Monitoring with unmanned aerial vehicles

Leading scientists:

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Consortium partners:

Faculty of Bioscience Engineering: Prof. Dr. ir. Kathy Steppe (Laboratory of Plant Ecology); Prof. Dr. ir. Frieke Van Coillie (Laboratory of Forest Management and Spatial Information Techniques); Prof. Dr. ir. Abdul Mouazen (Precision Soil and Crop Engineering research group); Prof. Dr. ir. Niko Verhoest and Prof. Dr. Diego Miralles (Laboratory of Hydrology and Water Management); Prof. Dr. ir. Kris Verheyen (Forest and Nature Lab); Prof. Dr. ir. Hans Verbeeck (Laboratory of Computational and Applied Vegetation Ecology), Prof. dr. ir. Jan Pieters (Biosystems Engineering);
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 # New faculty positions: 2

The initiative

In just a few years' time, 'drones' or UAVs (Unmanned Aerial Vehicles) have become ubiquitous. New applications continue to emerge and become progressively more reliable and affordable. At Ghent University (UGent), several research groups (see Consortium partners) use UAVs in their research. An international success was, for instance, the creation of the UGent spinoff company GateWing. Still, UAV-related research at UGent is fragmented, and the potential of this new technology remains largely untapped. With this initiative, we have the ambition to bring together this fragmented knowledge and create an **interdisciplinary centre of expertise on UAV research**.

Whereas the rapid technological advance in UAVs has facilitated commercially available UAV platforms, their full potential in applications is yet to be reached, especially in monitoring and remote sensing applications of terrestrial agricultural and natural ecosystems targeted by the UAV research centre. Here, the unsolved challenge is the full automation of the capture, analysis and dissemination pipeline. A tight interplay between drone flight control and data processing will allow much better and cheaper solutions than available today. Application knowledge is essential to achieve optimal solutions. In other words, an interdisciplinary approach provides a strategic advantage, which is why we combine the technological and applied expertise of the Faculties of Engineering and Architecture, Bioscience Engineering and Sciences.

Technological expertise to be provided by the research centre:

Smart UAV imaging: development of smart UAVs, defining their own flight track based on real-time analysis of incoming information to cover areas of interest (e.g., stressed canopies) and controlling their own path;

Image and video processing: advanced high throughput and real-time/low-latency algorithms for structure-from-motion, registration, super resolution and fusion algorithms for thermal, multispectral and hyperspectral cameras and LiDaR, incorporating atmospheric corrections and sun-sensor viewing angle influence;

Data extraction: automated quantification of crop growth, detection of vegetation stress and monitoring of land-use/land-cover changes over time, 3D models from point clouds, applications in different spatial-related domains such as archaeology, soil science, climatology, hydrology,...;

Database technology: for managing the large amounts of data derived from the observations, and all relevant flight parameters, for querying the data and disseminating it to end users.

Applied expertise to be provided by the research centre:

Data analysis: relating extracted data to variables relevant to the application;

UAV-optimized remote sensing products: rethinking remote sensing products (e.g., estimates of plant transpiration) by combining UAV data with continuous point measurements such as soil moisture or sap flow, or incorporating information from different viewing angles and 3D models;

New and innovative remote sensing technologies, such as sun-induced fluorescence (photosynthesis and productivity), and its combination with thermal remote sensing (transpiration), hyperspectral imaging, and microwave remote sensing (moisture content in soil and canopy);

UAVs as 3D sampling/measurement (e.g., air quality, microclimatic measurements) **or goniometer measurement devices** (e.g., bidirectional reflectance distribution function (BRDF) of complex natural systems).

Although the core research of the centre of expertise on UAV research will focus on innovative aspects of UAVs in terrestrial ecosystems and LUC/LCC, activities will cover other UAV monitoring applications as well. Examples are identification of the exact location of polluting gas emissions, wind turbine inspection, water pollution monitoring, and archaeology. The centre will also provide a crucial service to other research groups – within and outside UGent – and industry partners, carrying out flights and data processing for those who find it difficult to fly UAVs for practical, technical and/or legal reasons.

Impact and importance of the research centre:

Strategic importance: The proposed centre of expertise on UAV research will be of strategic importance to both UGent and Flanders. The Flemish industry has created the innovation network EUKA to promote this technology. The example of the UGent spinoff GateWing shows that even a modest investment can result in over 100 high-tech jobs in Flanders.

