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

[1] N. Dimitrova, "Connected by media[vision and views]", Multimedia, IEEE published on 08/07/2002.

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Introduction

➢ 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.

Novel Contributions of This Paper

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.
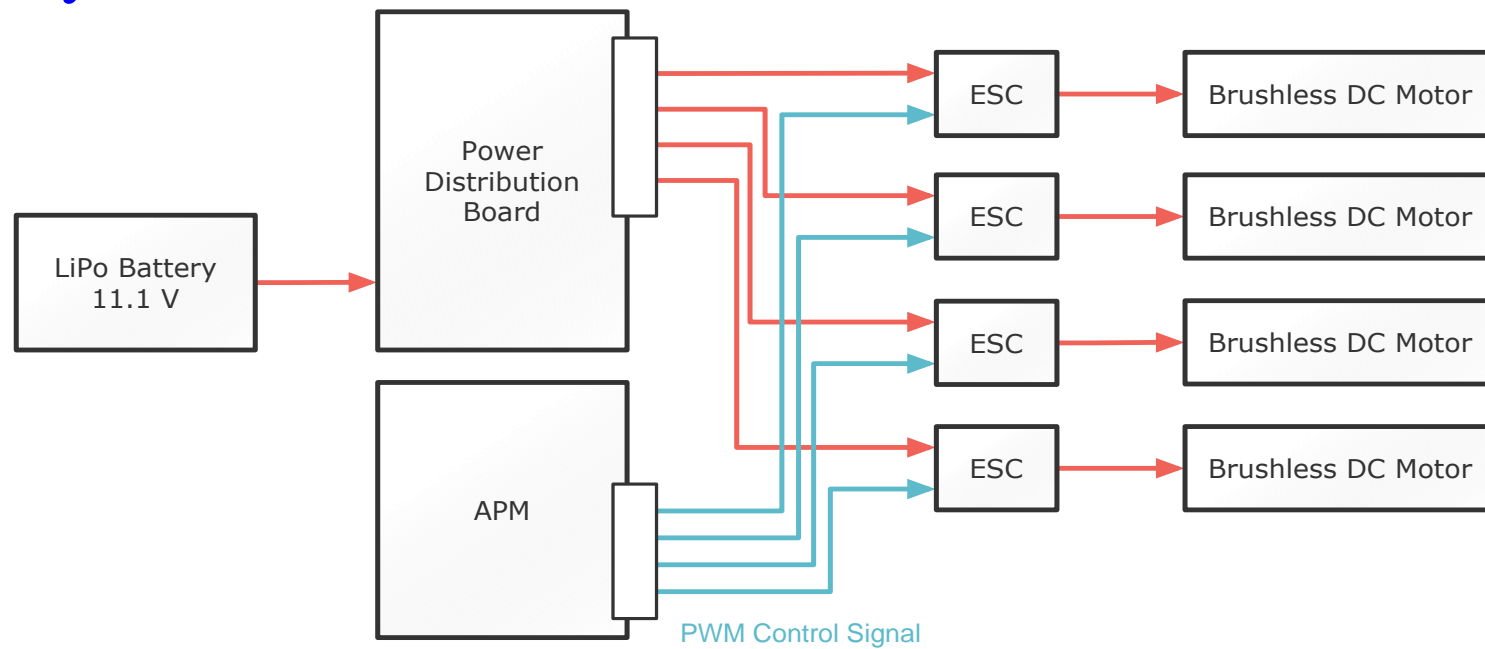
Hardware Components

A. *ArduCopter*

B. *Radio Controller*

C. *Ground control Station*

Hardware Components

A.ArduCopter:

