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The Current Role and Future Development of Unmanned Aerial Vehicles in Cartography and Geodesy

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Abstract
This article analyzes the application of Unmanned Aerial Vehicles (UAV) in cartography and geodesy, highlighting their advantages and future development. UAVs enable the creation of accurate maps, updating topographic data, conducting geodetic measurements, and carrying out ecological monitoring. The article discusses how UAVs equipped with high-precision cameras, LiDAR systems, and GPS technology allow for quick and efficient data collection, as well as the advantages they provide over traditional methods. Additionally, the growth indicators of UAV usage in cartography and geodesy, along with their economic efficiency, are also examined.

Keywords: UAVs, cartography, geodesy, aerophotogrammetry, LiDAR, GPS, topographic maps, geodetic accuracy, digital surface models (DSM), high-resolution cameras, ecological monitoring, natural disasters, GIS systems, urban planning, innovations.

Introduction

The role of Unmanned Aerial Vehicles (UAVs) in the fields of cartography and geodesy is steadily increasing. UAV technologies simplify processes such as creating accurate maps of the Earth's surface, updating topographic data, conducting geodetic measurements, and performing ecological monitoring, while also saving time. Due to their high accuracy and rapid data-collection capabilities, these technologies offer significant advantages over traditional methods. This article examines the application of UAVs in cartography and geodesy, their development, and future innovations in the field.

Use of UAVs in Cartography: Unmanned Aerial Vehicles (UAVs) play a highly significant role in the fields of cartography and geodesy, where they are utilized to create accurate maps of the Earth's surface, perform measurements, and update topographic datasets [1]. The data collected by UAVs is extremely precise, which contributes to producing detailed and reliable maps. In addition, UAVs equipped with high-resolution cameras make it possible to capture high-quality imagery over large areas [3]. With these systems, wide territories can be observed and mapped

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within just a few hours. This speed represents a major advantage over traditional methods, which often require several days or even weeks to gather the same amount of data [4].

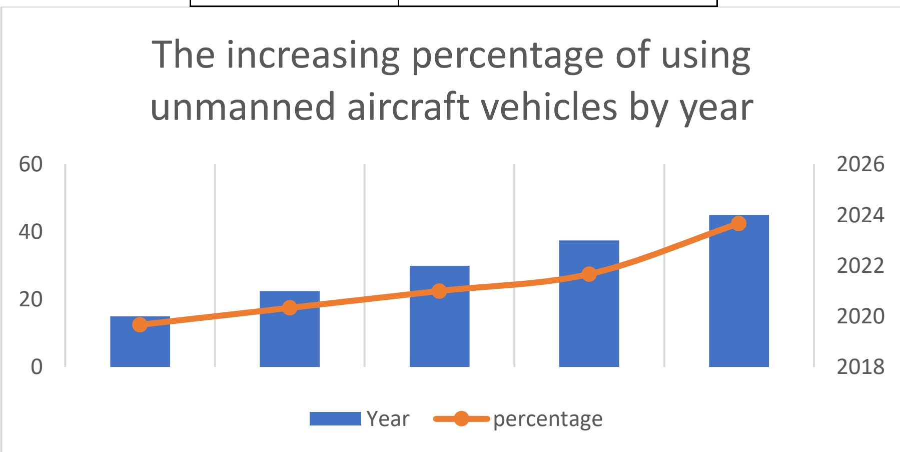
UAVs are frequently integrated with high-resolution cameras, LiDAR (Light Detection and Ranging—a technology that measures distance using laser beams to generate 3D representations of objects), or multispectral sensors. These technologies enable the production of topographic maps with 5–10 cm geodetic accuracy [7]. UAVs also allow the creation of Digital Surface Models (DSM), which are digital representations of the Earth's surface showing features such as buildings, trees, and upper terrain elevations. These models offer three-dimensional depictions of geographic areas and are highly useful for the development of topographic maps [5,10]. They help accurately represent elevation changes and natural features such as mountains and rivers.

Using UAVs significantly simplifies the process of identifying and analyzing surface morphology and environmental changes. To ensure geodetic accuracy, UAV operations typically incorporate GPS and other navigation systems, enabling measurement precision at the centimeter level [9]. UAVs also provide the ability to monitor mobile or hard-to-reach areas. For example, UAVs serve as an effective tool for cartographic monitoring in forests, mountainous regions, and water bodies. They are also widely applied in ecological monitoring and the observation of natural disasters.

