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Review / Обзор

Estimating the Potential of Unmanned Aerial Vehicle Use in the Oil and Gas Industry

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Оценка потенциала применения беспилотных летательных аппаратов в нефтегазовой отрасли

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airborne photographic survey, unmanned aerial vehicle, unmanned system, images, orthophotoplan, altitude map, topographic model, manned aerial photography, oil and gas industry, software products, topographic plan, monitoring of facilities, oil spills, pipelines, illegal activity.

The relevance of the study is explained by the need to use unmanned aerial vehicles (UAV) to serve engineering and geodetic tasks in the oil and gas industry. Airborne photographic survey using unmanned aerial vehicles is currently an advanced technology in the area of geodesy and it replaces such methods as tacheometry, satellite-based positioning in RTK modes, manned aerial photography, and aiborne laser scanning (ALS). The potential for using UAVs in the oil and gas industry today is truly enormous. Numerous safety and reliability problems, which traditionally have been cost consuming for oil and gas companies, can be effectively addressed using UAVs. The study included processing of data obtained from the unmanned complex in three modern software packages (Agisoft Photoscan Professional, v 1.2.5.2594 (Russia), ERDAS IMAGINE, v 2015 (USA) and Pix4Dmapper Pro (Switzerland)) of various automation degrees; assessment of accuracy in ArcMap software by superimposing a topographic plan on an orthomosaic with a scale of 1: 500 on the territory under consideration; calculation of economic and labor costs. As part of the study, it was proved that the use of UAVs was possible not only for the geodetic work, but also for solving other equally important tasks of the oil and gas industry, which leads to a decrease in economic and environmental risks, automation of processes related to monitoring of oil facilities, prevention of illegal attempts of pipeline tie-ins, oil spills. In addition, based on the obtained orthophotomaps, the economic, accuracy and labor-time feasibility of using unmanned systems were confirmed. It has been established that the use of unmanned aerial vehicles in various fields of oil and gas activities for solving engineering and geodetic problems is an integral part of any company engaged in the production and transportation of hydrocarbons.

Ключевые слова:
аэрофотосъемка, беспилотный летательный аппарат, беспилотный комплекс, снимки, ортофотоплан, карта высот, модель местности, пилотируемая аэрофотосъемка, нефтегазовая отрасль, программные продукты, топографический план, мониторинг объектов, разливы нефти, трубопроводы, незаконная деятельность.

Актуальность работы обусловлена необходимостью использования беспилотных летательных аппаратов (БПЛА) для решения инженерно-геодезических задач в нефтегазовой промышленности. Аэрофотосъемка беспилотными летательными аппаратами в настоящее время является передовой технологией в области геодезии, вытесняя такие методы, как тахеометрия, спутниковое позиционирование в режимах RTK, пилотируемая аэрофотосъемка, воздушное лазерное сканирование (ВЛС). Потенциал использования БПЛА в нефтегазовой отрасли на сегодняшний момент поистине огромен. Многие вопросы безопасности и надежности, на которые компании нефтегазовой отрасли традиционно тратят существенные средства, могут эффективно решаться с использованием БПЛА. Осуществлены: обработка данных, полученных с беспилотного комплекса в трех современных программных продуктах (Agisoft Photoscan Professional, v 1.2.5.2594 (Россия), ERDAS IMAGINE, v 2015 (США) и Pix4Dmapper Pro (Швейцария)) различной степени автоматизации; оценка точности в ПО ArcMap посредством наложения топографического плана на ортофотоплан масштабного ряда 1:500 на рассматриваемую территорию; подсчет экономических и трудовременных затрат. В рамках выполнения исследования доказано, что использование БПЛА возможно не только для геодезических работ, но также и для решения других, не менее важных задач нефтегазовой отрасли, что приводит к снижению экономических и экологических рисков, автоматизации процессов, связанных с мониторингом нефтеобъектов, предотвращению попыток незаконных врезок в трубопровод, разливов нефти. Также на основании полученных ортофотопланов подтверждена экономическая, точностная и трудовременная целесообразность использования беспилотных комплексов. Установлено, что применение беспилотных летательных аппаратов в различных сферах нефтегазовой деятельности для решения инженерно-геодезических задач является неотъемлемой частью любой компании, занимающейся добычей и транспортировкой углеводородов.

