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**Geological Survey of Ireland Research Programme
- Short Call 2015, Final Report -**

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Organisation name	University of Limerick
Organisation type:	☒ HEI ☐ Public Sector (other) ☐ Private Sector
Department/section	Mobile and Marine Robotics Research Centre, Electronic & Computer Engineering Department

Project Title	Semi-autonomous UAV landing in challenging conditions
Contract No.	2015-sc-054



Project Report (max 1500 words, excluding figures and headings):

(i) Objectives and scientific/engineering targets beyond the state of the art

The goal of the national programme of INFOMAR is focused on the creation of a range of integrated mapping products of the physical, chemical, and biological features of the seabed in the near-shore area. UAVs are used to survey and map the very shallow (eg <1m) waters, deemed unreachable by sea vessels.

According to the Irish Aviation Authority rules, it is forbidden use UAV farther than 300m from the pilot position and with a maximum altitude limit of 120m. This represent a significant limitation in the efficiency of the mapping task for a pilot stopped in a specific position.

Use of a mobile base for the pilot such as a moving ground vehicle or a vessel offshore can be a practical and effective solution to this problem and can greatly enhance the efficacy of mapping along the inter-tidal zone. One of the remaining big challenges for autonomous aerial vehicles is reliable take-off and landing in challenging conditions, such as from a moving marine vessel or an off-road vehicle near the coast.

These manoeuvres are extremely demanding for pilots due to the large number of variables involved, caused mostly by the relative motion of the two vehicles. The goal of this project was to develop reliable control techniques to aid the pilot, giving her/him a higher level of guidance of the UAV by automating lower level control.

(ii) Implementation (including reference to timelines, milestones, management)

The main objective of this project was to develop and demonstrate a working prototype of a UAV control system capable of aiding the pilot to land the vehicle on a variety of moving platforms. This was achieved through a novel integration of Global Navigation Satellite Systems (two receivers, one in the UAV and one in the landing platform) and state-of-the-art computer vision techniques.

Prior to project realization it was assumed that a commercial UAV system (quadcopter or similar) would be utilized (possibly one owned by GSI/INFOMAR). However, due to unforeseen circumstances, a suitable UAV system was not available for this project. For this reason an inexpensive commercial UAV system (Parrot AR Drone 2.0) has been acquired to serve as demonstration prototype platform to test developed software and control algorithms. Furthermore, the control system developed within the project can be easily adapted to suit larger commercial non-fixed wing platforms.

The timeline of the project can be summarized as following:

- Q1

During the first quarter we mainly developed the hardware system by the integration and combination of components and equipment available in our lab. The hardware system is composed of the following component:

1. Parrot AR Drone 2.0: an inexpensive commercial drone equipped with HD camera, GNSS, Accelerometer, Gyroscope, Compass, and WLAN communication.

The system required modification of camera position (original front-looking orientation has been modified to the bottom-looking orientation, in order to develop/use advanced mapping and vision functions).

2. Trail Landing Platform: consists of mechanical frame mounted on wheels, to simulate a moving platform (boat or a truck). The platform is equipped with a fiducial marker on top, GNSS system (Ublox neo-6m) and WLAN mobile station (Ubiquiti PicoStation M2).

3. Control Station: consisting of a laptop equipped with WLAN extension Antenna (Ubiquiti PicoStation M2) and a commercial Joystick used to control the motion of the drone in manual pilot mode.



- Q2

During the second quarter we developed the software for automatic positioning of the drone above the landing platform as an approach stage in landing manoeuvres.

The software is able to compare the relative (GNSS) position of the drone and the platform. Real-

