4-12-2011

Demo Abstract: R.A.V.E.N. – Remote Autonomous Vehicle Explorer Network

Paul Martin
paulmart@sas.upenn.edu

William H. Etter Jr
University of Pennsylvania, etterw@seas.upenn.edu

Rahul Mangharam
University of Pennsylvania, rahulm@seas.upenn.edu

Recommended Citation

Paul Martin, William H. Etter Jr, and Rahul Mangharam, "Demo Abstract: R.A.V.E.N. – Remote Autonomous Vehicle Explorer Network", . April 2011.

@INPROCEEDINGS{raven_ipsn11,
author={Martin, P. and Etter, W. and Mangharam, R.},
booktitle={Information Processing in Sensor Networks (IPSN), 2011 10th International Conference on},
title={Demo abstract: R.A.V.E.N. #x2014; Remote autonomous vehicle explorer network},
year={2011},
pages={123-124},
keywords={aerospace control;aircraft;remotely operated vehicles;Canadian police forces;R.A.V.E.N;UAV;United States police forces;attitude measurements;demo abstract;quadrotor aircraft;remote autonomous vehicle explorer network;unmanned aerial vehicles;wireless communication;Base stations;Cameras;Lead;Tracking;Wireless communication;Wireless sensor networks;Zigbee;Autonomy;Real-time systems;Unmanned Aerial Vehicles;control systems;cyber-physical systems},}

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Abstract
Unmanned aerial vehicles (UAVs) have recently become a viable platform for surveillance and exploration tasks. Several commercial quadrotor aircraft have been successfully used as surveillance equipment with groups such as United States and Canadian police forces, and additional applications for this technology could include exploration of ra-dioactive/hazmat environments, naval search and rescue, or surveying a building on fire, to name a few. Despite the agility and speed of the quadrotor platform, current systems lack the redundancy and collaboration of a multi-unit team; current implementations of quadrotor UAV flocks require expensive equipment, limiting the system to operation within range of external sensors. We propose a system for intelligently controlling multiple quadrotor UAVs using a combination of on-board vision tracking and wireless communication of attitude measurements. The proposed system uses a lead, human-controlled quadrotor and one or more quadro-tors that track and follow the lead unit autonomously. The forthcoming system aims to improve the execution time required to complete missions and increase both breadth of search and platform effectiveness.

Keywords
Real-time systems, control systems, cyber-physical systems, Autonomy, Unmanned Aerial Vehicles

Disciplines
Aerospace Engineering | Computer Engineering | Electrical and Computer Engineering

Comments
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Paul Martin William Etter Rahul Mangharam
Dept. Electrical & System Engineering
University of Pennsylvania
{pdmartin, etterw, rahulm}@seas.upenn.edu

ABSTRACT

Unmanned aerial vehicles (UAVs) have recently become a viable platform for surveillance and exploration tasks. Several commercial quadrotor aircraft have been successfully used as surveillance equipment with groups such as United States and Canadian police forces, and additional applications for this technology could include exploration of radioactive/hazmat environments, naval search and rescue, or surveying a building on fire, to name a few. Despite the agility and speed of the quadrotor platform, current systems lack the redundancy and collaboration of a multi-unit team; current implementations of quadrotor UAV flocks require expensive equipment, limiting the system to operation within range of external sensors. We propose a system for intelligently controlling multiple quadrotor UAVs using a combination of on-board vision tracking and wireless communication of attitude measurements. The proposed system uses a lead, human-controlled quadrotor and one or more quadrotors that track and follow the lead unit autonomously. The forthcoming system aims to improve the execution time required to complete missions and increase both breadth of search and platform effectiveness.

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1. INTRODUCTION

According to a 2008 report, during urban search and rescue missions there is a narrow 72 hour time frame to rescue a victim before the probability of finding and restoring a victim to full health drops to nearly zero [4]. Unmanned aerial vehicles (UAVs) have recently become a viable platform for surveillance and exploration tasks where human presence is inadequate. With several commercial quadrotor VTOL aircraft successfully used for surveillance with groups such as United States and Canadian police forces, additional applications for this technology could include the exploration of radioactive/hazmat environments or surveying collapsed buildings. Despite the benefits of these platforms, current systems use only one UAV and lack the redundancy and collaboration of multi-unit teams. Towards mitigating this drawbacks, we have designed a system for the intelligent control of quadrotor UAV flocks. This system consists of a lead, human-controlled unit and one or more units that track and follow the lead unit autonomously.

Quadrotor platforms have found increasing use in academic settings. The University of Pennsylvania's GRASP Laboratory has developed advanced controls for quadrotor platforms using a Vicon 3D motion capture camera system [2]. Students at ETH Zurich have developed the PixHawk quadrotor–a system that uses cameras for simultaneous localization and mapping (SLAM) as well as detection of objects. This method of SLAM offers potential in multi-quadrotor systems, though PixHawk does not extend their vision detection to relative localization between quadrotors [1]. The University of Essex has developed a multiple micro air vehicle (MAV) system using a separate base station unit with infrared ranging accurate to within 1 millimeter [3]. All of these solutions, however, limit operation to within range of the base station.

