Autonomous Aerial Assistance for Search and Rescue

Team F

System Development Review

March 6, 2017

Sponsor:
Near Earth Autonomy

Team Rescue Rangers

Juncheng Zhang
Karthik Ramachandran
Sumit Saxena
Xiaoyang Liu

Motivation

A Man Hunt Without The Man: Drones Help Locate Missing Child

AUGUST 11, 2014 BY KIRSTEN KING — 1 COMMENT

After spending almost two weeks lost in the Siberian forests and swamplands, four-year-old Karina is finally going home--and it is all thanks to a … [Read more...]

Royla Canadian Mounted Police Use Drone to Find Family Lost in the Woods

SEPTEMBER 8, 2014 BY DRONELIFE NEWS — LEAVE A COMMENT

RCMP say a drone was used to help locate a family that got lost in the woods. On Saturday at 4:30 p.m., two adults and their 17-month-old child … [Read more...]

Amateur Drone Pilot Finds Man Missing for Three Days

JULY 23, 2014 BY DRONELIFE NEWS — 1 COMMENT

from Examiner.com When Guillermo DeVenecia went missing last Wednesday, police and searchers were dispatched to find the 82-year-old man, who … [Read more...]

http://dronelife.com/

Drones in Search and Rescue

Drones vs Human Searchers/ K-9 Units

- Faster response time
- Greater Coverage
- Low risk

Drones vs Helicopters

- Much cheaper
- Less operational complexity (no refuelling, no strict piloting requirements)
- Can go places where helicopters can’t

Future of Search and Rescue

- Drones for Search and Initial Response
- Human Searchers/Helicopters for Final Rescue / Airlifting

SAR Use Case

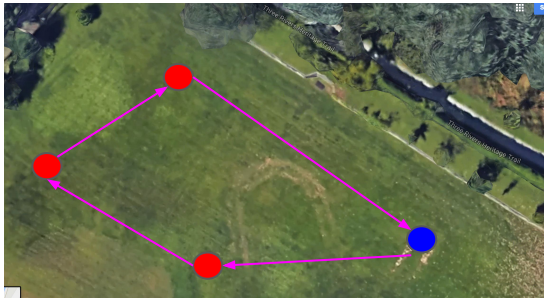
Current Use Case

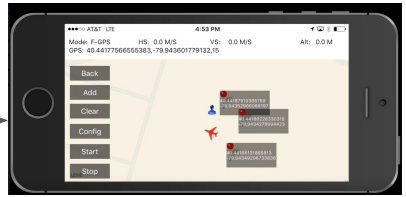
- Alerts circulated about potential missing humans and last known locations
- Drones deployed in regions of interest with multiple types of sensors.
- Sensor data analyzed manually to detect human signatures.
- Deploy rescue teams

Key Contribution

- ➢ *Eliminate laborious task of analyzing sensor data manually.*
- ➢ *Build a learning system to automatically detect human signatures and suggest likely rescue locations*