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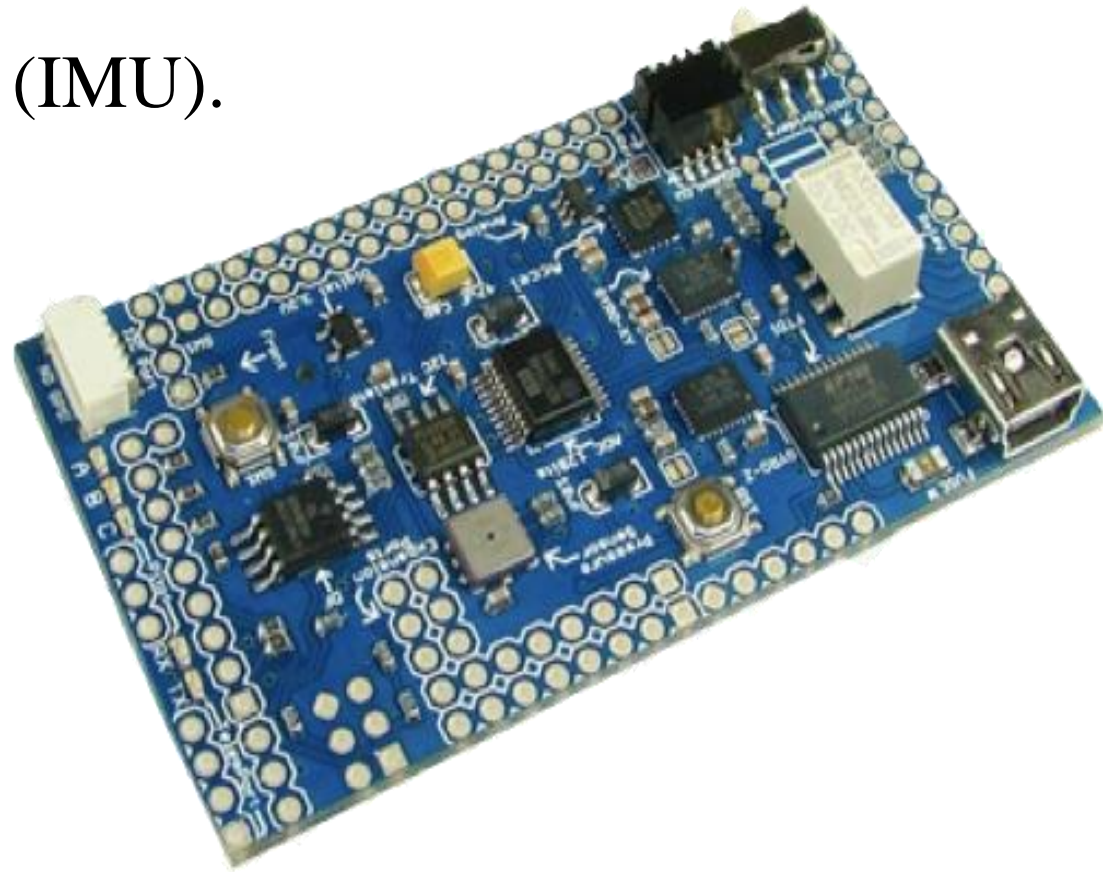- Drive System:

Hardware Components

A. ArduCopter:

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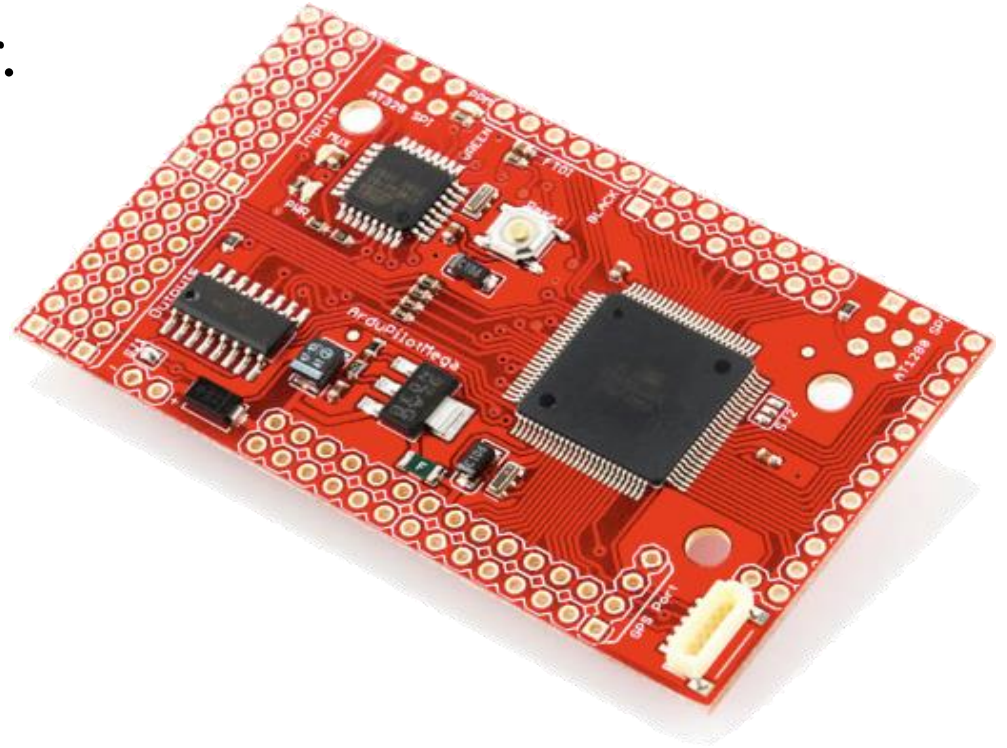
Hardware Components

