Autonomous Quadcopters, Research, Systems, and Global Impacts

by Ryan Skeele

Thesis Defense for the International Degree in Mechanical Engineering

Qualifications

My background

- Robotics Club
- Autonomous Aerial Vehicle Team
- Dynamic Robotics Lab
- Robotic Decision Making Lab

Development of a new autonomous quadcopter

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   - 4.5. Coordination
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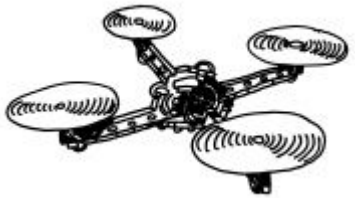

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Introduction

Two important questions….

What is a quadcopter?

Why quadcopters?

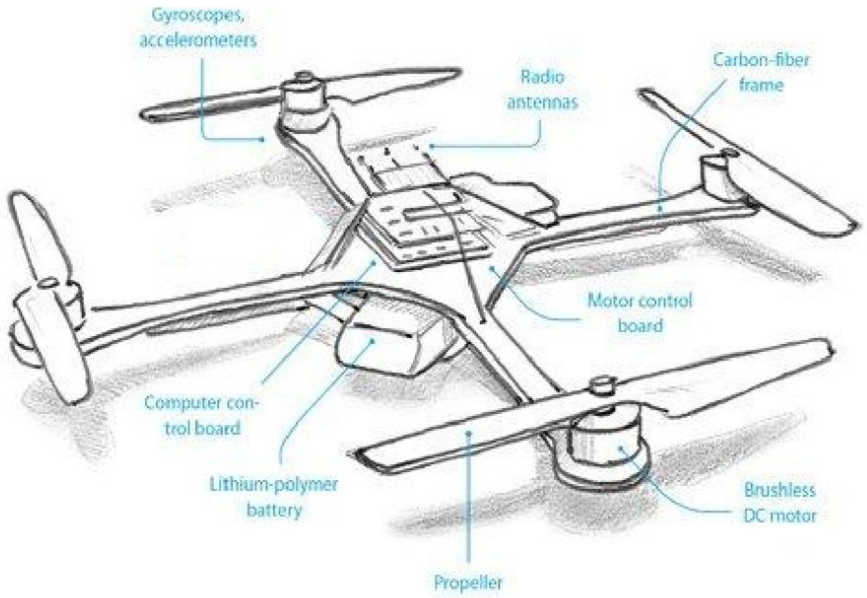
What?

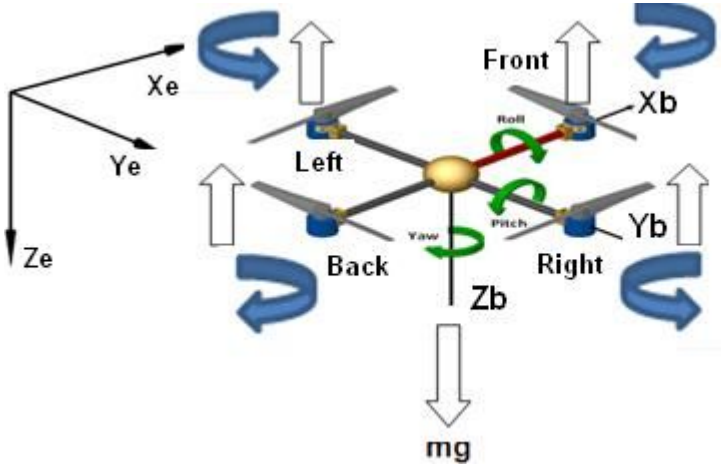
Flight Controller
- IMU-Accelerometer, gyroscope
- Magnetometer

Propulsion
- Electronic Speed Controller
- Brushless DC Motor
- Propellor

Power
- Lithium Polymer Battery

Additionals
- GPS
- On-board computer
- More sensors





Degrees of Freedom = Yaw, Pitch, Roll, X, Y, Z
Actuators= Four motors

Four propellers and 6 DOF = UNDERACTUATED!!!