Detailed Use Case

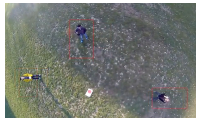


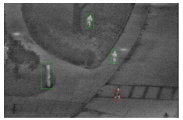


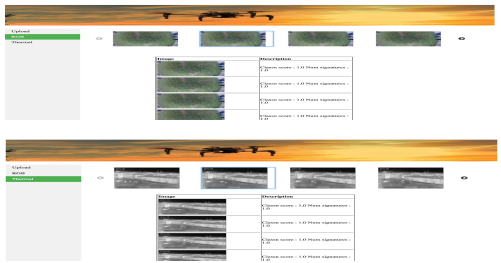
Plan waypoint mission

Matrice 100

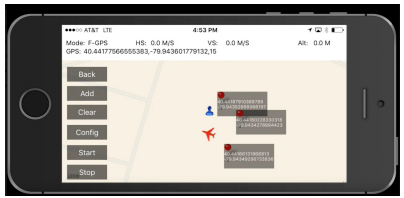
Collect Sensor Data







Process sensor data using ML



Plan rescue mission

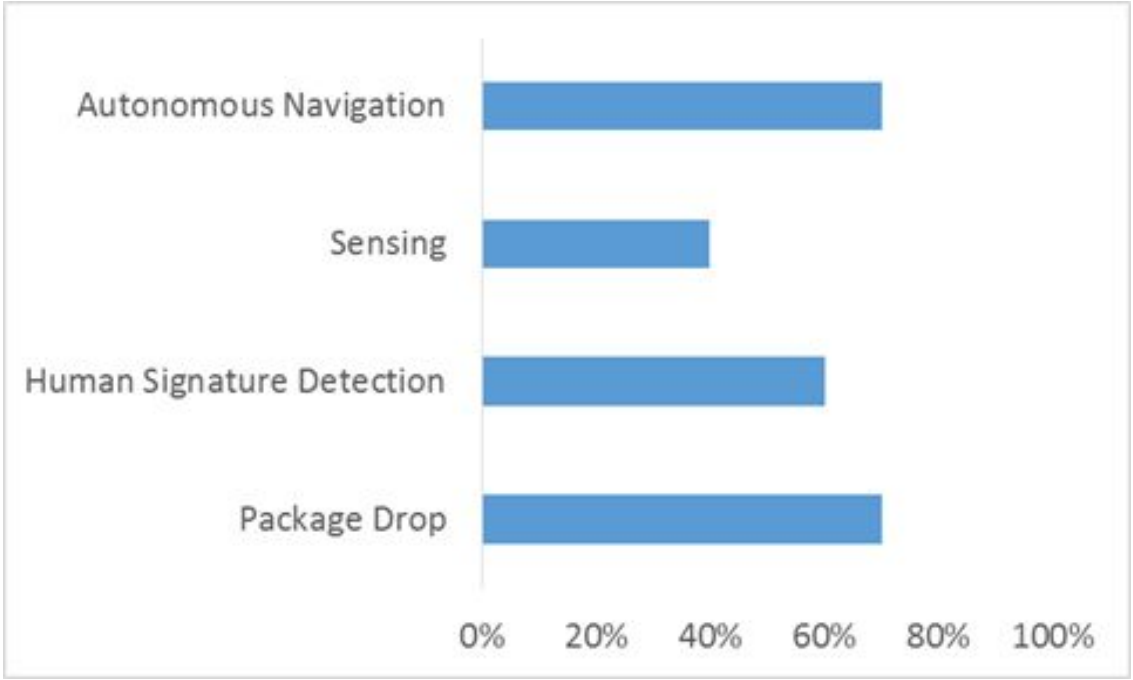
Rescue mission complete

Requirements

Functional Requirements The system shall:	**Performance Requirements** The system will:
M.F.1. Autonomously navigate through a set of provided locations of interest	**M.P.1.** Accurately reach the locations of interest with a tolerance of **+-5m**
M.F.2. Complete the search within limited time	**M.P.2.** Complete one iteration of search in an un-occluded operating area of **200m x 200m in <25 minutes**
M.F.3. Explore the surroundings around each location of interest	**M.P.3.** Attain up to **80%** coverage of the desired local search areas around each location of interest
M.F.4. Collect perceptual data while navigating	**M.P.4.** Collect perceptual data limited to 3 types - IR radiation, visual imagery, and sound
M.F.5. Process the data to identify human signatures	**M.P.5.** Identify at least **75%** of the locations with human signatures
M.F.6. Analyze the identified signatures to estimate human location	**M.P.6.** Estimate potential human signature location with **+-5m** tolerance
M.F.7. Navigate to the rescue location carrying the rescue package	**M.P.7.** Carry a rescue package weighing **100g**
M.F.8. Drop the rescue package	**M.P.8.** Drop the package at the rescue location with a tolerance of **+-5m**

