Q-Hummingbirds: **Distributed Cooperative Multi-UAV Platform for Agile Coverage and Surveillance**

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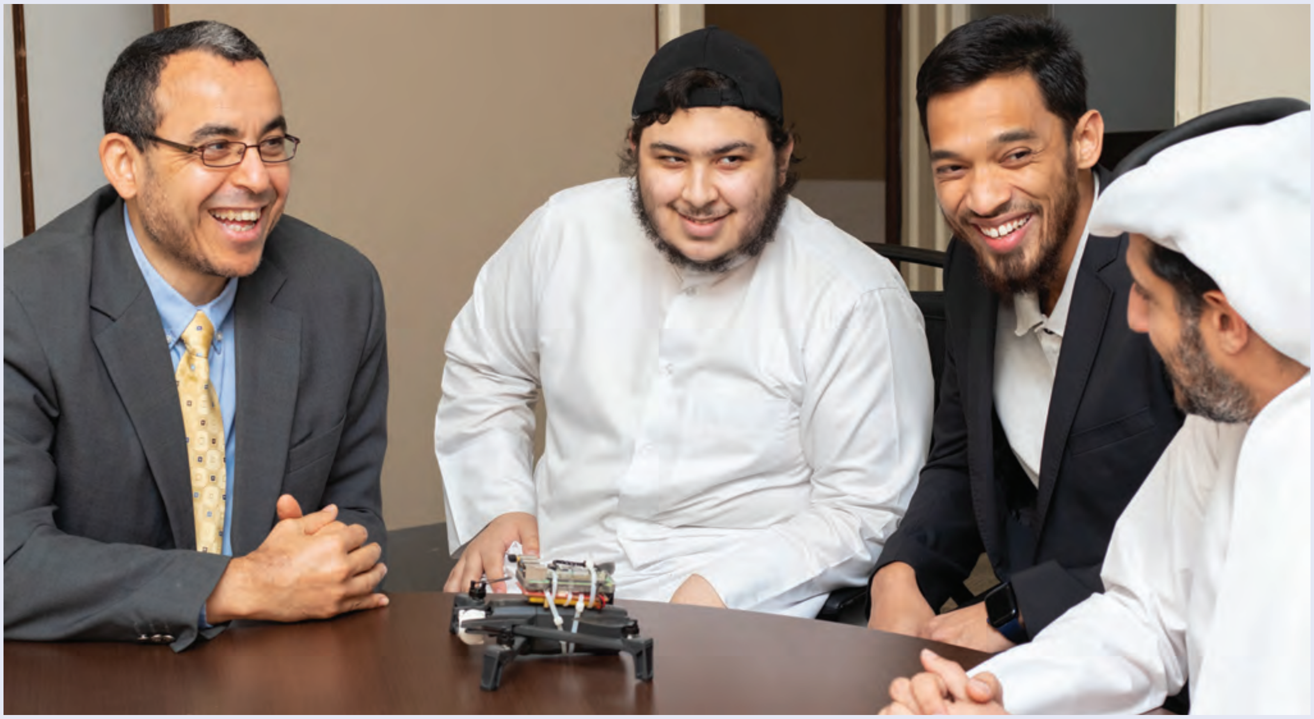

From left: Prof. Amr Mohamed, Abdelrahman Soliman, Mohamed Daniel Izham, and Dr. Abdulla Al-Ali.

As part of a high impact grant project no. QUHI-CENG-20/21-1 entitled "Q-Hummingbirds: Distributed cooperative multi-UAV platform for agile coverage and surveillance," supported by Qatar University, a research team have worked on developing an intelligent UAV platform using hardware integration and artificial intelligence (AI) techniques for search and tracking of mobile targets without knowing their exact locations. The team was led by Dr. Abdulla Al-Ali, and Prof. Amr Mohamed, and includes researcher Dr. Hend Gedawy. The UAV platform has many such as in military, national boarder security, farming, and marine biology.

Unmanned aerial vehicles (UAVs), more commonly known as drones, represent a highly promising technology that could revolutionize many fields in our lives. From home security to livestock tracking, and military reconnaissance to traffic monitoring, drones are indispensable. Unlike remote sensing using satellites, which has limitations recognizing detailed patterns due to far distances, autonomous UAVs flying over low altitudes provide efficient solutions for fine-grained monitoring, and hence they proliferated in countless number of Internet of Things (IoT), and cyber physical applications. However, the short battery life of the commercial micro-drones due to high mechanical energy requirements can be a major limitation, especially in applications that require drones' long trajectories to discover distributed targets (i.e. targets could be humans, vehicles, animals, etc.).

The objective of this project is to develop an integrated UAV system that can detect and track distributed targets at the shortest time possible with minimum energy consumption. The UAV is controlled from an on-ground command and control system that sends high-level commands to the drone dictating the best AI-based scanning strategy to cover the targets with minimum energy consumption and without knowing the exact targets' locations in advance.

