Unmanned Aerial Vehicles for alien plant species detection and monitoring

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Plant invasions represent a serious threat to modern changing landscapes. They have devastating economic impacts, affect human health, and threaten biodiversity and ecosystem functionality. Despite the increasing worldwide efforts to control and eradicate invasive species, their menace and abundance grows. This leads to growing research interest in this field. New techniques of fast and precise monitoring providing information on the spatial structure of invasions are needed in order to implement efficient management strategies.

Remote sensing (RS) can offer timely and fast detection of individual species and serve for monitoring of eradication efforts. Compared to traditional extensive field campaigns RS enables coverage of considerable areas while being significantly less resource intensive.

For plant species detection, proper timing of data acquisition is important because less distinct species might be detected only at certain phenological stages. Application of unmanned aerial vehicles (UAVs) can provide flexible data acquisition to support this requirement. Extremely high spatial resolution is easily attainable with close range RS. This enables detection of invasions in their earliest stages when only a few isolated individuals are present on the scene.

In an on-going project in the Czech Republic, we aim at developing an innovative method of mapping invasive plant species featuring a dedicated unmanned aerial system (UAS). We examine detection possibility of several invasive species: giant hogweed (Heracleum mantegazzianum), black locust (Robinia pseudoacacia), tree of heaven (Ailanthus altissima), and knotweeds (Fallopia japonica, F. sachalinensis and F. × bohemica). All are considered invasive in a number of European countries and North America (except for the American native black locust), and are listed among the hundred most aggressive invaders in Europe (DAISIE database). Our objective is to establish a fast, repeatable and efficient computer-assisted method of timely monitoring, applicable for large areas.

To facilitate straightforward and efficient acquisition of UAV imagery a dedicated unmanned system is being devised. The focus is on operational flexibility and affordability while maintaining sufficient spectral and spatial resolution.
Among the fundamental requirements for the system are:

- Capacity to carry multispectral camera payload
- Low cost
- Reliability
- Ability to map an invaded site of at least 80 ha within one hour
- Straightforward deployment with minimum pre-flight and post-flight procedures
- Ability to be deployed in rugged terrain, ability to operate from unprepared surfaces and in constrained conditions - take-off and landing area no bigger than 10x30m, obstacles in vicinity
- Transportability in a hatchback car, ability to be hand-carried by one person for at least 1km
- Reduced environmental emissions and noise signature
- Simple field maintenance
- Capability of being deployed by a trained operator without sound piloting skills

Certain criteria suggest deployment of rotorcraft-based platforms, but the majority favour a traditional fixed-wing concept because it is inherently more energy efficient, features lower complexity, sound signature etc. Given these considerations, a fixed wing aircraft is selected as the preferred UAV concept.

Although commercial systems that fulfil most of the criteria do exist (e.g. Sensefly eBee), in our project we adopt in-house developed unmanned systems that are readily available at Brno University of Technology. Being fully comparable to their commercial counterparts in terms of capability, they provide advantages in the form of modularity, extensibility and open architecture. This will allow us to optimize the UAS to fully meet the requirements of demanding field deployment during invasive plant mapping missions.

For the current experimental unmanned platform a motorised glider concept was selected to take advantage of the low wing loading. Combined with expanded polypropylene, a durable material featuring excellent impact properties, this concept ensures safe landings even in rugged terrain. The platform is hand-launched with no need for additional equipment such as a catapult.

Propulsion is constituted by a brushless DC electric motor driven from a lithium-polymer battery pack via programmable controller. A foldable propeller improves tolerance to hard landings. This concept ensures clean, emission-free operation with a very limited sound signature. A depleted energy source can be quickly recharged or replaced, minimizing the time between consecutive flights.

Based on previous experience with both commercial and open-source autopilot systems, ArduPlane platform was deployed as the primary flight control solution. It runs on Pixhawk hardware and enables the platform to operate in fully autonomous mode including take-off and precise landing.

The payload consists of two modified consumer digital cameras minimizing the cost of the solution. One camera captures standard VIS data while the second is adapted to acquire NIR signal. With typical flight altitude of 150m above ground level, the resulting ground sampling distance is no worse than 6cm/px. This spatial resolution is fully adequate for the invasive species of interest.
To assemble the captured images we deploy structure from motion (SFM) algorithm. All acquired spectral channels are processed in one step, resulting in fully co-registered VIS+NIR mosaic and detailed digital surface model (DSM), which all enter the classification process.

During the classification algorithm development, we implement pre-classification rules based on detailed DSM (i.e. maximum species height). Apart from the well-established pixel-based methods we focus on methods that include temporal analysis enabled by flexible UAV imagery acquisition and spatial and textural context (object-based image analysis). This reduces within-class spectral variation and so-called salt-and-pepper noise and improves results for less spectrally distinct species. Results of UAV imagery interpretation are compared with commercially available aerial and satellite optical RS data to assess the influence of both spectral and spatial resolution. First results of this comprehensive methodology show promising detection accuracy.

The main challenges being faced so far include radiometric inconsistency of the acquired UAV imagery due to unstable scene illumination, inferior spectral performance of consumer cameras, and DSM errors generated in areas where vegetation growth is highly variable. Methods of negotiating the aforementioned challenges are the subject of on-going research.

The presented approach featuring flexible UAV aerial data acquisition is at the forefront of future invasive species monitoring and eradication efforts. Once the proposed automatic classification methodology is thoroughly tested to produce reliable results and the UAS is fully optimized, the system shall bring a decisive edge to invasive species management policy makers. Not only has this technology enormous potential for the invasion ecology community, it can also greatly contribute to the ever-growing precision agriculture industry and related sectors.