Simulating Drone-be-Gone: Agile Low-Cost Cyber-Physical UAV Testbed (Demonstration)

Mouhyemen Khan[†‡], Sidra Alam[†‡], Amr Mohamed[†], Khaled A. Harras[‡]
[†]Dept. of Computer Science & Engineering, Qatar University, Doha, Qatar
{mouhyemen.khan, sidra.m.alam}@gmail.com, amrm@ieee.org
[‡]School of Computer Science, Carnegie Mellon University, Pittsburgh, USA
kharras@cs.cmu.edu

ABSTRACT

In this paper, we demonstrate Drone-Be-Gone (*DbeG*): a general-purpose, inexpensive, and agile UAV Cyber-Physical System (CPS) testbed. We implement on our testbed 2-D vision-based localization within 5 cm precision, controllability of multiple UAVs, a simulation environment of our testbed in 2-D (named *TeSLA*), and external processing units (EPU). The testbed has the ability to switch between centralized or distributed control and processing due to the addition of EPUs. The simulator will allow users to interact with our testbed virtually and observe its behavior.

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1. INTRODUCTION

Unmanned Aerial Vehicles (UAVs) continue to be the most dynamic sector of the aerospace industry as sensor and automation technologies mature. A sub-domain of UAVs involves the development of testbeds where researchers go beyond theory to more practical implementations. Prior efforts dealing with UAV testbeds typically have a large barrier of entry due to high-cost and extreme customization. Some testbeds are based on expensive motion capture systems [4], or expensive UAVs such as the Hummingbird or Dragan-Flyer [3, 4, 6]. Others include a network of UAVs and Unmanned Ground Vehicles (UGVs) in distributed/centralized fashion [1, 2], and are involved in search and rescue operations or geographical surveillance. Although significant work has been done on testbeds involving UAVs, there has been preliminary efforts in building less expensive testbeds. The Up&Away testbed uses AR.Drone as their UAV and is an initial attempt to build a low-cost CPS testbed [5]. This attempt however has poor localization, lack of distributed control and processing, and coarse-grained navigation of UAVs.

Drone-Be-Gone Testbed: In this paper, we present Drone-Be-Gone (*DbeG*): a general-purpose, inexpensive, and agile Cyber-Physical System (CPS) testbed using off-the-shelf UAVs with centralized or distributed control and processing. *DbeG* has four main features. *1) Vision-based 2-D localization*: Intensity-contour detection and our own Adaptive Tracking Window algorithm detects and distinguishes UAVs respectively inside the testbed. *2) Autonomous navigation for multiple UAVs*: We implement a lightweight navigation routine for controlling AR.Drone 2.0 from Parrot that handles UAV-drift during translational and rotational flights through a feedback control system. *3) Simulation environment of testbed*: We develop an effective simulation environment of our testbed in 2-D for safety testing of algorithms before deploying the actual testbed. The simulator is called ***T****estbed* ***S****imulation with* ***L****ocalization &* ***A****utonomy* (*TeSLA*). *TeSLA* combines our implemented localization and autonomous control of UAVs and serves as a safety pre-cursor before deploying on the real testbed. *4) External processing units (EPUs)*: The addition of EPU enables the groundwork for distributed control and/or processing. Intel Edison is the EPU used in *DbeG*.

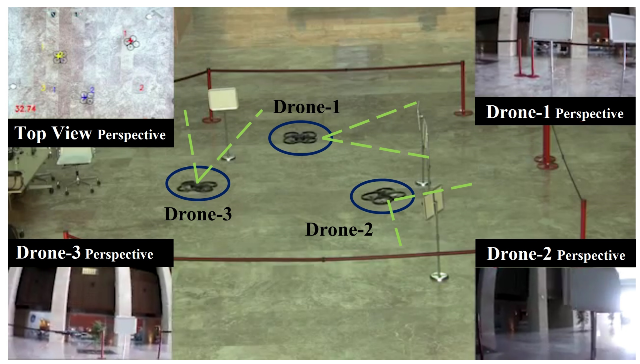

Figure 1: 3-drones (circled in blue) covering their respective targets. Green-dashed lines represent drone-FoV. Within each drone's perspective, the white stands are the targets.

Scenario on our testbed: The scenario depicted in Figure 1 highlights target coverage in a visual-sensor network where the drones are assigned targets to cover within their field-of-view (FoV) autonomously. The top-view perspective, each drone's perspective, and in-action view are shown in Figure 1. Drone-1 covers 2 targets since the targets are adjacent to each other and fit within the FoV of Drone-1. When the third target is introduced, Drone-2 flies to cover it since Drone-1 cannot cover it. The last target elsewhere on the testbed is covered by Drone-3 since Drone-1 and Drone-2 cannot cover the target along with their respective targets.

Drone-be-Gone Architecture: The underlying architecture behind our testbed is depicted in Figure 2a. It comprises of 2 major modules: *Central* and *Client*. Additionally, there is a special module that we call *Multi-homed* module.