The proposed approach relies on two major sub-parts, 1) A machine learning-based technique that can detect and identify targets, and 2) A reinforcement learning (RL) technique that can learn the mobility patterns of targets, and later tries to track the targets without knowing their exact locations. Targets are either fixed or mobile. In the case of fixed targets, the drone tries to learn the targets' locations assuming their distribution is fixed (e.g. military deployed fixed tanks). For moving targets, the problem is even more challenging, requiring the drone to learn a dynamic moving pattern of the targets. The object detection part is based on machine learning model that is pre-trained on images of targets taken from the drone's camera, to detect, identify, and count the number of targets in any camera frame. Many models were trained in this process, and the performance of one model can be seen in Performance the new state of the art YOLOv5 model has been used as part of this object detection algorithm. The location of the

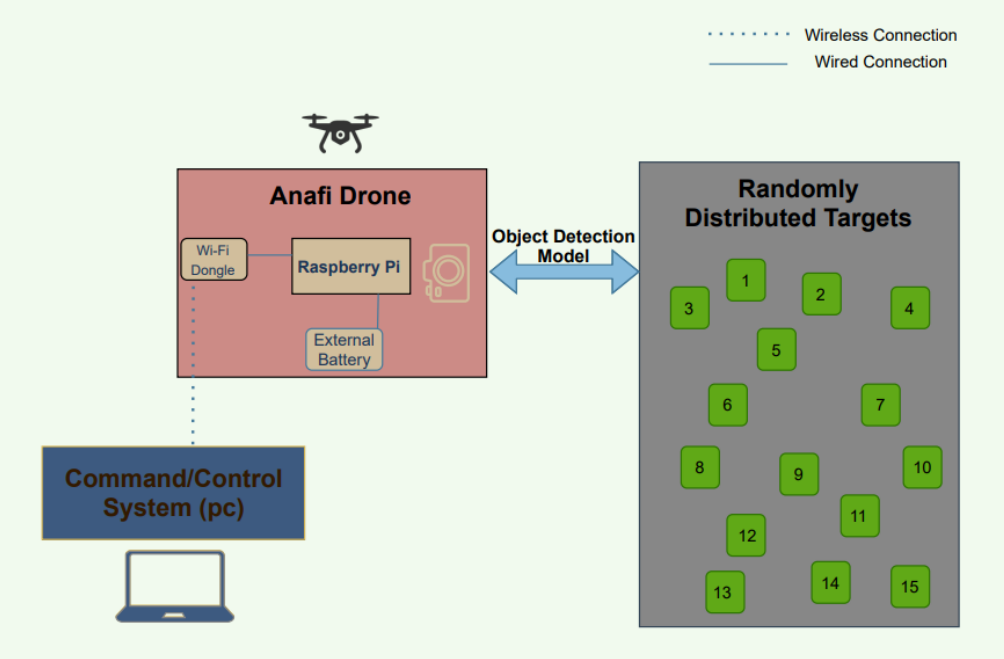

Figure 1. An illustration of the system design.

drone and the number of targets within its frame will then be fed to the reinforcement-learning algorithm to estimate the reward of the drone existing in any location. The more the drone finds targets in a certain location, the higher the reward achieved by the drone. With enough trials and explorations, an RL model can learn the mobility pattern of the targets and help the drone discover locations with maximum number of targets. Upon the model deployment, the drone will be able to autonomously move and complete its trajectory to find and track all targets in the shortest time possible, thus saving energy.

To facilitate the autonomous navigation of the drone, and run all the AI techniques and models, the team has designed a small computer (based on a Raspberry pi) with the required integrated sensors/adaptors (e.g. Wi-Fi and GPS adaptors) to attach to the drone. This hardware module will then provide all the intelligent control commands to navigate the drone, detect, identify, and count the targets in certain areas. An overview of the entire system design can be seen in Figure 1.

To make the system more practical, since the RL training in real systems may take a long time, the team has also designed a digital twin (simulated) environment that mimics exactly the real environment, and can be used for drone's learning and training. A software called Gazebo is used for simulating the environment as illustrated in Error! Reference source not found. and the sphinx plugin is used to publish data about the virtual drone. After training and testing the models within the simulated environment, the experiment is done in the physical world using the pre-trained models to see how the drone will perform, assuming the targets use the same mobility pattern in the real environment. The interaction in the simulated environment is shown in Figure 2.

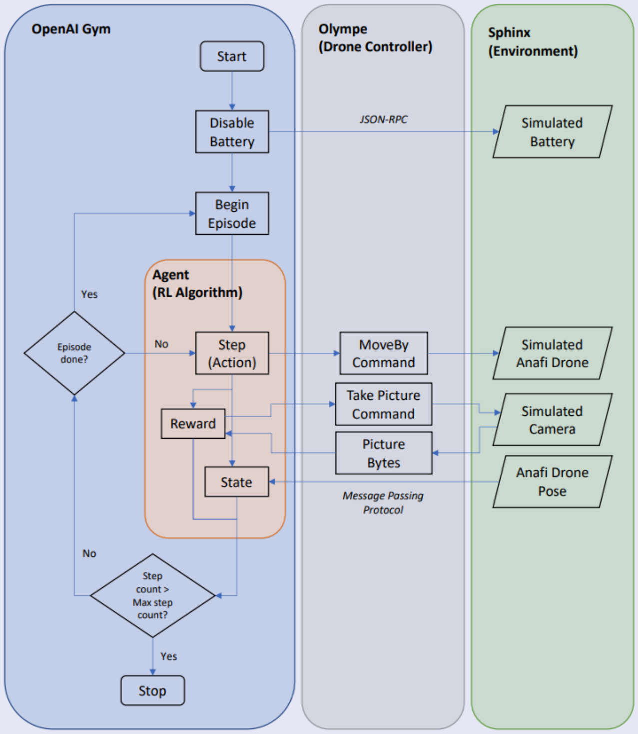

Figure 2. The interaction in the simulated environment.