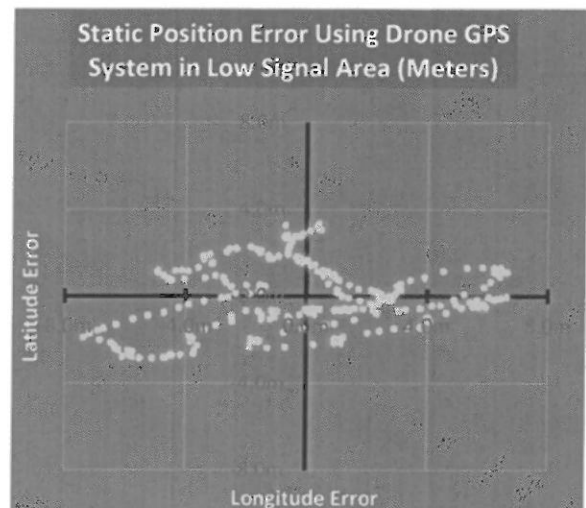
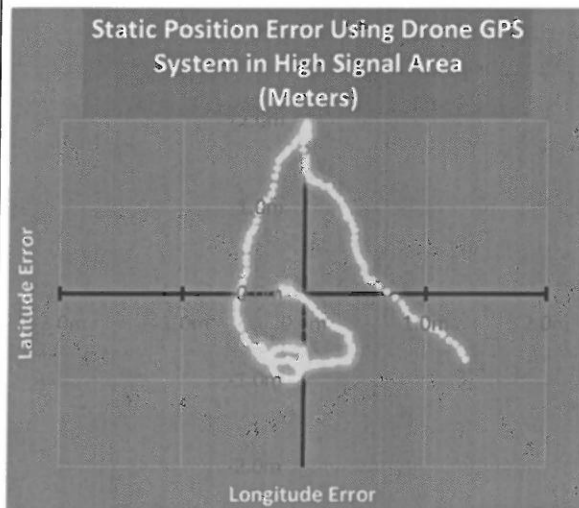
time measurements of position and orientation (attitude and heading) of the UAV and the Landing Platform are used to generate the vector (direction and distance) of the movement required in order to position the drone above the Landing Platform. The vector generated is sent to the control software that realizes a PID control of the Pitch and Roll in order to fly the UAV to obtain the requested position above the landing platform.

- Q3

The position accuracy of the drone, obtained from a simple GNSS system used in this project, is not high enough to provide conditions for reliable and safe automatic landing.

The main problem of the GNSS data is that the precision is strongly connected with the quality of the GPS signal.

We performed tests with different GNSS systems in poor and good GPS satellite constellation view/reception conditions. For example poor satellite constellation, restricted view of the satellites in the sky hemisphere due to terrain, structures, trees; good satellite constellation view of satellites: open view of sky hemisphere) Some of the results are shown in the following figures:



In order to get reliable position information in all conditions and move towards a more robust control solution, we decided to integrate the GNSS based flight control to moving target landing platform with a vision system implemented aiding system for final approach and land. The developed system uses a machine vision approach, implemented in LabVIEW, using a fiducial marker on top of the platform and image acquisition from the on-board camera. The developed algorithms provide accurate distance and pose estimation to target at high refresh rates suited to dynamic environments. To improve robustness of the detection algorithms, a more suitable lightweight camera from Point Grey, Blackfly with Kowa LM6HC lens, was also utilised. This showed a marked improvement in terms of image quality and pose & distance detection accuracy.



- Q4

In the last quarter of the project, the integration of both software modules into unique control system was completed. The system algorithm utilises the GNSS data to move the drone to the position above the platform within GNSS accuracy/tolerance limits. At this point, with appropriate wide-angle camera system and control of altitude, pitch and roll of the UAV/Camera system, the vision system acquires the target fiducial marker and the software switches to combined GNSS (from both UAV and landing platform) and relative position/orientation data to fiducial marker in order to complete a safe landing. During the landing phase, the system enables automatic following of the moving platform by the UAV and the pilot has control over vertical speed during landing operation. Furthermore, the pilot graphical user interface, also developed in LabVIEW, includes additional functionality such as battery level monitoring and distance and altitude monitoring from the operator/pilot in order to respect the licence/flying rule limits imposed by the Irish Aviation Authority (300m distance and 120m altitude limit).

(iii) Outputs (please use bullet points)

- Operational semi-autonomous take-off and landing system from/onto moving platforms for UAVs,
- Easily adaptable to other commercial quadcopters available in the market.
- Development of knowledge and expertise on potential use and limitations of GPS and Vision technology in order to realize a performing UAV landing system.
- Development of UAV control expertise in Ireland

Impact/value of the project (Max 500 words):

The project deals with a very real problem in the fast growing sector of unmanned aerial vehicles. The results obtained during the project lifetime represent an essential working solution necessary for use of UAV systems in performance of inshore mapping in compliance with Irish Aviation Authority rules (or Aviation Authority rules in other territories).

It also represents a good starting point for follow-on projects that would include an equipment budget for purchase of a capable commercial UAV. Other interesting developments for the future could include the

implementation of a commercial photogrammetry mapping solution or the integration of photogrammetry software already developed within the MMRRRC. For improved survey operations in the field, the developed or enhanced UAV inter-tidal zone mapping solutions could be integrated within autonomous aerial vehicles into the OceanRINGS platform, the suite of smart technologies for marine and subsea operations developed over the last twelve years, by the research team in Mobile & Marine Robotics Research Centre.