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Introduction

Airborne photographic surveying with the use of unmanned aerial vehicles (UAV) is currently an advanced technology in the field of geodesy; and it replaces such methods as tacheometry, satellite-based positioning in RTK modes, manned aerial photography, and airborne laser scanning (ALS). This is due to the lack of their competitiveness in terms of the following two basic criteria, i.e. cost and time required to complete works [1–7].

Today, the potential of UAV use in the oil and gas industry is really immense. Many safety and reliability problems, which traditionally have been cost consuming for oil and gas companies, can be effectively addressed using UAVs. It should be noted that the value of the unmanned aerial systems includes innovative software designated for recognition and processing of data obtained from UAV [8–14].

The use of new advanced solutions based on the unmanned technologies provides significant advantages to oil and gas companies, for instance, in engineering and geodetic fields, beginning with the monitoring of linear facilities (oil pipelines, water pipelines, gas pipelines, and power transmission lines) up to preparations of surveying plans [15–27].

UAV system makes it possible to get real-time high quality aerial photographs, videos, etc. A wide range of UAV functions allows surveying in visible and infrared ranges, shooting with a multispectral camera, thus, enhance functionality in conditions of a limited visibility. High battery performances in combination with long distance video transmissions make it possible to perform work by covering vast areas [28–32].

At the moment, in the territory of Perm Krai, the use of UAV is developing, while preferences are still given to conventional methods (tacheometry to prepare surveying plans and human resource involvement to monitor linear facilities). To illustrate a wide range of unmanned aerial vehicle functions, which can be used in the territory of Perm Krai, and to specify new applications, we used SenseFlyeBee aerial vehicle at one of the facilities belonging to an oil and gas company (the area of the territory of interest is 13.6 hectares). Images obtained from the UAV were processed, results of processing by different advanced software products were compared, and the economic effect of UAV use was demonstrated, as compared to the conventional geodetic methods, which are currently in use. Fig. 1 shows the UAV flight route at the oil and gas site of interest.

Orthophotoplan Preparation

As a result of SenseFlyeBee flights, 49 images in .jpg format were obtained. The images were processed by three software products, which are considered to be the best in their field: Agisoft Photoscan Professional, v 1.2.5.2594 (Russia), ERDASIMAGINE, v 2015 (USA) and Pix4DmapperPro (Switzerland). Fig. 2 demonstrates altitude mapping, an intermediate stage of the data processing.

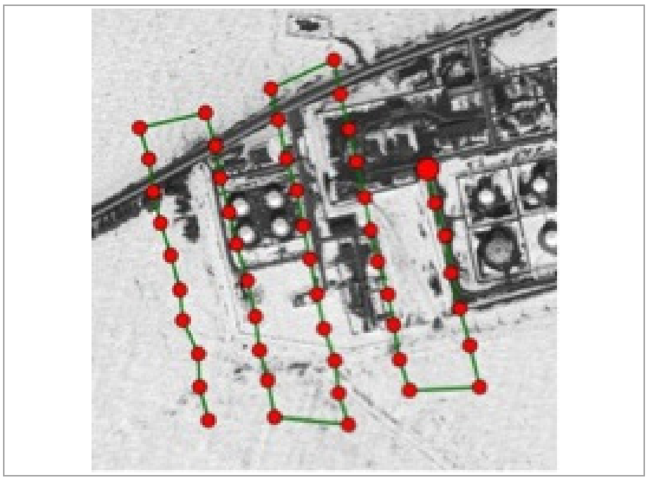

Fig.1. The rout plan of SenseFlyeBee unmanned aerial vehicle flight above the facility of interest

