

Indoor Micro-UAV Navigation with Minimal Sensing

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OUTLINE

OVERVIEW

BACKGROUND

METHODOLOGY

Door Detection

Independent Flight

CONCLUSION

PROPOSED PROJECT & SUCCESS CRITERIA

- ▶ Fly through door, land safely
- ▶ Arbitrary initial location
- ▶ Low-quality sensors
(Camera, IMU)
- ▶ 27g weight (42g w/ payload)



Success: <20% failure rate

Source: <https://www.bitcraze.io/crazyflie-2/>

BACKGROUND: UAV FLIGHT

- ▶ Autonomous navigation in constrained spaces
 - ▶ GapFlyt
- ▶ Small scale UAV control + external sensors
 - ▶ Crazyswarm
- ▶ Combination not well studied

Source:

Sanket et al. (2018)

Debord et al. (2018)



(a)



(b)



BACKGROUND: DOOR DETECTION

- ▶ Networks: segment/bounding box
 - ▶ U-Net
 - ▶ MobileNet (V2)
 - ▶ YOLO (Tiny)
- ▶ Non-learning methods
 - ▶ Corner & edge detection
 - ▶ Fuzzy logic
- ▶ Knowledge of full door- overkill for navigation?

Source: Akgul (2015), Ronneberger et al. (2015), Howard et al. (2017), Muñoz-Salinas et al. (2004), Redmon and Farhadi (2018)

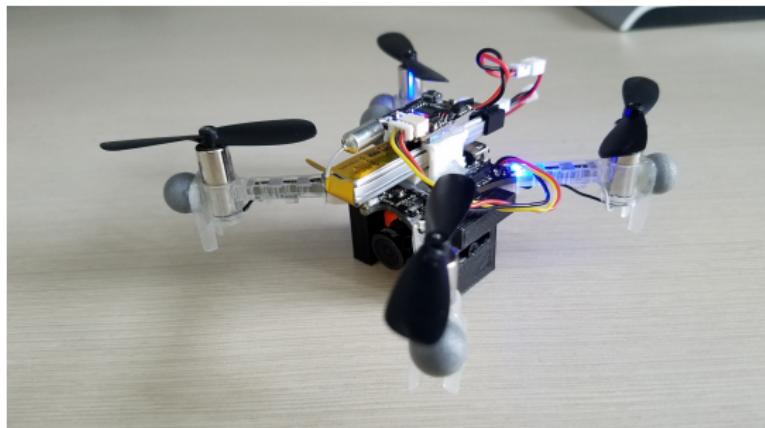
PROJECT OVERVIEW

- ▶ Initial setup
 - ▶ Motion capture
- ▶ Door detection
- ▶ Independent Flight

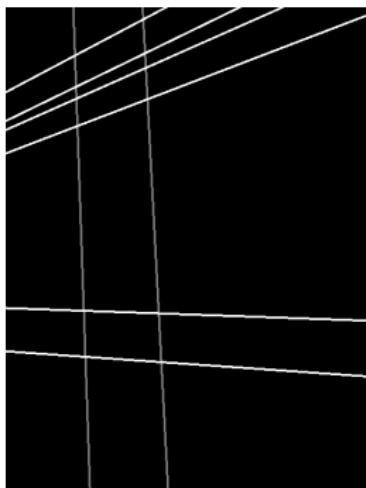
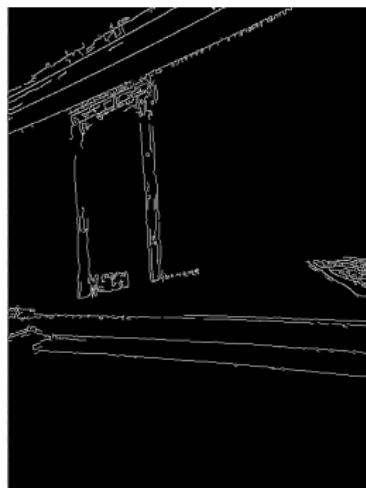
INITIAL SETUP

- ▶ Payload redesign, test flights finished
- ▶ Ground truth algorithm simulated
- ▶ Testing in real-life

