Experimenting with Low-cost UAVs

The use of Unmanned Aerial Vehicles (UAVs) as serious remote sensing platforms is a growing trend. They are already used in fields such as archaeology, construction, disaster relief, and the oil and gas industry. Sandy Avery and Bruce Gittins argue their ability to be deployed and produce results quickly, requiring only a small team to operate, enables their use in hardtoreach places.

Though the financial and technical cost of using UAVs is constantly dropping, there are still high entrance barriers to their use. Many purposebuilt survey drones cost in excess of tens of thousands of pounds and require a significant amount of expertise to both setup and fly successfully.

In early 2014, the University of Edinburgh undertook a project to look at the feasibility of lowering the entrance barriers to the use of UAVs for photogrammetric survey. This was achieved by using a lowcost and relatively simple UAV to collect still images using a standard compact digital camera. These images were then processed using Agisoft Photoscan to produce a Digital Surface Model (DSM). Photoscan is a StructurefromMotion software system, which detects points of similarity between images, creating an orientated pointcloud of these points which can then be interpolated into a high resolution DSM.

The Legal Framework

UAVs are potentially dangerous vehicles which risk interfering with the safe use of air space by others. The regulator of UK air space is the Civil Aviation Authority (CAA). They have taken a lenient view on the use of UAVs for academic and notforprofit use, with CAA permission being rarely necessary outside towns and cities. As long as the survey is in uncontrolled airspace, it is 50m from buildings or roads and 150m from any urban areas no CAA permission is required.

To use a UAV for commercial image capture or surveying close to people or properties, permission from the CAA is needed. The CAA requires evidence of pilot competence, and this will usually involve an independent training course, which can be expensive. The CAA must also be notified of every new location for flying unless an agreement has already been negotiated with them. Regardless of the use, suitable insurance coverage should be sought in case of accidents.

The UAV must remain in line of sight during the flight, with this being defined as being within 500m horizontally, and 400 feet (122m) vertically, of the pilot at all times. Currently the use of a video piloting system, aka First Person View (FPV), does not alleviate this requirement, and our experience suggests that assessing the flight direction, and therefore safe retrieval of small UAVs, has proved challenging at even just 200250m from the pilot.

For safe and effective flying we found that having a fourperson ground crew was wise. This allows the pilot to focus solely on flying the UAV, with a spotter keeping an eye out for any birds or other hazards, which may get too close and a navigator guiding the pilot to the targets. The fourth member made sure that members of the public remain at a safe distance of 30m to the designated and marked takeoff and landing zone and provided explanations of the work when operating in areas frequented by the public.

It was also found to be good practice to display several warning signs around the survey site as well as to provide leaflets to inform the public about the work in progress.

Technology

There are two broad categories of UAVs; fixed wing and rotary. Fixed wing UAVs most closely resemble a traditional aircraft configuration having a sizeable horizontal wing to provide lift with a single nosemounted engine. In contrast, rotary UAVs are rather like helicopters, having four or more engines mounted around the main body of the UAV to provide lift. The engines are usually electrically driven, so the carrying capacity of the platform needs to include the weight of batteries. Both types of UAV have their advantages and disadvantages. Fixedwing UAVs can systematically cover greater areas and generally provide a more stable camera platform, whereas rotary UAVs permit vertical takeoff and landings (thus being useful where space is restricted) and can very effectively hover over particular targets of interest.

A DJI Phantom FC40 was chosen as our survey platform. Its simple design, ease of use and low cost of around £350 ticked all the boxes. Its four engine rotary configuration was chosen over a fixed wing design as its ability to hover offered greater versatility, allowing it to be used for photogrammetric surveys as well as for video or image collection of hard to reach sites such as rooftops and cliffs. Its small size of only 29 x 29 x 39cm and relatively quiet engines were also a benefit, allowing it to work in environmentallysensitive areas.

The Phantom has a semiautonomous flight mode using its onboard GPS, which gives it the ability to stabilise itself against the wind as well as return to “home” if a fault develops or the control signal is lost. These functions worked surprisingly well and this level of automation is enough to make the UAV very easy to fly and a new pilot can be proficient with only a few hours of practice. It also provides a relatively stable platform in low to medium wind speeds, something which we have put to the test on several occasions when performing surveys in Scotland!

This UAV has a maximum flight time of around 1012 minutes and a carrying capacity of less than 500g; the heavier the payload the shorter the flying time. By modifying the camera mountings on the platform it was found that both a compact digital camera can be mounted below the UAV angled for surveying whilst the default FC40 camera is mounted to the front of the platform. This enables a rudimentary but highly practical First Person View (FPV) system to be created with live 720 pixel video to be streamed to a smartphone or tablet – giving the pilot a realtime, UAV eye view – at little additional cost. This further reduces the piloting training time because it enables the direction of flight to be more easily determined. This is often an issue when the vehicle is flying more than 100150m away from the pilot and in certain lighting conditions.