Positive economic impact: (i) The development of smart UAVs will be ground-breaking in numerous applications (e.g., precision agriculture, forest canopy and land degradation monitoring, monitoring and inspection of damage in industrial installations, 3D mapping) and has clear potential to become incorporated into commercially available UAVs; (ii) The global market for specific UAV software is growing parallel with that of the UAV market. With the increased availability of advanced cameras (thermal, multi- and hyperspectral) and sensors (LiDaR), more advanced software, such as will be developed in this centre, will be required; (iii) Precision agriculture, which plays an important role in the sustainable agriculture of the future, requires the assessment of spatial variation of canopy conditions and productivity (e.g., fertilization requirement, irrigation requirement, detection, identification and severity indication of stress, diseases or weeds). The new methods for detecting and mapping vegetation status and stress, developed in this centre, can be used for future commercial applications in precision agriculture.

Social and environmental benefits: (i) Contributing to a more sustainable planet, particularly to sustainable development in developing countries, where automated low-cost precision agriculture technologies are expected to have a large impact; (ii) UAVs offer eco(physio)logists and ecohydrologists a new tool to study within-ecosystem differences of sensitivity to environmental drivers. These new insights are crucial for understanding and predicting of how ecosystems will respond to climatic changes and how we can manage them to be more resistant and resilient.

Added value of the two new faculty positions

The two new faculty positions will be embedded in an interdisciplinary team, which will be composed of the consortium members. The new professors will focus on the process-related aspects of UAV monitoring, which brings new cross-domain problems and opportunities.

At the **Faculty of Engineering and Architecture**, the new professor will focus on two important research topics: *smart* and more and more *automated* UAVs and pre- and post-processing. This will require a close cooperation with IPI and DYSC, and the DDCM group, respectively. The professor to be hired in this faculty position 1 "**End-to-end data processing for Unmanned Aerial Vehicles**" will start a new research line that focuses on automating the image processing chain as a whole. This processing chain includes:

Smart UAV path control: Automation of the UAV flight based on real-time data analysis will increase the efficiency of UAV flights, both in area covered as the amount of detail required. Real-time computer vision will serve as an input to steer the drone towards specific areas for a closer look, depending on pre-specified conditions. This requires real-time data analysis and multi-sensor fusion.

Data processing: This includes research on (i) structure-from-motion, such as normalization of images taken under varying lighting conditions, denoising and deblurring, removal of motion artefacts, incorporating atmospheric corrections and correction of sun-viewing angle influences; and (ii) data fusion and co-registration, both spatial registration of images of the same sensor captured at different flights and automatic co-registration of images from different sensors (RGB, thermal, multispectral, hyperspectral cameras) as well as LIDAR or microwave remote sensing data.

Data extraction: Automated image classification (e.g., vegetation type, change detection) and transformation of data into end-user information (e.g., crop growth, vegetation health, tree number, plant height, geometrical models from 3D point clouds).

Data management and application interfaces: Managing the images and derived data in state-of-the-art database systems and ensure that they can be easily accessed and disseminated to end-users; manage updating this database and provide interfaces to end users.

Each of these topics could represent a research line on its own and in fact, at UGent, several research groups have highly-specialized expertise on some of the subtopics. However, what is lacking is expertise on the problems and opportunities that emerge at the *system level*, such as end-to-end optimisation (e.g., optimised flight planning, sensor installation and processing based on end-user needs) and real-time in-the-loop video processing (fast, reliable and energy-efficient processing technologies, which can interact with the UAV's control system).

The new professor should focus on these system-level aspects and should become (or be) more of a generalist than a specialist. The professor will cooperate with the existing experts in the consortium who have detailed expertise on some of the subtopics and specifically with application specialists in the consortium. The new professor is expected to create a research group over time and to attract research funding. Given the nature of the research, and the growing interest of industry, we expect that the professor will start applied research projects in close collaboration with existing experts in the consortium and specifically with the colleague of the Faculty of Bioscience Engineering (position 2), and in cooperation with industry and or end-users and be active on valorisation (in cooperation with UGent business developers). Experience with industrial cooperation is therefore an important asset. Moreover, given the interdisciplinary nature of the research, a strong track record in interdisciplinary cooperation is also an asset.

