An IoT-Enabled Modular Quadrotor Architecture for Real-Time Aerial Object Tracking

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Outline of the talk

- Introduction
- Novel Contributions
- Hardware Components
- Wireless Communication
- Object Detection and Video Processing
- Conclusion
Introduction

• Quadrotors are used with an on-board camera while one or two operators control the flight of the vehicle and the camera operation.

• Quadrotors have the advantages of simplified design, low cost and maneuverability.

• Multiple quadrotors can communicate with each other or with a base station, forming a subnet of the Internet-of-Things (IoT).

• A control algorithm can be used to analyze information from the whole swarm.
Introduction

- **Internet of Things**
  - The Internet of Things is a network of devices where each device in the network is recognizable and connected.
  - Given media, people and the internet, the three possible connectivities are people-to-people; people-to-media and media-to-media[^1].


The IoT-enabled aerial platform
Applications

- Industry: Inspection of pipelines, bridges and large structures, navigating to areas that are remote and otherwise hard to access.
- Civil: Search and rescue, traffic congestion analysis, fire monitoring, HAZMAT operations and the inspection of dangerous sites as well as environmental assessments and nature conversation.
- Law enforcement: Useful for surveillance, documenting crime scenes and gathering intelligence.
- Aerial photography, television and videography, real estate and property assessment.
Novel Contributions of This Paper

1. A low-priced quadrotor was built based on modification of existing proprietary and open-source platforms.

2. A medium resolution (640 x 480) optical camera system was designed and attached to the quadrotor.

3. A ground control station was designed and built.

4. PID control was implemented on-board.
5. Wireless video transmission was achieved with the help of off-the-shelf components.

6. The OpenCV computer vision software platform was modified to accomplish all video related tasks such as pattern recognition.

7. A library of serial communication functions was custom developed.

8. An average speedup of 20 X was achieved.
Hardware Components

A. ArduCopter

B. Radio Controller

C. Ground control Station
A. ArduCopter:

- **Frame**: The frame was purchased as a kit which contained the base, motor arms, motor mounts, landing gear, camera mount.
- **Drive System**:

![Diagram of ArduCopter hardware components](image-url)
A. ArduCopter:

- Controller/ Autopilot:
  - ArduPilot Mega (APM) - Controller board based on a 16MHz ATMega 1280 microcontroller.
  - PID control.
  - Motor Control.
  - Stabilizes vehicle.
Hardware Components

A. ArduCopter:

- **Sensors:**
  - Inertial Measurement Unit (IMU).
  - Gyroscope.
  - Magnetometer.
  - Three axis accelerometer.
  - GPS.
  - Sonar.


**B. Radio Controller**

- 6 Channel RF Radio Control unit and receiver is used.
- The 6 channels are:
  - Roll
  - Pitch
  - Throttle
  - Yaw
  - Mode (Stabilize/ Alt Hold)
  - Unused.
C. **Ground Control Station**

✓ It handles all the video processing.
✓ It consists of
  - Laptop Computer.
  - Wireless video receiver.
  - USB video capture device.
  - USB Xbee wireless module.
Wireless Communication

Control & Telemetry
• Two way communication
• Xbee
• 900 MHz
• Up to 10km range

Video
One way communication
RF
5.4GHz
1-3km range

Wireless Communication Setup
Object detection & Video Processing

- **Object Tracking**
  1. Detection of the desired object.
  2. Tracking of the object between frames.
  3. Analysis of changes in object position to determine the behavior of the object.

- **Object Detection**
  1. Position of the object relative to the camera.
  2. Lighting variations.
  3. Differences in the object models.
A. Template Matching

- Advantages
  1. Relatively easier to implement.
  2. Does not require a large training set of images.

- Disadvantages
  1. Slow.
  2. Object needs to be of same size/orientation as template.
A. Template Matching

For a 640*480 px image with 100*100 px template,

\[ \text{Number of comparisons} = (640-100) \times (480-100) \]
\[ = 540 \times 380 \]
\[ = 205200 \]

Sliding window method used for Template matching
B. Fast Template Matching

- The time taken by template matching is reduced by equally scaling down the source and template images.

- Perform template match on small images.

- If match is found, then original source image is searched around a small region of interest (ROI).

- Number of comparisons performed is greatly reduced.

- Results in a speed improvement of over 20 times.
Conclusions

- A versatile quadrotor platform based on open-source hardware and software was designed.

- A target recognition system was designed, programmed and implemented using custom and published algorithms with outstanding performance.

- Future research involves reducing computational capabilities and securely transfer image and video data using on-board secure digital camera (SDC).
THANK YOU