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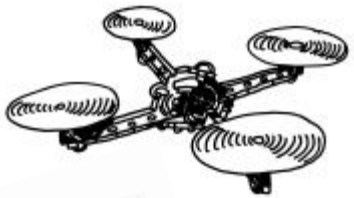

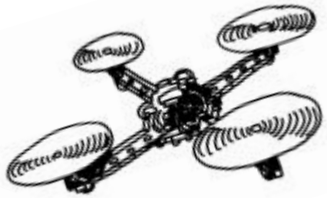

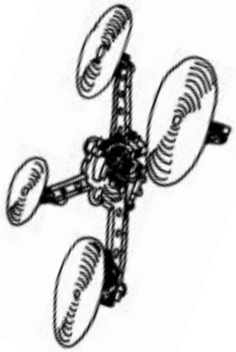

Why?

V.T.O.L.

Fast dynamics

The challenge!

More on this later….

They are cool!

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Problem Statement

Research Question:

What is the current state of autonomous quadcopter research, and the implications of these systems reaching the emerging global market?

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Importance

Only entry level literature that examines the main subsystems of an autonomous quadcopter.

Analyzes the global impact of market realization.

This will bridge the gap in understanding between the consumer and the researcher.

A base of knowledge to enter the field of autonomous quadcopters.

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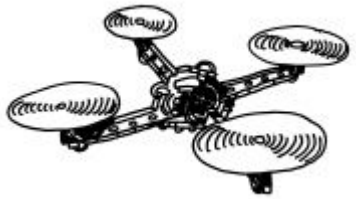

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Methods

My experience

- Robotics club
- Autonomous Aerial Vehicle Team
- Dynamic Robotics Lab
- Robotic Decision Making Lab

Development of a new system

- Literature Survey
- Design and repeat

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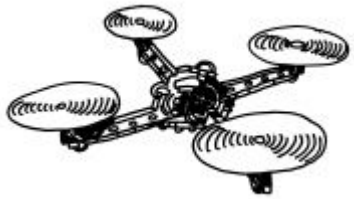

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Background

Definition- In order for a vehicle to be autonomous or even semi-autonomous it must take inputs from its environment and make high level decisions without the involvement of a user.

First UAVs used in military action was WWII. In the Iraq/Afghanistan war over 12,000 UAVs were deployed.

“The unmanned systems community must wean itself from the telecommunication bandwidth. Autonomy will certainly be required in order to accomplish this goal.” Unmanned systems roadmap 2007-2032

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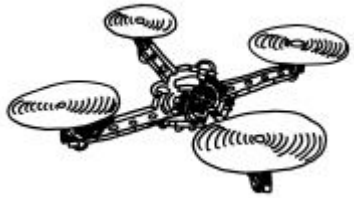

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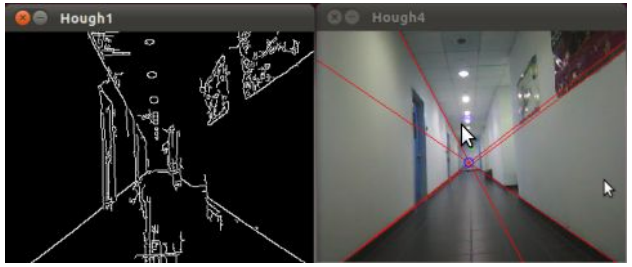
Perception

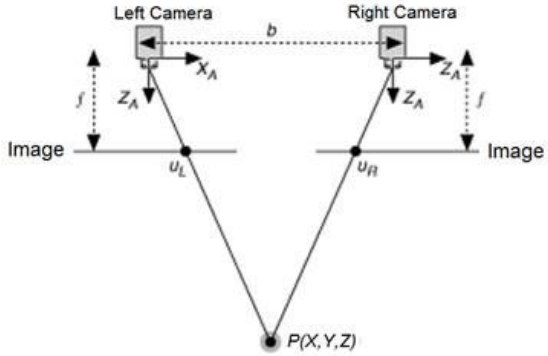
Monocular- Filtering edges can help navigate hallways and stairs

but don't generate 3D maps



Optical Flow- Key points are tracked between frames to determine velocity.

