shadow is created by combining 2D data from an original object with its 3D model. In this work, selected photographs of the original building facade are superimposed on the facades of the 3D model on four sides: north, south, west and east. To better demonstrate the adequacy of the 3D model, the superimposed photos are reduced in degree of transparency. After designing the 3D model of the object, the photos were analysed and a digital shadow was created to analyse the degree of defects on the façade.

3. Research results

3.1. Pilot site description

One of the pilot sites selected for the study was the building of Plate Mill No. 8 (SLS-8) of PJSC Magnitogorsk Iron and Steel Works, which is one of the largest enterprises in Russia and annually produces from 10 to 12 million tons of steel. The facility is designed to carry out technological processes for the production of bent sheet metal products. The building was put into operation in 1975. SLS-8 is a class II hazardous production facility (highly hazardous production facilities).

The constructive scheme of the building is a metal frame and ligament framework. The wall enclosure is composed of hinged slag thermosite concrete wall panels measuring 6000×1200×240 mm and 6000×1800×240 mm. The panels are fastened to the building framework in a flexible manner, ensuring the independence of longitudinal deformations of the panels and the building framework. Fixing is provided at four points. The gates and doors of the built-in premises are metal. The floors consist of metal and ceramic slabs and concrete.

The "usable" area of the frontal survey is the element surface of the hazardous production facility (building, structure or technical device) excluding the areas inaccessible to UAV control and non-informative areas.

The building of the main section building of roll-formed sections of SLS-8 was constructed in two stages:

- First stage: transverse spans "B - C", "C - D" in axes "34 - 44" and longitudinal spans "E - F", "E - G", "G - I" in axes "1 - 27";

- Second stage: cross spans "B - C", "C - D" in axes "28 - 34" and longitudinal spans "C - L", "L - M", "M - H" in axes "1 - 22".

The examination object is a single-storey, multi-bay industrial building with built-in premises, divided by longitudinal and transverse expansion joints into 6 temperature blocks.

Total length of the building - 372,0 m, including the length of two transverse spans - 192 m, width - 60 m, the length of three longitudinal spans of the first stage of construction - 312 m, width - 90 m, the second stage, respectively, 252 m and 78 m. The width of the L-M span is 18 m, and the width of the other spans of the workshop is 30.0 m. The height at the roof

ridge of transverse "H-D" bay - 21,600 m, the bay "E-E" - 19,850 m, longitudinal "K-L" and "M-L" spans in the axis "1 - 11" - 19,200 m. Construction area - 60,860.0 m²; construction volume - 1,123,850 m³.

3.2. Visualisation of pilot site models

The process of rendering a 3D model of a building is divided into three stages: preparation of the working area, design of the 3D model, rendering the 3D model.

Step 1: Preparing the working area. After creating the project file, the drawing is imported from AutoCAD and the main axes and levels are adjusted. The tool "Import from CAD formats" is used to import the finished drawing. When importing, the units to be used for further design must be specified. As the drawing is imported from related software, all numerical values are retained.

The Grid tool located in the Architecture panel is used to draw the principal axes. The axes are automatically numbered starting with a value of 1, but the numbering can be altered or changed to alphabetic notation.

Levels are constrained horizontal planes that are used to coordinate elements attached to levels, such as roofs, floors and ceilings. Most commonly, levels are used if the 3D model has more than one level. The Level tool is used to add a level. After assigning a numerical value to the level and a name, the new element appears in the Project Manager panel.

This work step also includes finding and setting the required families. A family is a library that contains the elements needed for detailed project visualization: wall views, roofs, ceilings, materials, doors, windows, staircases, columns, etc. There are two types of families: system families, i.e. built-in families, and component families (downloadable). To ensure that the 3D model of the SLS-8 building is adequate the families of windows and doors are set visually close to the original. This completes the stage of preparing the workspace for further design.