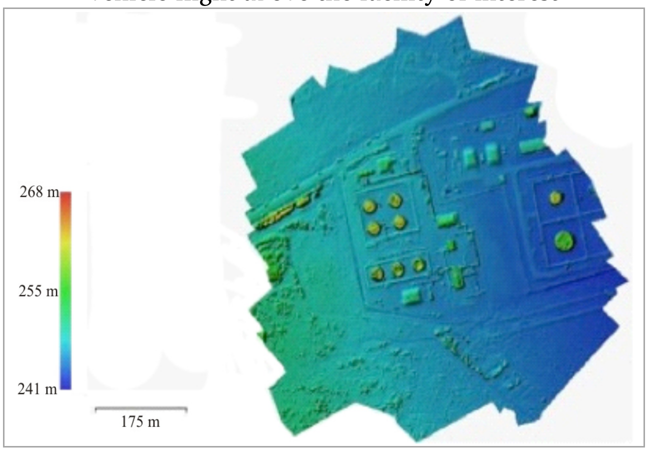

Fig.2. The altitude map of the facility of interest built in Agisoft Photoscan Professional, v 1.2.5.2594

a *b* *c*

Fig.3. View of a ready orthophotoplan obtained in the following software products:
a) Agisoft Photoscan Professional, v 1.2.5.2594; *b)* ERDASIMAGINE, v 2015; *c)* Pix4DmapperPro

Fig. 3 shows the final results of the data processing by the UAV in view of orthophotoplans. In the oil and gas industry, orthophotoplans allow presenting a situation on the ground surface providing as much details as possible; therefore, the quality of orthophotoplans is to be of a high level (empty zones and stitching lines shall not be seen).

Based on the analysis results, we can conclude that the orthophotoplan produced by ERDASIMAGINE (Fig. 3, *b*) cannot be further used in the research, as it contains a lot of *blind* zones, facilities are much distorted, and image stitching lines are clearly seen. In addition, it should be noted that the preparation of orthophotoplans in this software product is a rather time consuming, as it is mainly based on seaming space images and aerial photographs (obtained from the manned aerial vehicles) where tilt angles are small or close to zero. In the example given, UAV images obtained at angles significantly different from zero need to be processed.

The Assessment of the Accuracy of Prepared Orthophotoplans

In order to assess the accuracy of prepared orthophotoplans, and, therefore, find the most efficient software, a geodetic assessment of accuracy was performed with the use of ArcMap, v 10.5.

Table 1

Facility location error limit

Facility	At a scale of a map or a plan, mm
Geodetic network control stations, landmarks	0.2
Clearly outlined facilities	0.5
Unclearly outlined facilities and facilities in mountain areas, high mountain areas, and desert regions	0.75

In accordance with LUKOIL's industry standard STO 1.8.–2008 Digital topographic maps and plans: requirements concerning the content, structure, presentation format, and update rules in LUKOIL JSC and LUKOIL group companies, the requirements concerning positioning accuracy that specify error limits, as compared to actual values, for the location of facilities on digital topographic maps and plans are given in Table 1 [33–38].

Based on Table 1, error limits for clearly outlined locations of objects are 0.5 mm at a scale of a map or a plan. For a scale of 1:500, with regard to such error limits, the error limit in a plain view is going to be 0.25 m, and a vertical view error limit is going to be 0.16 m (1/3 of vertical interval) [39–42].

The surveying plans were prepared in ArcMap, v 10.5, software product by overlaying a topographic plan on an orthophotoplan with regard to all requirements at a scale of 1:500 (Fig. 4) [43–45].

On completion of accuracy assessment and based on the obtained results, we can conclude that the most accurate software for the processing of data obtained from UAV is Pix4Dmapper Pro.This is due to the fact that at a scale of 1:500, its error in plain view was 3 cm, and vertical view error was 9 cm. The assessment of the software accuracy, price, and cost effectiveness is given in Table 2.

Expenses associated with the preparation of an orthophotoplan of the facility of interest with the use of UAV are times less vs. those needed for conventional shooting. In case of conventional orthophotoplan building method, the approximate cost of one hectare of a densely built-over territory will vary in the range of 75,000–100,000 rubles; whereas, the use UAV falls in the range of 10,000–13,000 rubles. Hence, the cost of imaging of the territory with the use of UAV and further seaming of the orthophotoplan amounted to 130,479.09 rubles.