Current Status

Our Subsystems - Current status

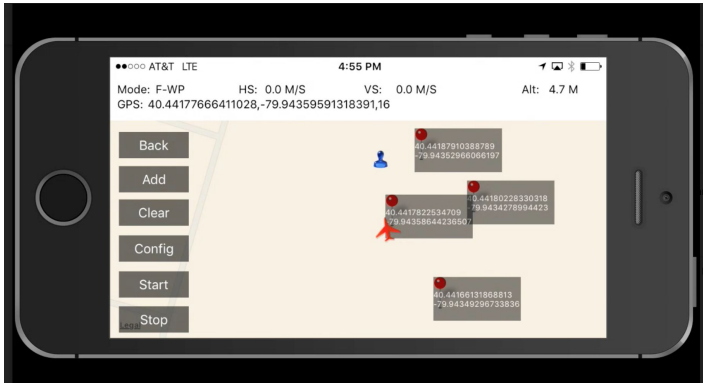


Autonomous Navigation Subsystem - Description

- **iOS app**
  - Provide waypoints
  - Initiate search mission
  - Initiate rescue mission
- **Aerial system -** ***changed to Matrice 100***
  - Waypoint navigation
  - Local search
- **Software to log time-stamped flight data**
  - GPS data
  - AMSL data
  - Aircraft pose data

Autonomous Navigation Subsystem - Current status

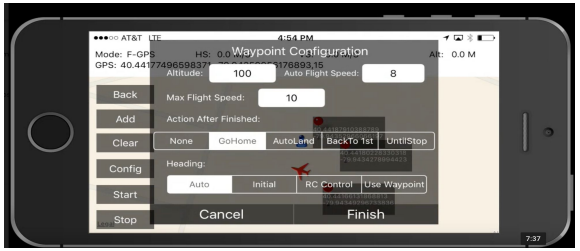
- **iOS app**
  - Provide waypoints - **ready**
  - Initiate search mission - **ready**
  - Initiate rescue mission - **pending**
- **Aerial system**
  - Waypoint navigation - **ready**
  - Local search - **pending and simplify**
- **Software to log flight data - pending**
  - GPS data
  - AMSL data
  - Aircraft pose data



Autonomous Navigation Subsystem - Testing

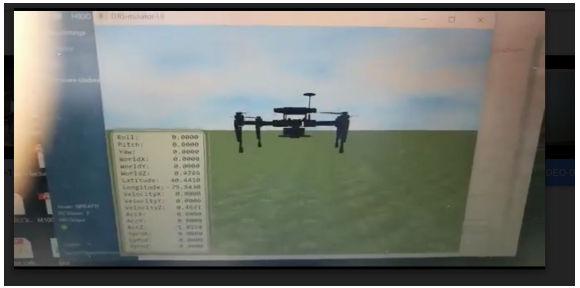
Implementation (iOS app)

- iOS app using DJI mobile SDK and sample code
- Changes to accept and display waypoints as GPS coordinates.



Testing

- Initial testing on DJI simulator
- Field testing leading to FVE
- Validated GPS random error by plotting std deviation of drone and phone GPS logs for multiple waypoints.



Sensing Subsystem - Description

- **RGB+Thermal camera:**
  - FLIR Duo R
  - Records both RGB and infrared videos
- **Cardioid microphone**
  - Tassccom microphone
- **Mounting for the camera**
  - Custom mount + Gopro mounting
- **Suspension cable for microphone**
  - To keep the microphone away from propeller noise

Sensing Subsystem - Current status/Testing

- **RGB+Thermal camera:** ***field testing yet to be done***
  - FLIR Duo R
  - Records both RGB and infrared videos
- **Cardioid microphone:** ***indoor testing done***
  - Tassccom microphone
- **Mount for the camera:** ***being shipped***
  - Custom mount + Gopro mounting
- **Suspension cable for microphone:**
  - To keep the microphone away from propeller noise