Step 2: Designing the 3D model. To build walls, use the Wall tool on the Architecture toolbar. Each wall needs to be given a thickness value. To do this, in the "Properties" panel of the selected wall, interact with the "Change Type" button. In the window that appears, change the numerical value in the "Width" item, then save all changes. Height of wall is set in drop-down menu on toolbar under "Height". It can also be changed in the Properties panel.

After the load-bearing and non-bearing walls have been built, the ceiling is constructed with the Ceiling tool in the Architecture panel. The ceiling boundaries can be defined in several ways: along the walls and by drawing a sketch. Drawing a sketch is used only when the ceiling is of an unusual design. Use the roof tool in the Architecture panel to build a roof on top of the ceiling. The roof is built along the contours of the walls and freehand with the Draw tool. The roof is flat for the purpose of this work.

Placement of windows, doors, and stairs on the model is done with the Windows, Doors, and Stairs tools, respectively. All these tools are located in the Architecture panel. The placement of these elements was carried out according to the drawing and photos of the original building, so that the adequacy of the model is maintained.

Step 3: Setting up the 3D area. After constructing the building in the View tab - Create panel - 3D View drop-down list - Default 3D View. In this workspace, you can customize the backgrounds for the 3D view, sky, lighting, and model placement. To select the background of the 3D View, sky, and lighting, use the Visual Style panel, Display Options tool. To rotate the shape, the rotation tool is provided in the upper right-hand corner.

As a result of performing all three steps, a 3D model of SLS-8 building is created, shown in Fig. 5 and Fig. 6.

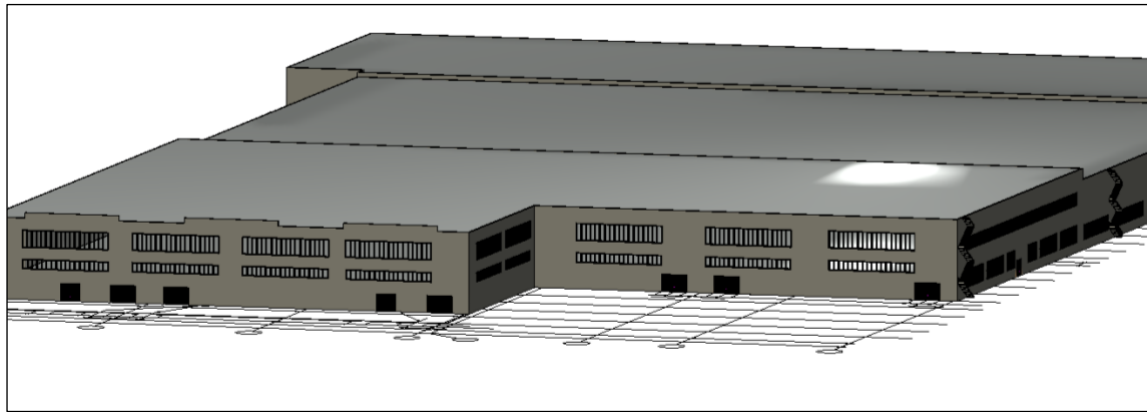


Figure 5 - Visualisation of the 3D model of the SLS-8 building (1)