In addition to geodetic activities, UAV can be used in dealing with other equally important tasks in the oil and gas industry, for instance, monitoring of cluster sites and construction of liner facilities (oil and gas pipelines), as well as in solving environmental problems arising during operations of wells and pipelines. Normally, in the real-time mode UAVs allow receiving good quality images that enable detecting oil spills and illegal activities.

Geodetic Monitoring of the Earthwork at Cluster Sites and Monitoring the Construction of Linear Facilities

The construction and development of sites at oil production facilities include certain work associated with preparing a particular territory for a further installation of process equipment, production and amenity rooms, groups of wells (clusters), etc. The entire area of a cluster foundation shall be subjected to banking around the perimeter. Such measures are important as they provide conditions necessary for environmentally safe operations of oil fields.

Data obtained from UAV makes it possible to quickly build a model of a well cluster territory, calculate volumes, and save money. An example of a cluster site monitoring with the use of UAV is shown in Fig. 5.

Today, the construction monitoring of linear facilities in the oil and gas industry with the use of UAV is a mandatory step for any company in

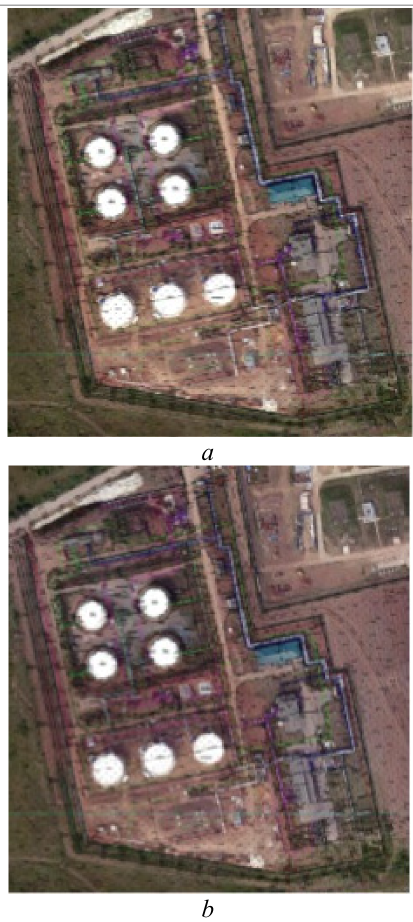

Fig. 4. Surveying plan obtained in the following software products: *a)* Pix4DmapperPro; *b)* Agisoft Photoscan Professional

Table 2

Comparative analysis of software products

Parameter	Pix4Dmapper Pro (Switzerland)	Agisoft Photoscan Professional, v 1.2.5.2594 (Russia)
Software price, rubles	495,900	199,500
Automation degree	Fully automated	Semi-automated
Time required to process 49 images, h	3	6
Number of people needed for processing	One	One
Accuracy assessment (plain view/vertical view), m/m	0.03/0.09	0.05/0.10

need to minimize risks, reduce costs, and enhance efficiency. Efficient maintenance operations of linear facilities require constant monitorings and services; however, it is not so easy to provide that. Fig. 6 shows a part of an oil pipeline where the difference between the design and actual position is clearly seen.

As a rule, UAV makes it possible to obtain good quality images in real-time modes to detect oil spills and illegal activities. Fig. 7 shows the results of processing the data obtained from UAV, which can be used to estimate the amount of the spilled oil and assess economic and environmental expenditures.

Therefore, the use of UAV is to enhance the quality and safety of operations, help to examine those elements of the process equipment components which are either hazardous, or inaccessible for personnel, unless the production process is stopped (for instance, flare systems), enable the prevention of illegal tapping attempts, save money, and mitigate environmental risks.

Conclusion

So, it has been found that the use of the unmanned aerial vehicles in different areas of the oil and gas industry to solve engineering and geodetic problems represents an integral part of activities of any company operating in the field of hydrocarbon production and transportation.