Stereo Vision- Features are compared between the two images then use the known distance between the cameras to determine position in 3D space.



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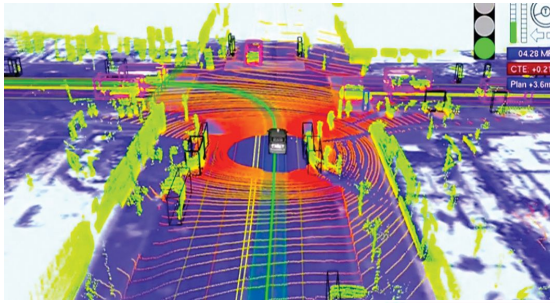
Perception

Motion Capture- Infrared emitters from camera. Reflectors and off board processing.

RGBD- Projects an infrared grid that an infrared camera uses to calculate distance away

Lidar- Laser is incrementally moved in a circle. At each interval a receiver measures the time for it to reflect back.



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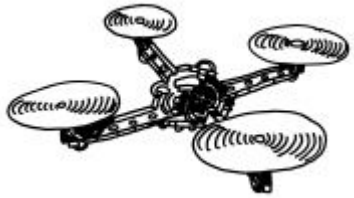

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Flight Control

PID- The PID control uses tuned constants and multiplies them with the measured error (proportional), the change in error (derivative), and the cumulitive error of the system (integral).

LQR- Minimizes a cost function. The sum of error from the measured and desired values.

MPC- Similar to LQR, MPC uses a cost function. The cost function is then optimized over a prediction horizon using a model of the system.


Automatic fault detection &
recovery to original position

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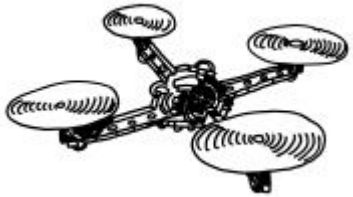

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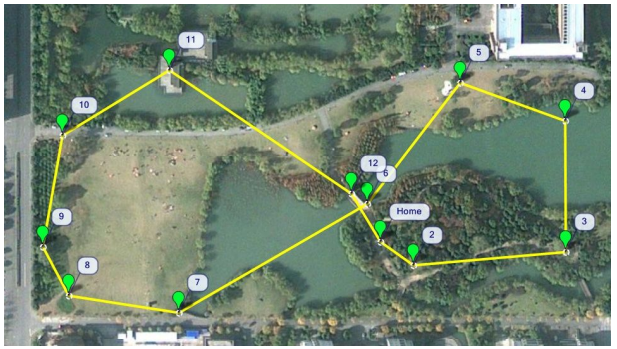
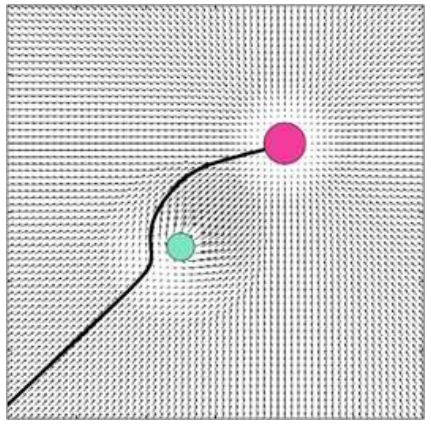
Navigation

Path Planning

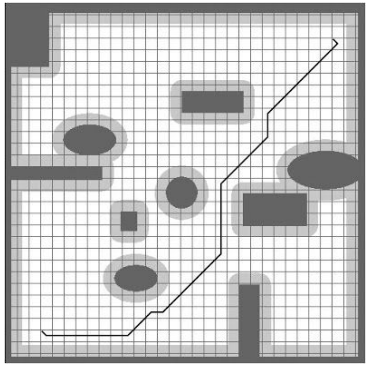
Waypoint- Users pick desired locations and the system follows in a direct line. Implemented on most systems through GPS.