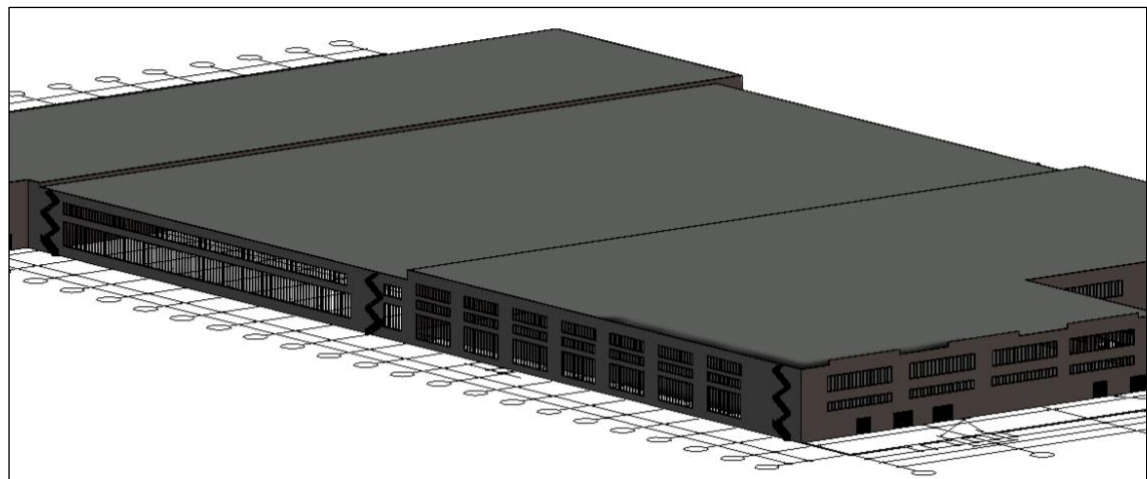


Figure 6 - Visualisation of the 3D model of the SLS-8 building (2)

The presence of the 3-D model made it possible to construct an informative shadow of the object. The information shadow was created by combining a photograph of the original building's façade with the façade of the 3D model. To demonstrate adequacy of 3D model, transparency of the original building's photo was reduced to a value of 75-80%. The two combined images are merged into one project to change the edges of the image. Examples of the created informational shadows of the SLS-8 building as part of this work are shown in Figure 7 and Figure 8.



Figure7 - Information shadow of SLS-8 (1)



Figure8 - Information shadow of SLS-8 (2)

3.3. Application of 3D and 2D visualisation models in the UAV flight map

There are two types of UAVs: programmable and remote-controlled. The first type of drone has special software based on which code is written to control the drone itself. Programmable drones remove some of the real-time control tasks from the operator or pilot. Despite this, the priority is given to drones with a remote control, as the flight of this type of drone is changed in real time by the remote control, and it is such drones are used in adverse weather conditions or for the study of hard-to-reach areas or places, where there are a lot of obstacles for the flight. It is worth noting that the use of a UAV on a remote control unit offers the possibility of automation. For this purpose a flight map is used. The UAV flight map is intended for the formation of the route of the drone (from one point to another) in the study of a particular area. In this work, the UAV flight map for a frontal survey is based on a building façade with a scale grid built using the methodology developed by the authors and described in [22].

Since the pilot operation in this study is part of the project for the frontal survey of the façade of industrial buildings or structures of PJSC MMK, the flight map creation module is presented as a Web-application. The main roles involved in the construction of the flight map are: manager and technologist-pilot. The manager's screen form is shown in Fig. 9.

MMK UAV-HPF

Image processing HPF / Getting a flight map Tel: +7(000)000-00-00

1 Map number:
 Date of compilation:
 Pilot performer:
 IdUs(Pilot)-Surname N.
 Manager:
 IdUs(Manager)-Surname N.
 Object:
 IdDPO: DPO.Name
 IdEDPO: ElementDPO.NameEDPO
 IdComp: Components.NameComp

3D-model of the object

2

2D-model of the component

3

Characteristics of points:
 Distance:
 4

5

Date of receipt: Date of execution:

Figure 9 - Manager's user form during the creation of a flight task

In Fig. 10 symbols are introduced: 1 - flight parameter definition area, data for which are read from database; 2 - 3D model visualization area; 3 - 2D model and flight path visualization area; 3.1 - form number in interface map; 4 - flight parameter definition area: distance (value entered by user) and dates (read from database); 5 - function buttons area.

In the form shown in Fig. 9 the user (manager) is presented with a 3D model of the building being surveyed and with an information shadow of one of the building facade sides for which the flight is planned. The manager determines the distance to the object during the flight. After interacting with the "Begin" button, a form for the designation of the facade survey zones appears. Each grid cell defines an area on the facade, which is captured in a frame from a given distance according to the specifications given in [23].