All the components need to be integrated on the drone

Sensing Subsystem - Challenges

Plans changed to build our own sensing payload

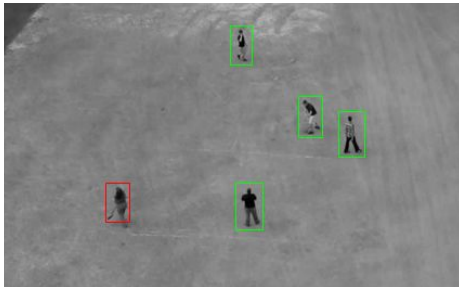
- **RGB+Thermal camera:**
  - Still to be mounted and tested
- **Cardioid microphone:**
  - Mounting such that it does not interfere with camera view
  - Testing for safety

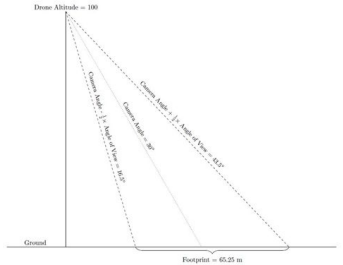
Signature Detection Subsystem - Description

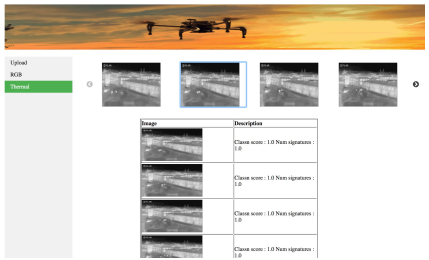
- **Algorithms to detect human signatures:**
  - Visual
  - Thermal
  - Sound
- **Fusion layer**
  - Combine results of various signature detection algorithms
- **Rescue location identification:**
  - Estimate rescue location based on the fusion layer output
- **End-to-end data processing software**
  - Input: raw video and audio data
  - Output: important locations

Signature Detection Subsystem - Current status

- **Algorithms to detect human signatures: 70%**
  - Visual (60%) : HoG+SVM, HoG+FNN, FNN, Tracking
  - Thermal (50%) : HoG+SVM
  - Sound (60%) : Melody extraction based voice activity detection
- **Fusion layer: 30%**
  - Combine results of various detection algorithms
- **Rescue location identification 60%**
  - Estimate rescue location based on the fusion layer output
- **End-to-end data processing software 50%**
  - Input: raw video and audio data
  - Output: important locations







Signature Detection Subsystem - Testing

Algorithms to detect human signatures

- **Visual:**
  - HOG + FNN: 90% accuracy for human candidate images(40x24)
    - Test set = 229 images, Training set = 504 images, Validation set = 167 images
  - End-to-end FNN: 85% accuracy for similar settings
- **Thermal:**
  - HOG+SVM: 86% accuracy for human candidate images(32x16) from OTCBVS Benchmark Dataset and Thermal Infrared Dataset
  - Training set: 4728 pos, 5430 neg; Testing Set: 850 pos, 1060 neg
- **Sound:**
  - Tested on multiple sound samples with drone noise in the background. Above 80% accuracy in detecting voice activity.

Signature Detection Subsystem - Challenges

Algorithms to detect human signatures:

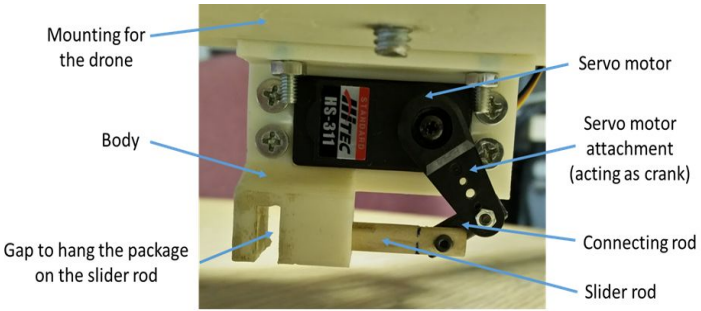
- **Visual:**
  - Testing with our own data, work on different poses
  - Detecting other signatures - tent, backpacks
- **Thermal:**
  - Testing with our own data - resolution pretty low (160x120)
  - Detecting other signature - heated stove
- **Sound:**
  - Achieving accuracy in the presence of background noise

Rescue location identification:

- Make the approximations work well

Package Drop Subsystem - Description/Status

- **Package drop mechanism: 80%**
  - Small modifications to be made
  - Test and consider metal fabrication
- **Software for autonomous package drop: *pending***
  - To initiate autonomous package drop at the rescue location
  - Will receive rescue location from the signature detection software
- **Onboard computer**
  - To initiate package drop
- **5V Power source**
  - Mobile power bank being used
  - Will power Raspberry pi, package drop mechanism and the camera



Project Management

Schedule

	Tasks	Jan,2017			Feb,2017				Mar,2017				April,2017				
		1/16/2017	1/23/2017	1/30/2017	2/6/2017	2/13/2017	2/20/2017	2/27/2017	3/6/2017	3/13/2017	3/20/2017	3/27/2017	4/3/2017	4/10/2017	4/17/2017	4/24/2017	5/1/2017
1	**Autonomous Flight System**																
1.3	Implement autonomous waypoint navigation																
1.4	Implement Local Search strategy																
2	**Sensing**																
2.4	Process specific sensor data																
2.5	Design sound sensor mounting																
4	**Signature detection and analysis**																
4.3	Develop thermal signatures' detection algorithm																
4.4	Develop human sound detection algorithms																
4.5	Fusion of Algorithms																
4.6	Migrate codes to Python																
4.7	Performance optimizations/scaling (as per SVR)																
5	**System Integration and Testing**																
5.3	Build SDPD payload; integrate into the syatem																
5.4	Data collection pipeline from UAV to base																
5.5	Test waypoint navigation + search;																
5.6	Test end to end system for the whole operation																

Semester Test Plan

PR #	Capability Milestones	Associated Tests
PR8 *(Feb 15)*	- Neural network based RGB image classification	**8.1** Preliminary test of revised RGB-based human detection algorithms
PR9 *(Mar 1)*	- Complete hardware integration - - Working versions of signature detection algorithms	**9.1** Test thermal and RGB signature detection algorithms **9.2** Test local search on Matrice 100 **9.3** Test sensor payload mounting **9.4** Test sound detection algorithm on data collected during flight
PR10 *(Mar 22)*	- Likely human signatures' location reporting - autonomous package drop, full system integration	**10.1** Test integrated human signature detection software **10.2** Test signature location reporting software **10.3** Test autonomous package drop software
PR11 *(Apr 5)*	- System integration	**11.1** Test navigation and sensing subsystem integration
PR12 *(Apr 17)*	- Full System Test	Rehearsal of SVE
SVE *(Apr 26)*	- Full System Test	Spring Validation Experiment

Spring Validation Experiment 2017

Objective:

To validates the system's ability to autonomously search for a human in a search and rescue scenario and also dispatch a rescue package

Test conditions:

Location	Open area at NREC with GPS access and normal wind
Equipment	UAV; Laptop; Rescue package; Representations of human signatures: 4 humans, tent, stove, backpacks
Personnel	Whole team

SVE Test 1

Objective:

The goal is to demonstrate the ability to navigate a set of waypoints precisely and collect sensor data from three different sensing systems.

Sno	Procedure	Verification Criteria
1	Place the following signatures at 6 different locations: 1. Human making sound, 2. Human without sound 3. stove, 4. Tent , 5. Backpack, 6. Sound source	
2	Place distance and altitude measurement devices (laser distance meter) at one of the waypoint locations.	
3	Mount all the sensor payloads on the drone.	
4	Provide GPS locations of waypoints to the drone and launch waypoint mission	Location error at particular measuring waypoint should be less than +-5m. Altitude error at particular measuring waypoint should be less than +-1m

SVE Test 2

Objective:
Goal of this test is to demonstrate ability to detect human signatures.

Sno	Procedure	Verification Criteria
1	Run integrated human detection software to report likely locations with human signatures.	The system should report at-least 5/6 locations with human signatures.