When dispatching a swarm of quadrotor units to a location, the challenge of determining the platform's placement in space with respect to the surroundings (localization) is increasingly important as the simplicity and familiarity of the environment diminish. As previously determined by the systems described above, methods currently used require pre-installed systems, limiting both the range and effectiveness.

A cost-effective and manageable solution is to allow the user to guide the lead quadrotor, creating a "clear" path for

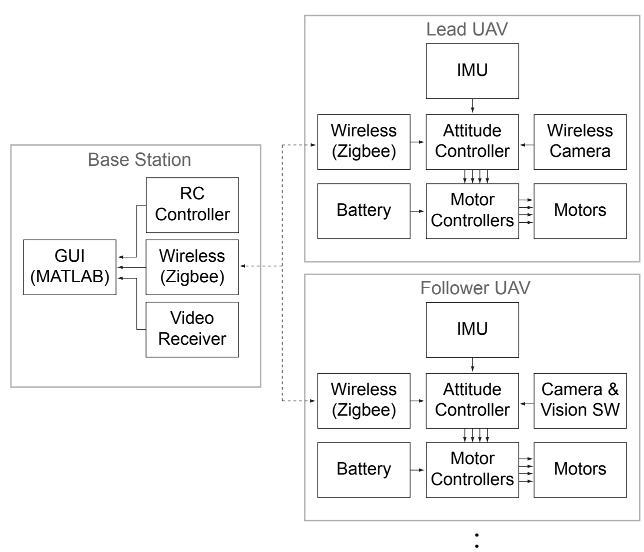

Figure 1: System overview

IPSN'11, April 12–14, 2011, Chicago, IL, USA
ACM xxx-x-xxxxx-xxx-x/xx/xx.

other units to follow. The tracking of the lead quadrotor unit is accomplished via a combination of infrared camera tracking and wireless transmission of attitude information. This system eliminates the requirement of standard localization equipment or a human operator for each quadrotor, effectively managing resources during a critical mission.

2. MATLAB MODEL

The MATLAB model is written to simulate the physics of the experimental setup, the control loops for stabilization, potential flight trajectory extrapolation algorithms, and potential sources of errors. Quadrotor units are written as objects, allowing us to command a desired Euler angle for any quadrotor, actualized by a virtually-tuned PID. Each quadrotor unit designated as a "follower" has a simulated camera view of the unit in front, allowing us to design algorithms given the same sensor data that is available in the experimental platform. In addition, simulated RF data with a pseudo-random noise is sent to each quadrotor, allowing for a more accurate relative localization consensus.

3. EXPERIMENTAL PLATFORM

The experimental platform has three subsystems. The first is the lead quadrotor UAV, shown in Figure 2, a human-controlled unit that receives commands from and transmits information to the second subsystem – the base station. The base station is composed of a graphical user interface (GUI) that allows the user to see in real-time the view from the lead quadrotor, while controlling it with a wireless radio control unit. Any pertinent environmental information (e.g. infrared detection of heat signatures, radioactivity levels, etc. depending on the sensors installed) is transmitted via wireless RF from the lead quadrotor to the base station. The final subsystem is composed of one or more follower quadrotor UAVs. These are identical to the lead UAV with the exception of additional vision processing hardware. Each follower quadrotor receives inertial measurement unit (IMU) data from the lead and other follower quadrotors. This data includes the spatial orientations (yaw, pitch, and roll), the current accelerations experienced, and the altitude. This information, coupled with object tracking information from the front-facing cameras (distance and relative position), allows the follower quadrotors to perform a relative SLAM based off of the coordinates of the lead unit. This data is also sent to the base station where a graphical representation of the quadrotor vehicle network is displayed.

4. NETWORKING QUADROTORS

Robust communication layers are very important to the success of both the MATLAB model and the experimental platform. Towards this, we are using Zigbee communication at 900 MHz to avoid the more popular 2.4 GHz interference we might encounter. Each quadrotor is given a unique address, and acknowledgements are sent to ensure the successful transmission of data. XBee Pro 900 modules are used on both the quadrotors and the base station for transmission of attitude, altitude, and battery data, and a 1.2 GHz 800 mW video transmitter is used to relay the lead quadrotor video to the user.

5. SYSTEM EVALUATION

Evaluation and verification of the hardware and software components is accomplished through measuring the performance of the following quadrotor's ability to track and follow the leading quadrotor. This can be based on the effectiveness of the data transmission between the two quadrotors (such as dropped packets and inaccuracies), the camera vision tracking system implemented on the follower and its ability to detect the leader, and the physical displacement between the two quadrotors during a range of movements carried out by the leader.

Figure 2: Quadrotor Platform

6. DEMO REQUIREMENTS

The nature of our experimental platform is such that a large space and protective precautions are required. Although safety measures have been taken to ensure the proper failsafes are in place, we request a roped off section of 20 ft^2 in order to fly without danger of coming close to an observer.

7. DEMO SCRIPT

Observers visiting our demo will be able to view the following capabilities of the quadrotors in flight. A computer monitor will show information regarding the current settings of the tracking algorithms as well displacements between the two quadrotors. The lead quadrotor, under human control, will be placed through a series of movements that the following quadrotor will attempt to track.

8. REFERENCES

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