The manager is interactively given the opportunity to define the grid cells for which the surface is to be surveyed. Each selected cell is numbered according to the order of selection. If it becomes necessary to delete one of the cells, a left mouse click on the zone number will delete the cell and renumber all previously selected zones. After selecting the necessary cells, a flight map is drawn from one point of the area under study to another. Note that the flight path is always plotted from the bottom left corner and runs first along the X axis and then the Y axis. An example of the constructed flight map is shown in Figure 10.

The following symbols are used in Fig. 10: 1 - grid; 2 - position numbers; 3 - frame cell; 3.4 - shape number on the interface map; 4 - non-information element; 5 - usable area.

The 2D model image with flight path returns to the form of the flight map on which the execution task to the pilot is generated.

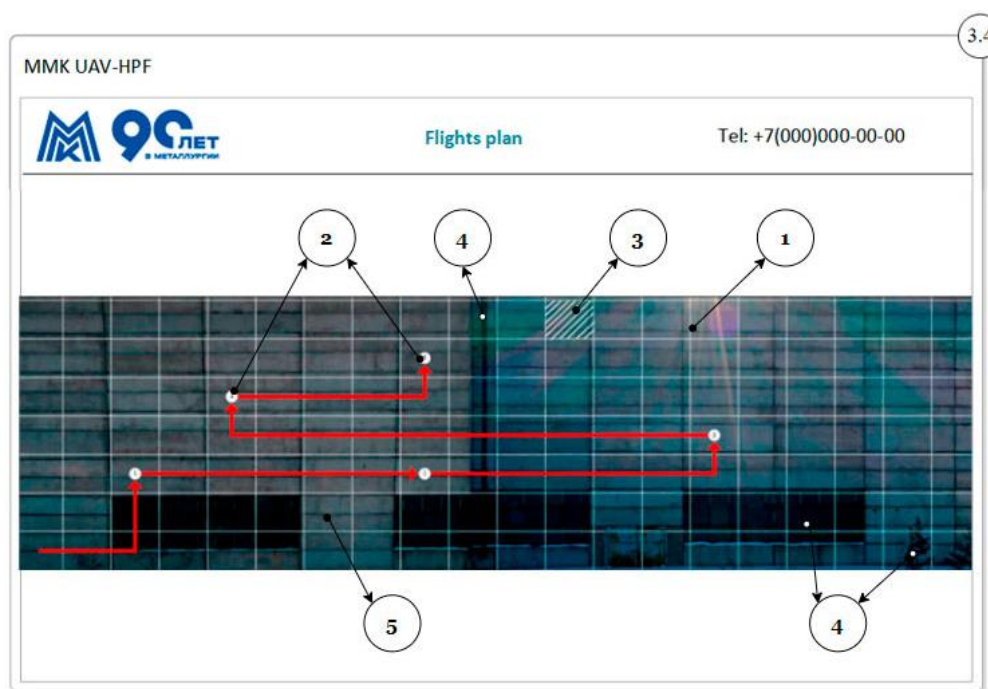


Figure 10 - Plotted flight map on the user interface

4. Conclusions

1. The analysis of the application fields of drones has shown that their use allows simplifying and automating the range of tasks that are solved using graphic information and visualisation technologies. One of the areas of industrial safety activities is the examination of hazardous industrial facilities, in which the collection of visual information with the use of UAVs is performed. Use of technical means installed on UAVs for photographing external surfaces of objects allows forming data base of images.

2. On the basis of combining images of real objects and their drawings it is possible to create 3D models and 2D models that are used in the formation of documentation for the construction of flight tasking in the interactive mode.

3. In the future the results will be integrated into the system of examination of hazardous industrial facilities when determining the tasks of flights to the survey. In addition to the above it is planned to develop this research to build an optimal flight trajectory with time and length limitations of the trajectory.

4. The result of this research is a flight map based on the digital shadow. The flight map is used for further UAV launching and collection of data on the condition of the façade of industrial buildings and structures.

Funding

The work is carried out with the financial support of MMK under Agreement No.247715 dated 05.07.2021 between MMK and Nosov Magnitogorsk State Technical University "Development and Application of Control Methods of Territories, Buildings and Structures of MMK using Unmanned Aerial Vehicles (UAV)".