Proportion of Work Performed Using UAVs in Cartography and Geodesy: The amount of cartographic and geodetic work carried out using UAVs is growing rapidly across the world. Over the past five years (2020–2024), the use of UAV technologies in these fields has increased by approximately **30–40%**. This rise reflects the improving efficiency and expanding capabilities of UAV systems. Currently, UAV-based operations account for roughly **25–30%** of all cartographic and geodetic activities. On a global scale, the growth trend can be summarized as follows:

Table 1

Year	Growth %
2020	12.5 %
2021	17.5 %
2022	22.5 %
2023	27.5 %
2024	42.5 %



Global growth indicator of UAV usage in geodesy and cartography

Economic Efficiency in Performing Cartographic and Geodetic Work: The cost of UAV services varies depending on the technical equipment used and the conditions of their operation. The prices of measurements, aerophotogrammetry, LiDAR, and GIS services carried out using UAVs are generally lower compared to traditional methods. The comparison table of UAVs, aircraft, and helicopters used for cartographic and geodetic work is presented below. Let us examine the costs involved in surveying an area of 1 km².

Table 2

	UAV		Aircraft	Helicopter
Aerophotogrammetry	Time	3–4 hours	1–2 hours	2–3 hours
	Cost	$200 – $400	$800 – $1,500	$1,000 – $2,000
	DJI Phantom 4 RTK, DJI Matrice 300 RTK		Cessna 172, Piper Navajo, King Air	Bell 407, Eurocopter AS350
Mapping	Time	4–5 hours	2–3 hours	3–4 hours
	Cost	$300 – $500	$1,200 – $2,500	$1,500 – $2,500
	DJI Matrice 600, SenseFly eBee X		Beech craft Bonanza, Cessna 208	Sikorsky S-76, Airbus H125
LiDAR-Based Mapping	Time	6–7 hours (LIDAR)	4–5 hours	5–6 hours
	Cost	$1,000 – $2,000	$3,000 – $5,000	$4,000 – $6,000
	DJI Matrice 300 RTK LIDAR, RIEGL VUX-1		Cessna 208B Grand Caravan LIDAR	Bell 407 LIDAR, AS350 LIDAR
High-Accuracy Data Acquisition	Time	4–5 hours	2–3 hours	3–4 hours
	Cost	$400 – $600	$1,500 – $3,000	$2,000 – $4,000
	DJI Phantom 4 RTK, SenseFly eBee RTK		Piper Navajo, Cessna 172	Bell 206, Robinson R66

Comparison table of UAVs, aircraft, and helicopters for cartographic and geodetic work
Aerophotogrammetry

Unmanned Aerial Vehicle (UAV): UAVs are an efficient and cost-effective option for aerophotogrammetry. Drones such as the DJI Phantom 4 RTK and DJI Matrice 300 RTK capture high-accuracy images and enable the conversion of the surveyed area into a digital model.

DJI Phantom 4 RTK

DJI Matrice 300 RTK

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This method is suitable for small and medium-sized areas, allowing complete image acquisition within 3–4 hours. The costs range from $200 to $400, making it significantly cheaper than traditional methods.

Aircraft:
Airplanes such as the Cessna 172, Piper Navajo, and King Air are used for aerophotogrammetry.

Cessna 172 Piper Navajo

King Air

They can scan a larger area in a single flight and are capable of covering extensive regions within 1–2 hours. The main advantages of this method are the ability to fly long distances and reduced dependence on weather conditions. However, the costs are higher compared to UAVs ($800–$1,500).

Helicopter: Helicopters such as the Bell 407 and Eurocopter AS350 allow stable imaging at lower altitudes.

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Bell 407

Eurocopter AS350

They are distinguished by their maneuverability and ability to capture stable images even in difficult terrain conditions. Aerophotogrammetry conducted using a helicopter takes approximately 2–3 hours. However, operational costs are high, ranging from $1,000 to $2,000.
Map Creation

Unmanned Aerial Vehicle (UAV): For mapping, UAVs such as the DJI Matrice 600 and SenseFly eBee X are used. These drones collect high-resolution images and synchronize them with GPS coordinates to produce digital maps. This method takes 4–5 hours and costs between $300 and $500.