Potential field- Uses repulsion and attraction vectors to navigate around obstacles towards a target position.



Cell decomposition- Map is broken into cells with an accompanying connectivity map and robot uses a search algorithm to find path to target



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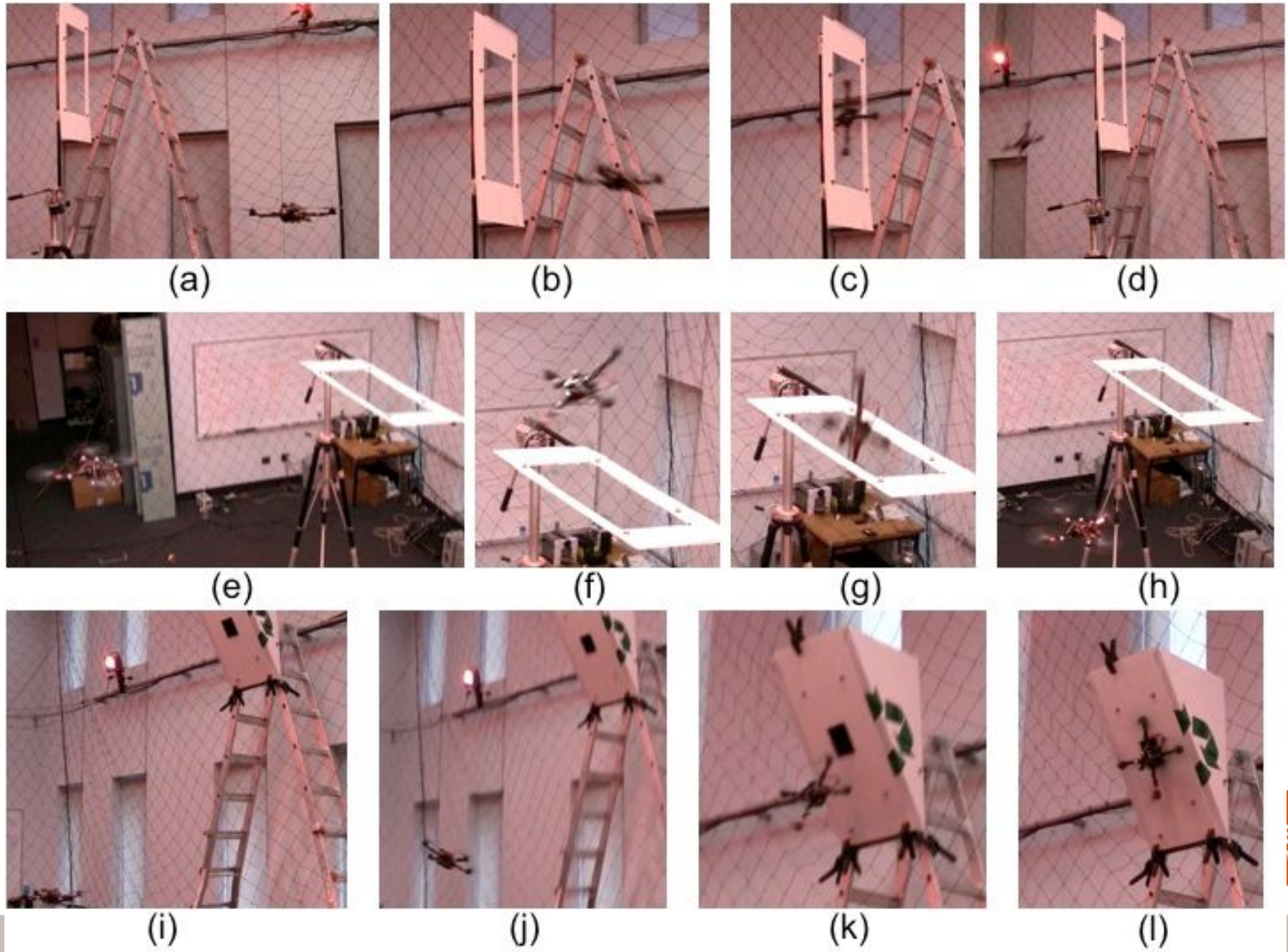
Trajectory Optimization- Minimum Snap