References

1. Number of commissioned buildings // EMISS. State statistics (<https://www.fedstat.ru/indicator/43296>)
2. Makhutov N. A., Chetverik N. P., Khanukhov Kh. M. Promyshlennaya bezopasnost' i monitoring tekhnicheskogo sostoyaniya zdaniy i sooruzheniy [Industrial safety and monitoring of the technical condition of buildings and structures] // Bezopasnost' truda v promyshlennosti, № 10, 2008, pp. 64-69 [in Russian].
3. Vasilin N. Ya. Bepilotnyye letatel'nyye apparaty [Unmanned aerial vehicles]. M. : Potpourri, 2007, pp. 98-105 [in Russian].
4. Zubarev Yu. N., Fomin D. S., Chashchin A. N., Zabolotnova M. V. Ispol'zovaniye bepilotnykh letatel'nykh apparatov v sel'skom khozyaytve [The use of unmanned aerial vehicles in agriculture] // Bulletin of the Perm Federal Research Center, № 2, 2019, pp. 47-51 [in Russian].
5. Kim J., Kim S., Ju C., Son H. Unmanned Aerial Vehicles in Agriculture: A Review of Perspective of Platform, Control, and Applications // IEEE Access, 2019, pp. 1-17.
6. Roslavtseva S. A., Zhulev A. I. Perspektiva primeneniya bepilotnykh letatel'nykh apparatov (BPLA) dlya tseley meditsinskoy dezinfektsii [The prospect of using unmanned aerial vehicles (UAVs) for the purposes of medical pest control] // National Priorities of Russia, № 3 (42), 2021, pp. 250-252 [in Russian].
7. Laksham K. B. Unmanned aerial vehicle (drones) in public health: A SWOT analysis // Family Medicine and Primary Care, 2019, pp. 342-346.
8. Thiels C., Aho J., Zietlow S., Jenkins D. Use of Unmanned Aerial Vehicles for Medical Product Transport // Air Medical Journal, 2014, pp. 104-106.
9. Polka M., Ptak S., Kuziora L. The Use of UAV's for Search and Rescue Operations // Procedia Engineering, 12th international scientific conference of young scientists on sustainable, modern and safe transport, № 192, 2017, pp. 748-752.
10. Abhijith V., Parvathy B., Vismaya Dev G. H., Unnikrishnan R.S., Praveen K. R., Vivek A. Unmanned Aerial Vehicle for Search and Rescue Mission // 4th International Conference on Trends in Electronics and Informatics (ICOEI), 2020, pp. 684-687.
11. Zharinov D. A. O vozmozhnosti primeneniya bepilotnykh letatel'nykh apparatov dlya okhrany voyennykh aerodromov [On the possibility of using unmanned aerial vehicles for the protection of military airfields] // Aerospace Forces. Theory and Practice, № 5, 2018, pp. 54-59 [in Russian].
12. Blistanova M., Blistan P. Support for Protection of the Large Object Using UAVs // Advances in Military Technology, № 11, 2017, pp. 227-237.
13. Noskov I. V., Noskov K. I., Tinenskaya S. V. Dron-tekhnologii v stroitel'stve – sovremennyye resheniya i vozmozhnosti [Drone technologies in construction - modern solutions and opportunities] // Bulletin of Eurasian Science, № 5, 2020, p. 27 [in Russian].

14. Volkan A., Ulubeyli S., Kazaz A. Unmanned aerial vehicles in the construction industry: applications and implications // 4th International Conference Energy & Engineering Congress, 2019, pp. 490-500.

15. Tatum M. C., Lui J. Unmanned Aircraft System Applications in Construction // Procedia Engineering. Creative Construction Conference, № 196, 2017, pp. 167-175.

16. Magomedov A. K. Prospects for the use of unmanned aerial vehicles at different stages of the life cycle of buildings and structures // Issues of sustainable development of society, № 7, 2022, pp. 736-740. – EDN IJWYHE [in Russian].