Initial Flight



DOOR DETECTION - HOUGH TRANSFORM



Initialization/Tracking

DOOR DETECTION - CONVOLUTIONAL NEURAL NET



- ▶ Redesign - output center of door (less computation)
- ▶ Small networks- ground station resources
- ▶ U-net, Tiny YOLO v3, MobileNet, own design

Detection- Training Set



DOOR DETECTION - COMPARISON

On training set:

	Hough Method	CNN
Mean msec/image	254.314567058	23.9195841163
Std. dev. msec/image	261.605686471	6.60748004691
Mean Accuracy (px)	73.6029293414	36.2429306581
Std. dev. Accuracy (px)	67.5749586736	25.5508142198

INDEPENDENT FLIGHT - DEAD RECKONING

- ▶ Calculate unit vector pointing at door
- ▶ 2 Versions:
 - ▶ Known position of door & UAV (i.e. VICON) - Simulated
 - ▶ Unknown positions, based on visual information - In progress

Ground Truth

INDEPENDENT FLIGHT - RECURRENT NEURAL NETWORK

- ▶ Train network w/ waypoint navigation ground truth
- ▶ Has memory - deal with velocities

INDEPENDENT FLIGHT - REINFORCEMENT LEARNING

- ▶ Similar inputs/outputs as regular RNN
- ▶ Initial setup complete
- ▶ Train w/o ground truth, reward instead:
 - ▶ D - distance from door
 - ▶ O - distance to obstacles (step function)

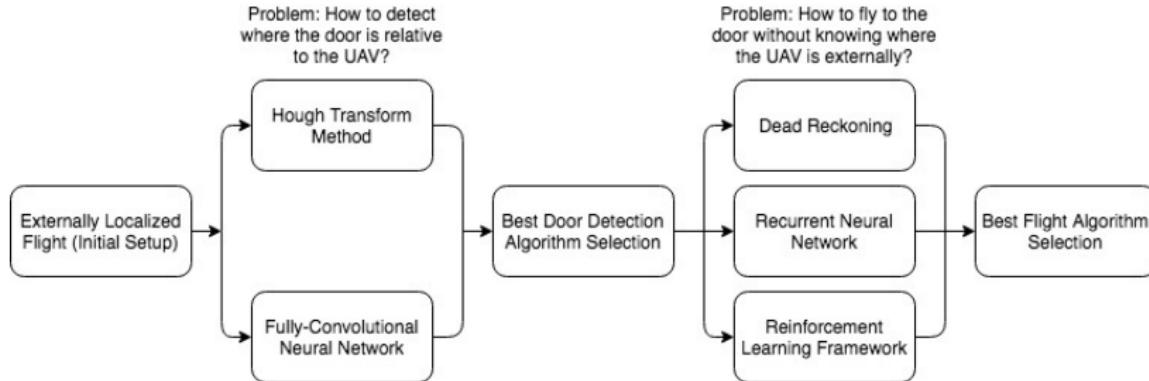
$$Reward = K_1/D + K_2 * O + K_n * OtherFactors$$

BUDGET & SCHEDULE

- ▶ Within budget for wood to build door (\$20)
- ▶ Oct 25 - Initial setup of UAV flight
- ▶ Dec 12 - Door detection algorithms compared
- ▶ Apr 05 - Independent flight algorithms compared

CONCLUSION

- ▶ Explore intersection of small size, auto navigation
- ▶ Compare methods for door detection
- ▶ Compare methods for independent flight



Questions

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SIMULATION

- ▶ Virtual Robotics Experimentation Platform (VREP)
- ▶ Input/Output same form as real Crazyflie
- ▶ Noisy, low resolution camera
- ▶ Noise IMU
- ▶ Delay to mimic data down-link

MOTION CAPTURE

- ▶ VICON
- ▶ Set of cameras
- ▶ Track balls on desired object
- ▶ Provide orientation/position but only w/i tracked space
- ▶ Safety net: bad UAV orientation/path = shut down



Source: Josinski et al. (2014)

HOUGH TRANSFORM

- ▶ Edge detector
- ▶ Parametrize line:
- ▶ $r = x * \cos(\theta) + y * \sin(\theta)$
- ▶ For each edge point: determine all r, θ solving above,
increment table
- ▶ Maximums of table give lines majority of points agree on