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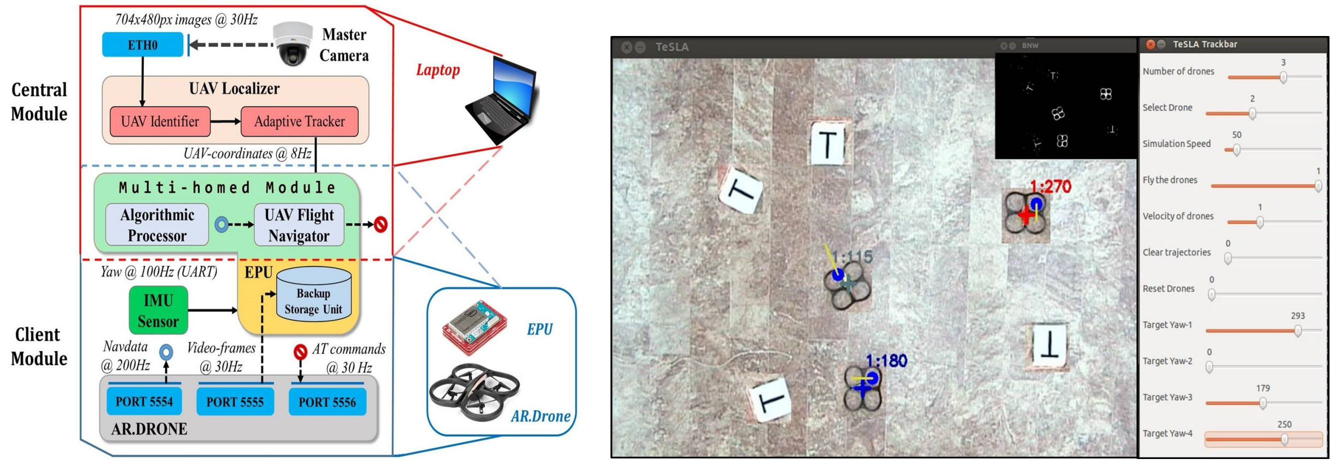

(a) Drone-Be-Gone's Architecture

(b) Drone-Be-Gone's simulated version - *TeSLA*

Figure 2: *DbeG's* architecture showing each major module's corresponding hardware location. *TeSLA* allows interactivity through placement of multiple drones, targets, creating individual trajectories for drones, and an interactive trackbar for parameter tuning. *TeSLA* can also be linked with an external algorithm to model the testbed's behavior.

Central and *Client* module has exclusive sub-modules which perform mandatory responsibilities - localization and sensory acquisition respectively. *Multi-homed* module contains sub-modules which can be located in either of the major modules. Based on the location of these sub-modules, the major modules can be tasked with desired responsibilities thereby allowing easy migration between a centralized to distributed platform or vice-versa. The *desired* responsibilities can be algorithmic processing or drone navigation.

2. DEMONSTRATION

This demonstration aims at providing an interactive experience with our testbed through the aid of *TeSLA*. Indeed, it will not be possible to demonstrate the testbed live since the actual localization relies on using a Network Camera overlooking the testbed from above. However, *TeSLA* serves as a handy-tool in demonstrating our testbed's overall performance in a cohesive manner i.e. localization and UAV navigation when integrated with an external CPS application. In addition, we will also present the AR.Drone 2.0 mounted with and controlled by Intel Edison as its EPU. The performance of our testbed, *DbeG*, the simulator, *TeSLA*, and its integration with *DbeG* can be viewed at:

https://youtu.be/rw8rN87tJvA

TeSLA: *TeSLA* simulates *DbeG* in 2-D and incorporates *DbeG's* localization and autonomous navigation routines. However, *TeSLA* goes beyond just the integration of the aforementioned routines. Using *TeSLA*, we are able to observe the performance of our system when integrated with an external CPS application, such as coverage algorithms, on our testbed. The integration of localization, navigation and an external CPS application in action provides us with insights into the nature of our system and serves as an effective safety precursor. It is designed using OpenCV bindings for Python.

Demonstration Setup: For the purposes of our demonstration, we will utilize a laptop running *TeSLA*. Specifically, a Lenovo Y50 laptop will run the simulation and will be made available to the audience to interact with all required modules already installed. A sample coverage algorithm will also be pre-loaded in the laptop in order to demonstrate *TeSLA's* performance.

Audience Interaction: Participants will be able to interact with *TeSLA* as portrayed in Figure 2b. The user will be able to choose the number of drones and also provide individual trajectories for each drone. A trajectory is made up of a destination point and orientation. The user will also be able to place targets anywhere on the testbed and rotate them. The user can also subject *TeSLA* to the coverage algorithm after placing targets anywhere on the testbed to see the drones in action.

3. ACKNOWLEDGMENT

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