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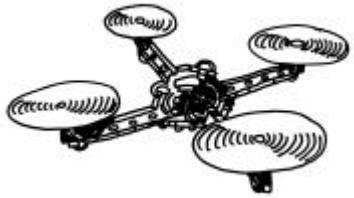

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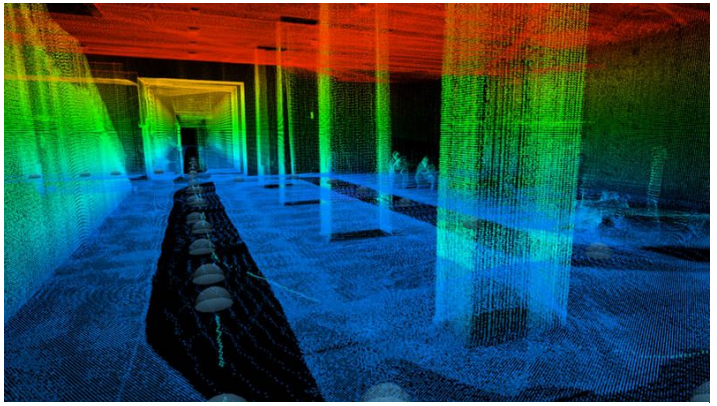
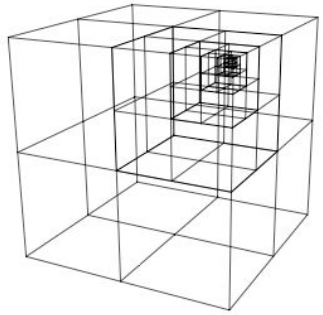
Mapping

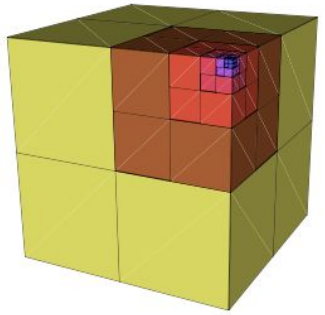
Point Cloud- Collection of x, y, z points in 3D space. Datasets become quite large.

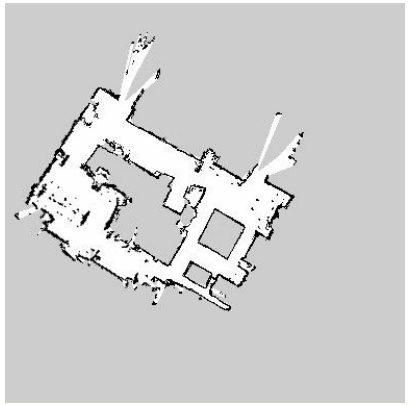
Octomap- Updates voxels as occupied, unoccupied, or unexplored. The voxels are stored in an Octree for efficiency.

Projected 2D, 2.5D Maps- A slice or projection of obstacles onto a 2D representation. A 2.5D map stores height measurements of obstacles.