Aircraft: Mapping conducted using aircraft such as the Beechcraft Bonanza and Cessna 208 can cover much larger areas than UAVs and allows data collection within 2–3 hours. However, the costs are significantly higher, ranging from $1,200 to $2,500.

Helicopter: Helicopters such as the Sikorsky S-76 and Airbus H125 are used for mapping operations. Their main advantage is the ability to obtain high-accuracy imagery even in complex terrain conditions. The mapping process takes 3–4 hours and costs between $1,500 and $2,500.

LiDAR-Based Mapping

Unmanned Aerial Vehicle (UAV):

LiDAR technology is widely used for producing accurate terrain models. Systems such as the DJI Matrice 300 RTK LiDAR and RIEGL VUX-1 allow LiDAR scanning to be completed in 6–7 hours. The cost ranges between $1,000 and $2,000, making it the most economical option for small and medium-sized areas.

Aircraft: Aircraft equipped with LiDAR systems (e.g., Cessna 208B Grand Caravan LiDAR) can cover large areas in a single flight. The main advantage is rapid scanning and wide-area measurement. LiDAR scanning takes 4–5 hours, but the cost is significantly higher, ranging from $3,000 to $5,000.

Helicopter: Helicopters (Bell 407 LiDAR, AS350 LiDAR) are used for LiDAR mapping in difficult terrain conditions. Their most significant advantage is deep terrain analysis and precise measurement of inaccessible areas. Helicopter-based LiDAR mapping takes 5–6 hours and costs between $4,000 and $6,000.

High-Accuracy Data Acquisition

Unmanned Aerial Vehicle (UAV): Drones such as the DJI Phantom 4 RTK and SenseFly eBee RTK are used to collect high-accuracy spatial data. This method takes 4–5 hours and costs between $400 and $600. Its main advantages are rapid results and low cost.

Aircraft: High-resolution aerial images can be obtained using aircraft such as the Piper Navajo and Cessna 172. This method takes 2–3 hours, but costs $1,500–$3,000, making it more expensive than UAV-based surveying.

Helicopter: Helicopters such as the Bell 206 and Robinson R66 allow real-time acquisition of high-accuracy images. They can provide the highest-quality imagery, but with costs ranging from $2,000 to $4,000, they are the most expensive option.

Development of UAVs in Cartography and Geodesy

UAVs are introducing significant innovations in mapping the Earth's surface, performing measurements, and updating topographic maps within the fields of cartography and geodesy. They provide high-resolution imagery and enable fast and efficient surveying of large areas. The data obtained using UAVs helps produce accurate and reliable maps. In the near future, the development of these technologies is expected to bring notable advancements in several areas.

Technological Advancement of Autonomous UAVs: UAVs are expected to become more autonomous, with artificial intelligence (AI) increasingly automating mapping workflows. This will allow UAVs to operate independently across surveyed territories. Data collected through AI-supported systems will be analyzed rapidly, errors will be identified automatically, and updates will be made in real time.

High-Precision LiDAR Technologies: The capability to obtain high-accuracy 3D data through LiDAR systems will continue to advance. When integrated with UAVs, LiDAR will enable precise measurements and the creation of complex 3D models even in challenging and hard-to-reach areas. Improvements in LiDAR technology will further enhance the accuracy and efficiency of topographic map production.

Digital Mapping and GIS Systems: Data collected by UAVs is transferred to Geographic Information System (GIS) platforms, allowing maps to be continuously updated. Digital maps and 3D models can be displayed interactively in mobile applications, helping users gain accurate and real-time insights into specific territories.

Urban Planning and Infrastructure Monitoring: UAVs enable rapid monitoring of urban infrastructure, transportation systems, and construction sites. High-resolution maps and 3D models are effectively used for planning, detecting changes, and analyzing results in a timely manner.

Development of Digital Surface Models (DSM): The DSM creation capabilities of UAVs continue to improve, enabling the acquisition of accurate elevation and terrain data. These models play an important role in land resource management, agriculture, and natural resource monitoring.

Innovations and Emerging Professions: New industries and services are emerging with the growing use of UAVs. The demand for skilled UAV operators and data analysts is increasing. Consequently, the education system must evolve to train new specialists and meet the needs of the expanding geospatial sector.

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