Advanced technologies based on the use of UAV mitigate economic risks by 5–10 times, automate processes associated with the monitoring of oil facilities, and enable the prevention of oil spills and attempts of illegal tapping.

Based on the orthophotoplans prepared in the following three software products: Agisoft Photoscan Professional, v 1.2.5.2594 (Russia), ERDASIMAGINE, v 2015 (USA), and Pix4DmapperPro (Switzerland), the cost-effectiveness of using the unmanned systems was proved.

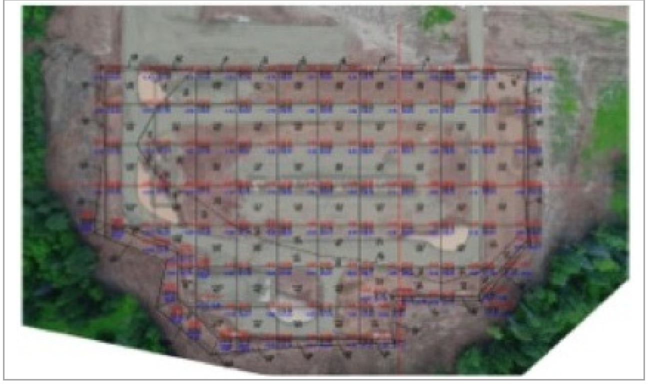

Fig. 5. Monitoring the earthwork at a cluster site

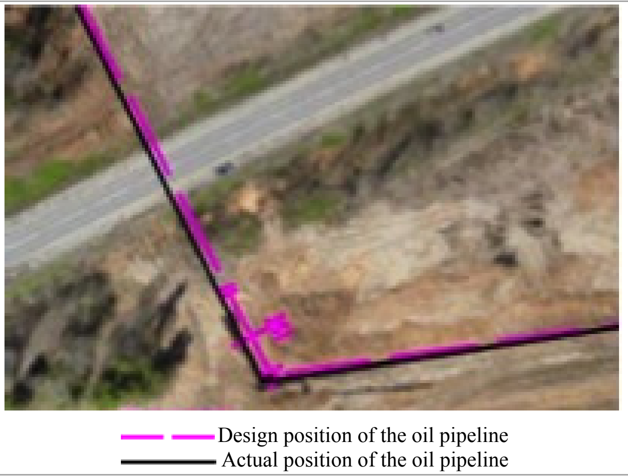

Fig. 6. Difference between the design and actual position of the oil pipeline

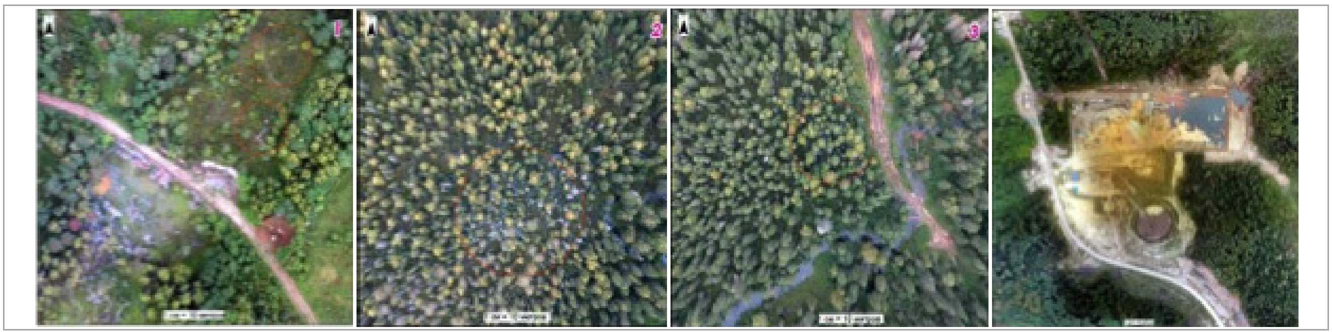

Fig. 7. An example of processing UAV data on an oil spill

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