17. Serbin S. D., Smirnova O.A. Creation of digital twins at mining enterprises // Digital transformation of economic systems: problems and prospects (ECOPROM-2022): Proceedings of the VI All-Russian scientific and practical conference with foreign participation, St. Petersburg, November 11–12, 2022. - St. Petersburg: POLYTECH-PRESS, 2022, pp. 541-544. – DOI 10.18720/IEP/2021.4/165. – EDN DOSOTI [in Russian].

18. Efremov R. B., Pshidatok S. K. Sozdaniye 3D-modeli fasada pri pomoshchi nazemnogo lazernogo skanirovaniya [Creation of a 3D facade model using ground-based laser scanning] // Issues of the development of modern science and technology, № 2, 2021, pp. 38-43 [in Russian].

19. Tkacheva A. A., Danilin I. M. Ispol'zovaniye dannykh lazernogo skanirovaniya v modelirovaniy lesnykh landshaftnykh stsen [Use of laser scanning data in modeling forest landscape scenes] // Journal of the Siberian Federal University. Series: Technics and Technologies, № 6, Vol. 10, 2017, pp. 727-740 [in Russian].

20. Lurie I. K., Prokhorova E. A., Semin V. N., Ushakova L. A. Kartografirovaniye seti zheleznykh dorog dlya kompleksnoy otsenki razvitiya transportnoy seti Rossii [Mapping of the railway network for a comprehensive assessment of the development of the Russian transport network] // Geodesy, cartography, geoinformatics and cadastres. Science and education: Collection of materials of the III All-Russian scientific and practical conference, 2019, pp. 289-292 [in Russian].

21. Kornienko V. D., Ezhov G. A., Narkevich M. Yu., Logunova O. S. Klassifikatsiya iskhodnykh dannykh dlya intellektual'noy sistemy ekspertnoy otsenki vizual'no opredelyayemykh defektov i povrezhdeniy [Classification of initial data for an intelligent system for expert evaluation of visually determined defects and damage] // Bulletin of the Cherepovets State University, № 6 (111), 2022, pp. 53-64 [in Russian].

22. Narkevich M. Yu., Logunova O. S., Kornienko V. D., Kalitaev A. N., Surovtsov M. M., Luganskaya D. A., Chernysheva A. S. Intellektual'naya sistema prinyatiya resheniy pri otsenke kachestva zdaniy i sooruzheniy na opasnykh proizvodstvennykh ob'yektakh: opredeleniye trayektorii dvizheniya bespilotnogo letatel'nogo apparata [Intelligent decision-making system in quality assessment buildings and structures at hazardous production facilities: determining the trajectory of an unmanned aerial vehicle] // Bulletin of Nosov Magnitogorsk State Technical University, №1, Vol. 20, 2022, pp. 50-60 [in Russian].

23. Kornienko V. D., Narkevich M. Yu., Logunova O. S., Kozlova A. E., Zaitsev I. P. Metodika sbora i obrabotki informatsii dlya kontrolya sostoyaniya territorii, zdaniy i sooruzheniy na opasnykh proizvodstvennykh ob'yektakh metallurgicheskogo predpriyatiya [Methods of collecting and processing information for monitoring the state of the territory, buildings and structures at hazardous production facilities of a metallurgical enterprise] // Electrical systems and complexes, № 4(57), 2022, pp. 76-87 [in Russian].

24. Narkevich M. Yu., Logunova O. S., Arkulis M. B., Sagadatov A. I., Klimov S. S., Kabanova V. V., Nikolaev A. A., Deryabin D. I. Prikladnaya tsifrovaya platforma dlya otsenki dinamiki kachestva opasnykh proizvodstvennykh ob'yektov na metallurgicheskom predpriyatii: struktura i algoritmy [Applied digital platform for assessing the dynamics of the quality of hazardous production facilities at a metallurgical enterprise: structure and algorithms] // Bulletin of the Cherepovets State University, № 5(110), 2022, pp. 29-48 [in Russian].