Unmanned Aerial Vehicles: Applications for Natural Resource Management and Monitoring

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ABSTRACT
Unmanned aerial vehicles (UAV) are commonly used in the defense and espionage industry. As the technology advances and costs decrease, the deployment of UAVs for natural resource applications becomes more obtainable. The USDA Forest Service, San Dimas Technology and Development Center, tested a UAV for mapping and monitoring capabilities on research sites near Volcano National Park. The tests proved that 8 cm per pixel resolution mapping is possible with UAVs. However, improvement is needed in areas such as aircraft state data and automated image processing. With improvements the system will have full high-resolution, forest mapping abilities. Currently the unit is fully capable of mapping forest edge and stream images, which could be used for SMZ monitoring. This may be particularly useful in the southern states where trespass rights by state inspection officials are limited.

Introduction

Many successfully adapted new technologies in the field of forest engineering have had military development as their point of 'birth'. Examples of such technologies include Geographic Positioning Systems (GPS) and mapping with Geographic Information Systems (GIS), lasers for range finding, radio frequency tagging for supply chain management, and self-leveling vehicles for working on steep terrain (Rumsfeld, 2003).

A new technology, using unmanned aerial vehicles (UAV) combined with digital imaging for use in the espionage and defense industry, is currently being developed by the military. The technology is reaching maturity and becoming available for non-military use. Considerable advances have been made in the technologies commonly incorporated in UAV use including guidance systems, aircraft reliability and durability, digital photography, hardware and software applications, and battery options. These technological improvements combined with an overall decrease in ownership costs present a fantastic opportunity for UAV applications in forest engineering and forest resource management.

This paper reports on the initial testing of a currently available UAV technology for forest management purposes. The paper also explores potential field applications of forest engineering as well as noting some possible limitations that need to be addressed before this technology will play a critical role.

UAVs and their Capabilities

UAVs, also known as 'drones', come in a wide variety of sizes, ranging from palm size units up to standard sized aircraft exceeding 12.5 tons. The UAV industry has not fully agreed upon exact classifications, but generally consist of micro UAVs, mini UAVs (5 to 20 pound gross take off weight), small UAVs (20 to 80 pound gross take off weight), tactical

UAVs, and High Altitude Long Endurance (HALE) UAVs.

Configuration varies with the intended use of the vehicle and the funds available. Rotor-wing units have hovering capabilities, while fixed-wing units tend to have longer flight durations and are inherently more stable in flight. Flight times range from several minutes to a few days.

Generally, there is a trade off of system accuracy and UAV size. Smaller UAVs tend to have less accurate aircraft state data. This type of information includes pitch and yaw of the aircraft, as well as location information, which tends to use a form of GPS. This aircraft state data can directly impact the accuracy of the data collected by the UAV.

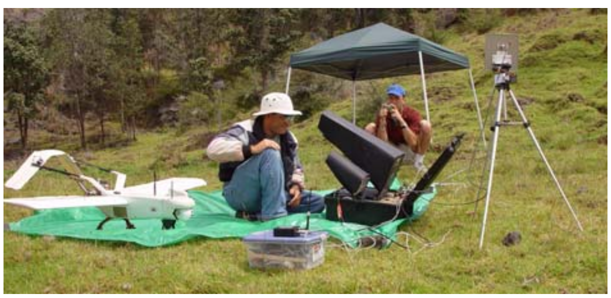

Figure 1: UAV components

UAV Testing

The USDA Forest Service, San Dimas Technology and Development Center, tested a UAV for mapping and monitoring capabilities on research sites near Volcano National Park. The goal of the test was to provide high-resolution, on-demand imagery for invasive species monitoring, since current imagery was unsuitable. The tests proved that 8 cm per pixel resolution mapping is possible with UAVs.

After a thorough market search, it was determined that the Bat III, produced by the MLB Company, was the most appropriate unit to use, due to its availability as an off-the-shelf-unit. Additionally, the US Fish and Wildlife Service used previous versions of the Bat for similar applications. MLB technicians performed all the functions necessary for the flight, including flight planning and operation of the unit.

The Bat III has a 15 lbs gross weight and is capable of a 4 lb payload, depending upon sensor configuration. Despite the 72 inch wing span and 56 inch length, the modular design of the unit makes it relatively easy to transport. This unit is capable of autonomous take-off and landings as well as autonomous flight. Maximum flight duration is six hours with a seven mile telemetry limit and a 200 mile fuel limit. A 23 cc two-stroke engine propels the Bat III to speeds ranging between 25 and 50 mph.