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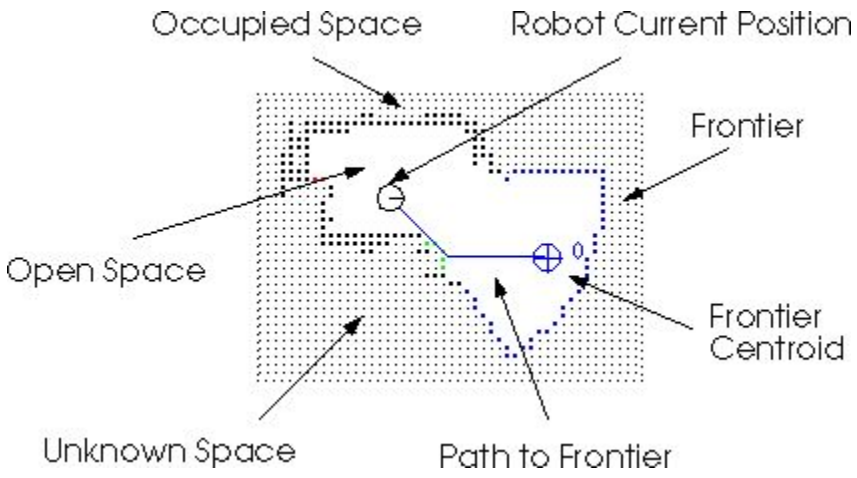
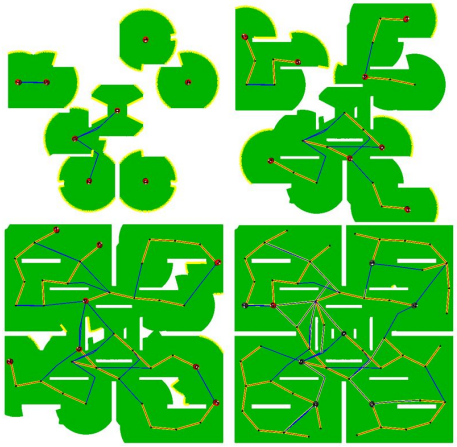
Coordination

Cooperative Mapping

Frontier-Based Exploration



Sensor-Based Random Graph



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Motion Coordination

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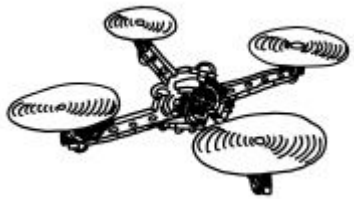

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Market Analysis

Three sectors: military, business and humanitarian

Questions

Is there need/demand?

What systems are currently in place?

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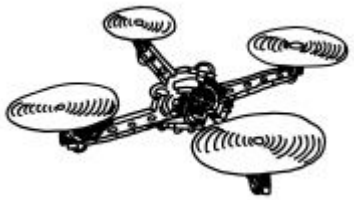

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Military

Reconnaissance Vehicles

wanted for a fixed eye

Tactical Vehicles

IARC competition

Saving lives

There are over 3,000 deaths from improvised explosive devices (IED) in the Iraq/Afghanistan wars that have occurred since 2001. (Roberts, CNN)

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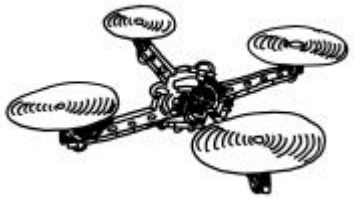

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Business

Delivery

- Industry of $175 billion in 2008
- FedEx ships more than 10 million packages a day

DHL- performed first test delivering medicine

Amazon Prime Air- 30 minute delivery service

amazon Prime Air

Dominos- First tests delivering pizza

- More than 10 million miles travelled a week to deliver dominos pizza

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Business

Cinematography-

Recent movies have used quadcopters for aerial cinematography. The movie sector is also a multibillion dollar industry.