The platform lacks the ability to follow preplanned waypoints and does not (easily) provide a log of its travelled route. We compensated for this by thorough preflight planning combined with field checking of the image coverage. Some cameras also come with builtin GPS and the geotagged pictures can be used to produce a rudimentary flight path for the UAV if necessary. Alternatively, lowcost and lightweight GPS logging modules are widely available. However, some problems were identified with the Phantom’s homing ability. If the GPS signals are lost, or if there is a serious headwind with declining battery life, its ability to get out of trouble by itself or return home could be an issue. As such it should only be used in an emergency or when there is no other option.

Cameras

Traditional metric survey cameras are extremely expensive and rather too heavy for our purposes – they have been designed to be mounted on conventional aircraft or large balloons. The limited payload of the DJI Phantom means that it is usually used with the popular GoPro digital camera. We were able to compare this device with a Canon SX230 HS, and their usability and the accuracy of their products were compared.

The GoPro Hero 3 is a lightweight, durable camera which required no modification to be used in an aerial surveying role. It has several benefits such as a wide-angle lens and a fast continuous shooting mode (0.5second). This allows for good coverage and rapid image capture. However, there are also limitations. We established that images were often blurred whilst the UAV was in motion owing to the relatively slow shutter speeds. The UAV therefore had to be paused over the target long enough to ensure good steady images had been taken. This situation could be improved by a vibrationdamping gimbal system. However, many of the camera settings were also locked in a constantly changing ‘auto’ setting mode leading to exposure inconsistencies between images.

Other limitations include fisheye distortion, low resolution and the effects of a rolling shutter. GoPro cameras are designed for sportsuse, where fixed optics and a particularly wide field of view ensure that none of the action is missed. Unfortunately this also causes the fisheye distortion. Alternative ‘modes’ were available but these simply cut a lower resolution image out of the wide field of view, resulting in the effective resolution for the GoPro being rather less than its advertised capability (5 or 7 megapixels compared to the expected 11 or 12 megapixels). The rolling shutter led to problems with capturing video when the UAV was travelling at speed. The motion of the rolling shutter would lead to a wobbling effect in the video which has been affectionately named the ‘jello effect’. This is difficult to rectify through video editing, though a neutral density filter did produce some improvement. Together, these limitations led to distortion in the captured images, leading to a drop in the accuracy of any digital surface models which were produced.

In contrast, the Canon SX230 Powershot has superior resolution, a full 12 megapixels, as well as the ability to manually adjust the shutter speed, down to 1/3200 second, ISO settings and FStop. These enable easy adaption for a variety of environments as well as producing higher resolution images with little or no motion blur or colour distortion. In particular the Canon’s high ISO setting and shutter speed meant that a damping gimbal was not required thus lowering the overall cost. However the Canon is slightly heavier than the GoPro – reducing flight times. It is programmable using a scripting language and the Canon Hack Development Kit and therefore proved highly customisable. This was needed to provide an intervalometer function for capturing images at regular intervals. The combination of the FirstPerson View (FPV) system with a remote camera trigger also enables images to be taken only as desired.

Testing showed that the Canon’s faster shutter speed allowed the camera to take higher quality images more consistently than the GoPro, and this consequently enabled production of a more accurate DSM. The average vertical accuracy for the Cannon DSM was ±7cm, whereas images from the GoPro gave a vertical accuracy of only ±25cm. However, the GoPro is far better for capturing video than the Canon, which struggles to compensate for the unstable platform, especially in wind.

Conclusions

UAVs of all shapes and sizes are gaining popularity and are being used in a variety of different roles. They are a new source of data and promise to revolutionise the way it is collected. This project has shown that it is perfectly possible to use a lowcost UAV platform for serious photogrammetry, with excellent results produced with little prior experience. It has validated the prospect of smaller organisations sourcing their own data and challenging the monopoly that larger organisations have had on aerial data and imagery.

The DJI Phantom was capable of carrying an alternative camera that produced rather better results than the moreusual GoPro device. These results are reflected in the quality of the orthophotos and DSM, which can be produced. In addition to vertical photography, the vehicle also provides an excellent platform for oblique photography favoured in archaeological survey and for video, although an appropriately stabilised GoPro camera proved to be the more satisfactory option in the latter case. The total cost of the package (UAV and camera) was less than £700.

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