Due to the constraints placed on the test and the limited size of the available landing areas, both takeoffs and landings were performed manually. The data collection portion of the study used preprogrammed flight plans which utilized the autonomous flight capability.

The Bat III collected both still imagery and video imagery in flight. A live video feed was successfully transferred to the base station during flight, provided that the base station remained within line-of-sight to the Bat.

Using Photo Stitch software by Canon Inc. imagery sets of 10 or less, gathered along a road, forest edge, or stream course, could be rapidly mosaicked. However, within a forest stand mosaicking images became more difficult due to the lack of obvious control points within the images. These images required orthorectification using the state data available on the aircraft. As a result, forest stand maps required higher power image processing capabilities.

The UAV images were used to create second-generation orthophotos for some of the areas flown. Some difficulties encountered in this mapping process included a lack of suitable image overlap, unsuitable precision of aircraft state data, and a lack of control point flexibility within the processing packages. The cost of mapping through US processing companies ranged between $50 to $200 per image, on a 71 image set. These costs can be expected to decrease as contractors become more familiar with UAV image processing and processing volume increases.

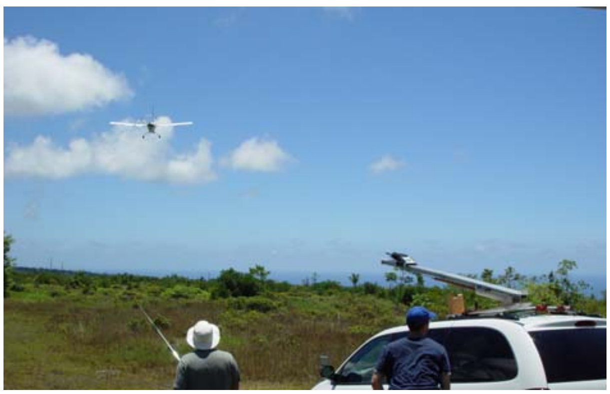

Image 2: UAV launch

Potential FE Applications

Currently there are a number of potential applications of UAVs to resolve forest engineering related problems.

BMP Inspections

Whether a state has a forestry practices act, or they have voluntary BMPs, the EPA requires the state forestry agency to help protect water quality. Locating harvest sites and inspecting forestry operations is a cumbersome and time-consuming activity. This is especially true in remote locations that are harvested over unspecified time frames. In some cases, driving to a single harvested tract can take a state official an entire day. Additionally, in most southeastern states the State Forestry agency does not have the right to trespass onto forested land to inspect for potential water quality violations (Yonce and Visser, 2003).

For this purpose the use of a UAV presents many opportunities. For those states that do not have a notification requirement, a high altitude flight would replace the current manned flight to locate recently completed or active harvest sites for reporting purposes to the EPA. Once located, a low altitude flight could capture high resolution images that would allow a state official to inspect environmental 'performance', such as the adequate use of SMZs, the quality of the stream crossing, the use of water-bars or turn-out structures on the skid-trails, and most importantly locating any active erosion sites that may be impacting water quality.

The ability of UAVs to fly in low cloud cover and moderate precipitation provides an additional advantage in SMZ monitoring. Given their ability to be deployed quickly, a specific area of concern could be checked during or immediately after a rain event. This type of low elevation, low visibility flight would not be permitted for manned aircraft due to Federal Aviation Administration (FAA) regulations.

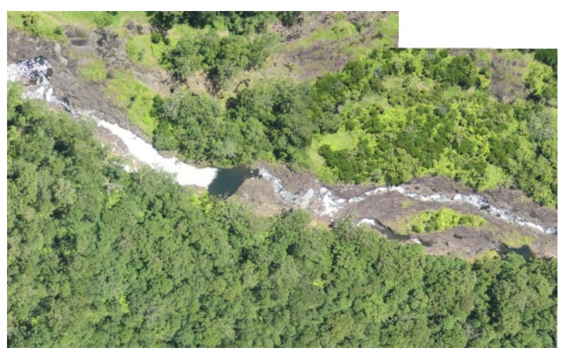

Figure 3: Mosaicked Images of Forested SMZ

Timber Theft

Timber theft continues to be a large financial concern to forestry companies, and a recent study in just 12 counties in South West Virginia indicated up to 12 million dollars were being stolen every year (Baker 2003). Issues include the extensive forest boundaries, difficulty in finding boundaries on the ground, and a lack of manpower to actually monitor for illegal logging practices. UAVs could be programmed to fly boundaries of large forested landholdings; the images collected could then be analyzed manually or with automated comparison software to detect changes in the landscape. Any harvesting activities located can be verified with legal harvesting operations.