Structural Inspection-

There are over 300,000 miles of pipeline in the unites states

Costs are $3,000 an hour for helicopter inspection

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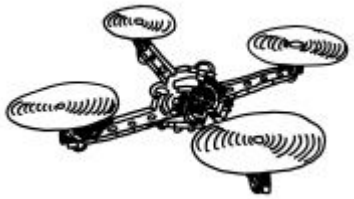

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Humanitarian

"1 billion people do not have access to all season road,"
(Andreas Raptopoulos, TED Talk 2013)

Enter Matternet:

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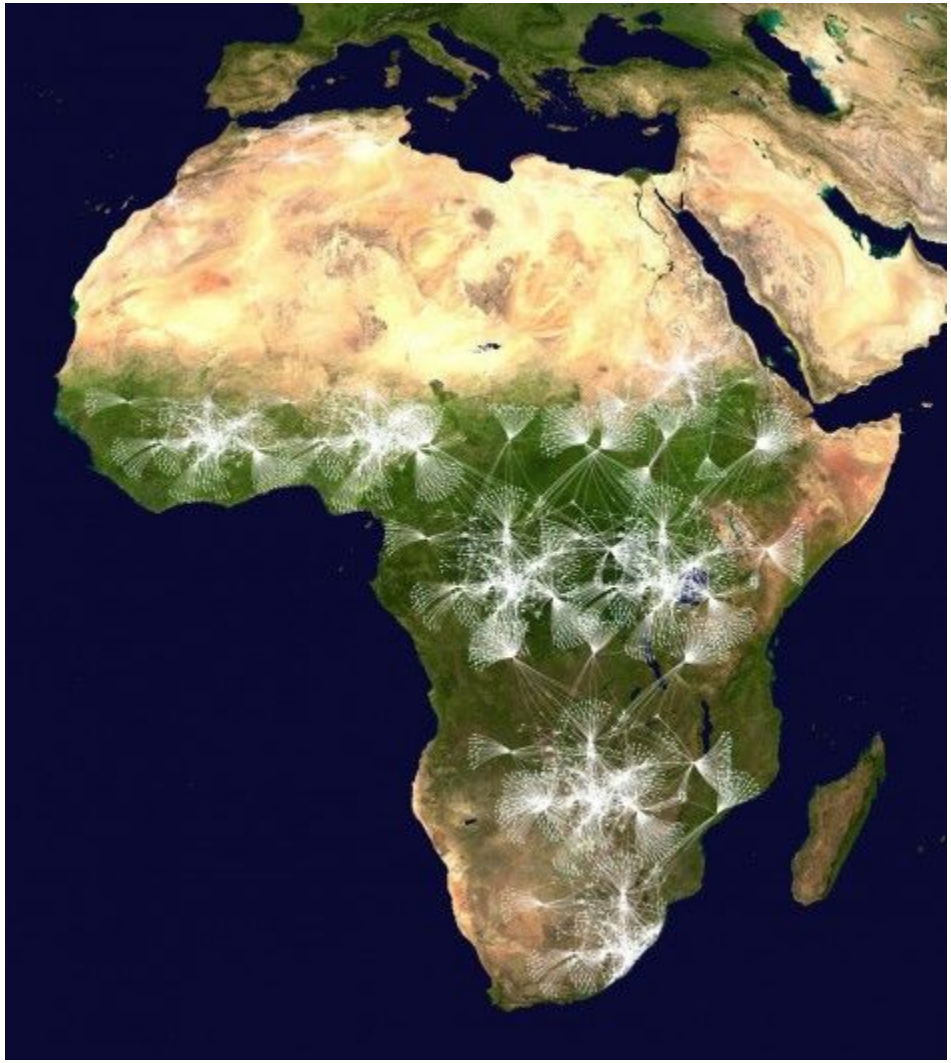
Network to Deliver

Medicine

Blood (HIV/AID) tests

Food

Water



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Disaster Relief

Compose hazard maps

Search for signs of life

Deliver aid

Create mesh networks for communication

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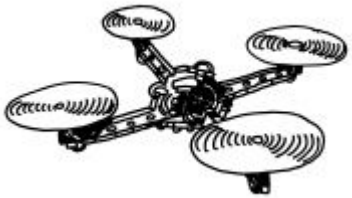

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Conclusion

1. Quadcopter basics
2. Why quadcopters
3. Overview of current research
4. Analysis of market demand and impact

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THANK YOU!

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QUESTIONS?

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