SVE Test 3

Objective:
Goal of this test is to demonstrate finding precise human location and autonomously dropping rescue package

Sno	Procedure	Verification Criteria
1	Run software to find precise gps location of human for rescue, based on sensor data.	
2	Launch mission with GPS location of rescue.	The system should drop the rescue package with error less than +-5m of the human gps location

Budget

Part List 1 , Sponsor Provided

Description	Manufacturer	Model	Unit	Weight (g)	Cost
Dual Camera	FLIR	FLIR Duo	1	84	$999

Part List 2 , Provided not by the sponsor

Description	Manufacturer	Model	Unit	Weight (g)	Cost
Aerial Platform	DJI	Matrice 100	1	680	$3250
Battery Heater	DJI	Inspired 1	1	100	$20
Battery Sticker	DJI	Inspired 1	1	0.2	$2
Audio Recorder with Shotgun Microphone	Tascam	DR-10SG	1	50	$199.00
mount for Hero 4	Gopro		1	80	$28.99
10 feet rope	Paracord Planet		1	20	$6.79
Wind muff for microphone	DR-10SG		1		$12.99

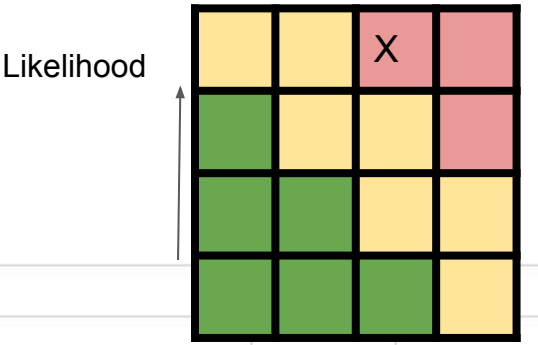
Summary

- Total Budget = $5000
- Total Cost = $3519.77
- Percentage spent to date = 70.4%

Additional Purchases

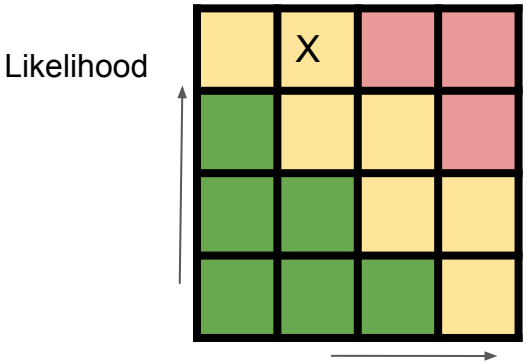
- Audio Recorder ~ $199
- Dual RGB/Thermal camera for testing on Matrice $ 999(NEA)
- For microphone mounting system ~ $48.77

Risks and Mitigation



RISK SUMMARY					
Title	Inability to achieve high accuracy in signature detection		**Date Submitted**	10/22/2016	
Owner	Juncheng/Sumit		**Risk Type**	Technical	
Description	Sensor data especially sound might be very noisy and could generate inaccurate results				
Consequence	Will impact accuracy with which system can detect signatures				
RISK MITIGATION					
Action	**Date**	**Success criteria**		**Risk level**	**Status**
Evaluate feasibility of VAD offline	11/10/2016	Ability to detect human voice in offline noisy data with moderate accuracy		10	DONE
Evaluate design for suspended microphone sensor	1/20/2017	Ability to suspend microphone 10 feet below the drone and fly the drone safely		10	
Evaluate the accuracy RGB & thermal signature detection offline	02/05/2017	Ability of detecting above 60% humans in one frame in both the algorithms (different poses & different dataset)		20	

Risks and Mitigation



RISK SUMMARY				
Title	System integration will expose some problems		Date Submitted	12/08/2016
Owner	Karthik/Sumit/ /		Risk Type	Technical
Description	We have to integrate 4 subsystems together while each of them used different interfaces and we might underestimate the work we require to do			
Consequence	Cannot complete the whole mission			
RISK MITIGATION				
Action	Date	Success criteria		Risk level
Do the intergration in advance	3/22/2017	Ability of accomplish the pipeline and apply all the thins to a certain use case		20

Thank you!