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Implementation of Remote Sensing and Unmanned Aerial Vehicle Technologies in Higher Education Institutions to Address the Challenges of Modern Agricultural Production and Geodetic Research

The current stage of agricultural development is characterized by rapid digital transformation. Worldwide, the concepts of Agriculture 4.0 and Smart Farming are being actively implemented, relying on geographic information systems (GIS), remote sensing technologies, global navigation satellite systems (GNSS), unmanned aerial vehicles (UAVs), artificial intelligence, and large-scale geospatial data analysis.

For Ukraine, these technologies have become particularly important. Under the conditions of martial law, the need for rapid territorial recovery, monitoring of land resources, damage assessment, and ensuring food security, remote sensing has become one of the most effective tools for obtaining timely and reliable spatial information.

At the same time, the modern labor market requires specialists who possess not only traditional geodetic knowledge but also digital competencies related to unmanned aerial systems, photogrammetric software, geographic information systems, and three-dimensional modeling.

For this reason, one of the strategic priorities of Mykolaiv National Agrarian University has been the establishment of the Laboratory of Geodesy, Digital Photogrammetry, and Remote Sensing.

The primary objective of the laboratory is to integrate advanced geospatial technologies into the educational process, conduct scientific research, and prepare highly qualified specialists for agriculture, geodesy, land management, cartography, and civil engineering.

One of the laboratory's key components is an unmanned aerial vehicle (UAV) capable of simultaneously acquiring high-resolution RGB imagery and multispectral data. This technology enables the calculation of vegetation indices, assessment of crop physiological conditions, monitoring of crop development, and early detection of problem areas before visible symptoms appear.

For modern agriculture, this provides opportunities for timely decision-making regarding fertilizer application, plant protection measures, irrigation management, and yield forecasting.

In addition to agricultural applications, UAVs are extensively used in geodetic surveying. They enable rapid topographic surveys, production of high-resolution orthophotos, digital terrain models (DTMs), digital surface models (DSMs), and three-dimensional representations of surveyed areas.

These technologies are particularly valuable for land inventory, cadastral surveying, infrastructure monitoring, post-disaster assessment, and documenting the consequences of military activities.

Remote sensing technologies have been successfully integrated into the educational process. Students specializing in geodesy and agriculture study modern methods of geospatial data acquisition through specialized courses. The educational approach combines theoretical knowledge with practical training covering the complete technological workflow.

Students learn mission planning, aerial data acquisition, geodetic control, photogrammetric data processing, and the generation of digital maps and three-dimensional terrain models.

An essential component of this educational process is the use of professional software packages. These applications automatically generate orthophotos, digital

terrain and surface models, calculate areas and earthwork volumes, and perform comprehensive spatial analyses.

Another important direction of laboratory development is the implementation of digital three-dimensional modeling technologies. A 3D scanner enables students to create accurate digital replicas of real-world objects with varying levels of complexity. Beginning with small objects, students gradually advance to modeling architectural structures, engineering facilities, terrain features, and real estate objects.

Such technologies are widely applied in architectural heritage preservation, engineering design, construction, cadastral surveying, and the development of digital twins.

Virtual reality technologies further expand educational opportunities. The use of VR headsets allows students to interact with three-dimensional models in immersive virtual environments, analyze complex spatial structures, and better understand the relationships between terrain features and engineering infrastructure.

The final stage of the digital workflow involves additive manufacturing using a 3D printer. Digital models can be transformed into physical models representing land parcels, architectural objects, terrain surfaces, or engineering structures. This integrated workflow enables students to understand the complete lifecycle of geospatial data—from data acquisition to the creation of final digital and physical products.

Flight simulators also play an important role in professional training. Combined with professional remote-control systems, simulation software enables students to safely develop UAV piloting skills before conducting real flight operations, significantly reducing operational risks and equipment costs.

Looking ahead, the implementation of remote sensing and UAV technologies in higher education is expected to include artificial intelligence for automated image interpretation, object classification, integration of Sentinel and Landsat satellite data, development of digital twins, and broader adoption of augmented and mixed reality technologies.

These innovations contribute to the creation of a modern educational and research environment that closely reflects current industrial demands and international standards for professional education.

In conclusion, the integration of remote sensing technologies, unmanned aerial vehicles, geographic information systems, digital photogrammetry, three-dimensional modeling, and artificial intelligence represents an essential step toward modernizing higher education.

These technologies provide students with practical skills that meet the requirements of today's digital economy while supporting innovative solutions for agriculture, geodetic surveying, environmental monitoring, and the post-war reconstruction of Ukraine.