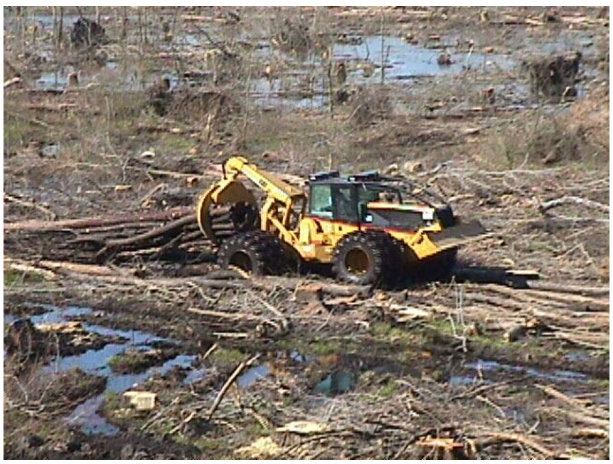

Figure 4: Image of active harvest operations

Road Maintenance

Forest roads and skid trails are typically the main source of erosion in forest operations. Even closed roads and trails are a concern. Using the corridor mapping capability UAVs can be programmed to fly over the complete forest road network and inspect for bank blow-outs or compromised drainage structures. If trouble spots were detected, an observer could retask the UAV during the same flight to take a closer look at those areas. Again, there is the benefit of using the UAV during or immediately after a rain event.

Trespass

Trespass is another issue where UAVs can aid forestry companies. Typical trespass issues for forestry include:

- ATV traffic compromising BMP structures (such as waterbars)
- ATV users constructing new trails through the forest
- poaching of managed game species
- dumping of refuse along roads
- arson

A UAV could be deployed at times when these behaviors are suspected to occur. The small size and relatively quiet operation of many UAVs would permit rapid surveillance of an area with minimal likelihood of detection.

Research

Forest operations research commonly compares the production rates of equipment on a particular site. With the relative ease of UAV deployment, high-resolution images could be collected as needed. For example collecting images twice a day would provide an effective means of mapping progress and provide production rates on a per acre basis. Higher intensity collection would provide data on machine interaction and bottlenecks. Combining these maps with site data would allow for further analysis, including the effect of slope on an operation.

UAV issues

Although the opportunities for using UAVs are great, there are still some potential problems to overcome. The current cost of purchasing the UAV system which was tested by the San Dimas Technology and Development Center is approximately $42,000, which includes the base station, UAV, guidance software, and training. Replacement cost of the drone in case of a crash and complete loss is estimated at $20,000.

Digital flight path coordinates that provide a wide margin of safety around objects the UAV might impact in flight are critical as the drones typically do not have warning or evasion systems. Therefore inaccurate input of desired flight coordinates, especially altitude, could result in a crash. Along with collisions with hillsides, other objects will also pose problems, including water and cellular towers, trees, and other aircraft.

Although significant advances have been made in automated high-resolution digital mapping (e.g. merging digital images, automated identification of land-use change, identification of potential trespass), significant software development still needs to take place for this technology to be a turn-key solution for many small forest managers. The relative inaccuracy of aircraft state data currently collected by small UAVs also presents challenges to image analysis software.
Additionally, the UAV community has been funded by, and as a result, is focused on defense related work. This work has funded the efforts required to develop the current capabilities of UAVs, but the needs and concerns of the defense industry are not entirely identical to those in the natural resource profession. This means that the UAV industry will need to modify their product and approach to consistently deliver usable goods to those working with natural resources.

However, the products will not be derived from the UAV community without support from those in the forest industry. Currently the FAA has chosen not to differentiate among different sized UAVs or to provide a gradient of flight requirements for UAVs. As a result, “see and avoid” procedures are required for UAVs as well as other aircraft, and UAVs are not allowed to exceed one thousand feet above terrain in US civil airspace. This requirement does limit the opportunities for many small UAVs. While the FAA and industry are discussing the matter, the applications of these units within the natural resource field will not be considered in the possible creation of these requirements, unless the UAV community learns the needs and intentions of users in the field.

Conclusions

Although there are still many limitations to the use of UAVs in forest engineering, broad utility has already been demonstrated in situations where manned flights would pose an unreasonable risk to the aircraft’s pilots and passengers. UAVs and data provided from UAV flights have just recently become available to the general public, and while image manipulation is currently time-consuming and imprecise, relatively minor upgrades to the flight platform and software used for mosaicking will soon allow more accurate, efficient automated image processing. Such imagery makes evaluation much simpler and makes UAV applications more cost effective.

References

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