At the **Faculty of Bioscience Engineering**, the new professor will focus on important research topics related to the development of UAV-optimized remote sensing products and innovative new remote sensing technologies. This will require a close cooperation with existing experts and application specialists at the Faculty of Bioscience Engineering and the Faculty of Sciences. In addition, flight services are expected to be performed for other partners, both within or outside the university, or with industry partners. The professor to be hired in this faculty position 2 "**Applied UAV expertise**" will start a new research line that focuses on:

Establishment of an operational UAV flight centre: Operational UAV remote sensing includes each step of the remote sensing process, from UAV flight preparation (including legal aspects), flight planning and execution, acquisition of data and ground-based reference measurements to the data processing and the actual data interpretation.

Development of UAV-optimised remote sensing products with innovative technologies: This includes: (i) exploration of innovative and new technologies (e.g., sun-induced fluorescence in combination with thermal remote sensing) and its incorporation in remote sensing algorithms for assessing soil moisture, transpiration, productivity, biotic or abiotic stress. These algorithms will be specifically developed for UAVs in order to benefit from the added information UAV remote sensing offers (e.g., signal viewed under different viewing angles; availability of 3D model); and (ii) use UAVs to increase the understanding of remote sensing products and models to improve satellite remote sensing products. For example, use UAVs as giant goniometers, resulting in BRDF measurements of vegetation, which can be used to fine-tune radiative transfer models and to study sun-induced fluorescence or the relation between vegetation and soil characteristics.

Applications in precision agriculture and natural ecosystems: Optimising the use of UAVs in field crop production, precision agriculture and fusion of UAV-technology with other precision agriculture technologies; similarly, application of UAV-technology to study natural ecosystems. Both will require close collaboration with the existing experts in the consortium.

For these three research areas, the new professor should be acquainted with thermal, hyperspectral and/or microwave remote sensing, and should have sound knowledge of plant/crop physiological processes to be able to bridge the gap

between remote sensing and plant/crop physiology. Basic knowledge of both precision agricultural practices and (forest) ecological processes is recommended. The new professor is expected to create a research group over time and to attract funding. We expect that the professor is capable of initiating, supervising and acquiring research funding, of managing interdisciplinary projects, and of collaborating with existing experts in the consortium and the colleague of the Faculty of Engineering and Architecture (position 1) in particular. Given the interdisciplinary nature of the research, a strong track record in interdisciplinary cooperation is also here an asset.

The two faculty positions will be **engaged in education**. UAVs and UAV remote sensing is already part of some courses, such as the master course in Precision Agriculture. They will both interact and cooperate with other departments for UAV acquisitions and observations. With the increasing importance of UAVs in our society, more courses, bachelor and master theses will depend on basic UAV knowledge, which the two professors will provide. This will include interfaculty education, to students of engineering and bioscience engineering, but also to geography or biology students.

The two professors will **work as a team**, which will be reflected in co-authorship of papers and co-promotership of master and PhD students. This team work is essential because it allows new research directions enabled by cross-domain optimizations: rather than customizing engineering solutions to application needs or performing only fundamental research in specialized application domains, co-developing applications and engineering solutions will produce not only new forms of innovation; it will also produce them faster. This produces benefits for both research and valorisation.

Sustainability of the collaboration

The main responsibility of the two new professors is to focus on the interdisciplinary and end-to-end aspects of UAV-based monitoring and to promote applied and fundamental research in this area. However, to succeed in this endeavour, they need to cooperate with the existing consortium members. This will be reflected in co-promotership of research projects, master theses and PhDs and in joint publications.

Administratively, the two new professors will be associated with the Faculty of Engineering and Architecture and the Faculty of Bioscience Engineering, respectively. However, in order to ensure smooth cooperation, frequent contact will be needed between all involved professors and researchers of the **interdisciplinary centre of expertise on UAV research**. More in particular, a very close cooperation will be established between the two new professors, who will in the long run lead together the centre of expertise on UAV research and will cooperate closely when applying for funding and working on projects.

A key aspect of the proposal is to leverage cross-domain optimisations. This implies a close cooperation between not only the professors, but also the researchers they will supervise, and of course existing researchers. This formation of interdisciplinary teams will be stimulated by research meetings and by (where possible) pairing application/engineering PhD researchers, i.e., having them focus on different aspects of the same problem in joint workspaces. This “flexible approach” allows embedding researchers in an interdisciplinary team, while still remaining in close contact with other technical or application researchers.

At each faculty, the new professor will be embedded in the department of the leading scientist of this initiative, where the new professors will receive the needed assistance in terms of administrative and technical support.