A.ArduCopter:

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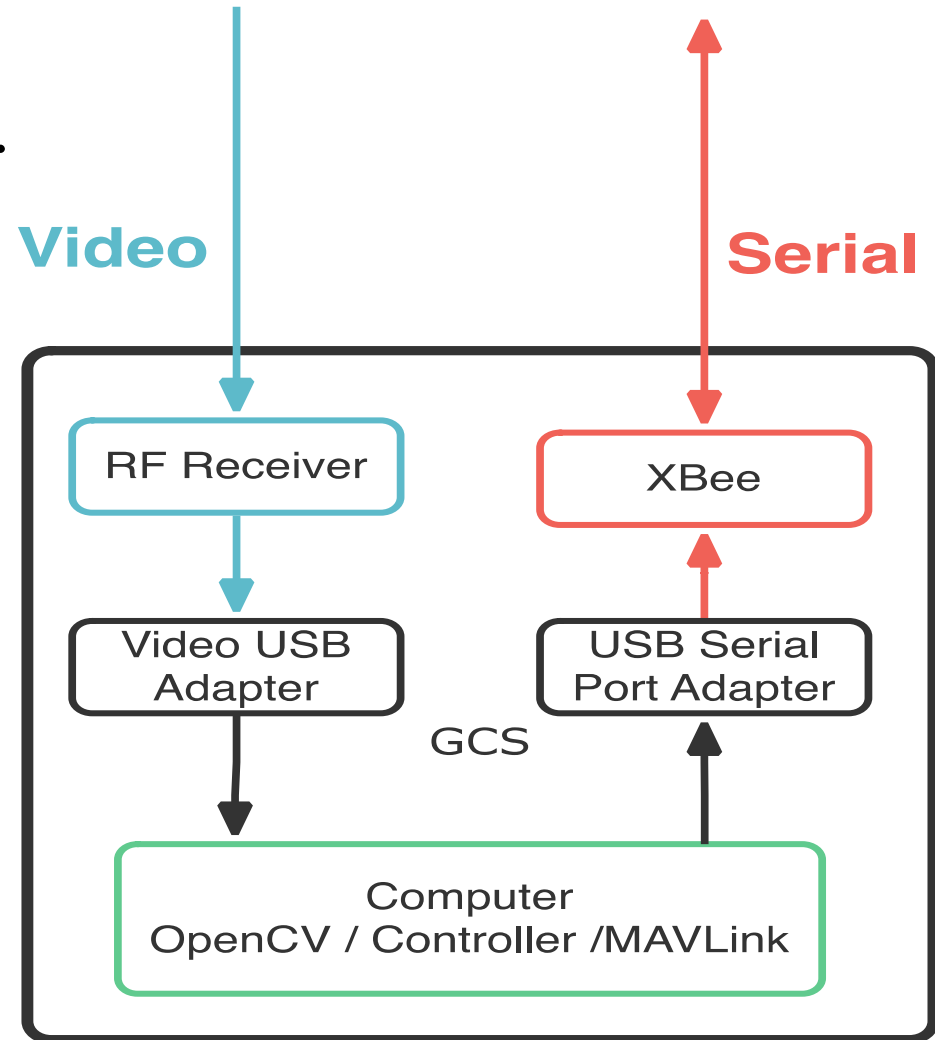 - ✓ Sonar.

Hardware Components

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.

Hardware Components

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.

Video   **Serial**

RF Receiver

XBee

Video USB Adapter

USB Serial Port Adapter

GCS

Computer
OpenCV / Controller /MAVLink

Wireless Communication

Control & Telemetry

- Two way communication
- Xbee
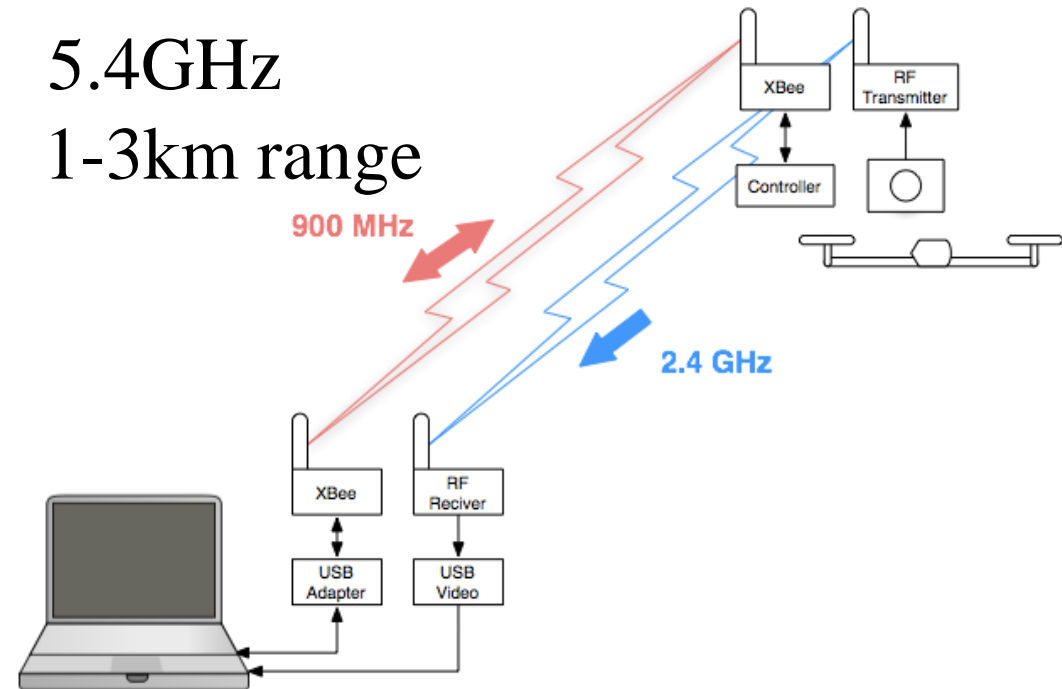- 900 MHz
- Up to 10km range

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.

Object detection & Video Processing

A. *Template Matching*
 ➤ *Advantages*
1. Relatively easier to implement.
2. Does not require a large training set of images.
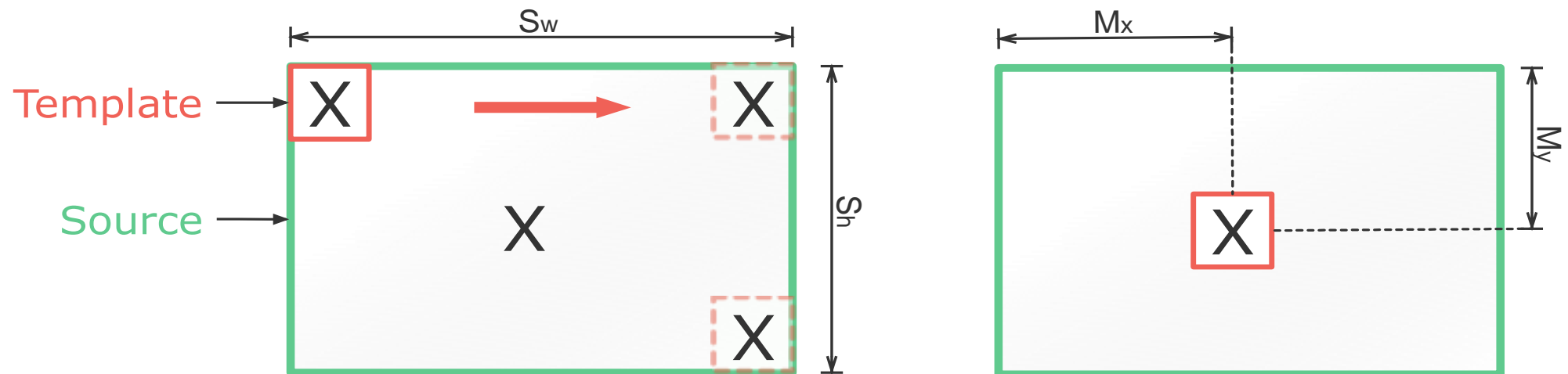

 ➤ *Disadvantages*
1. Slow.
2. Object needs to be of same size/ orientation as template.

Object detection & Video Processing

A. *Template Matching*

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

Number of comparisons $= (640-100) * (480-100)$

$$= 540 * 380$$

$$= 205200$$

Sliding window method used for Template matching

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Object detection & Video Processing

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).

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