HawkEye

Final Presentation

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Introduction and Motivation

- What is Hawkeye?
  a. An automatic drone tracking system with live aerial footage
  b. Shoots aerial video that does not require human control, eliminating human error

- Use Cases:
  a. Useful for recreational filming, rescue missions etc.
  b. Imagine shooting exciting videos of sports events (your Turkey Bowl game), or having a hands-free vlogging experience!

- Key User Requirements:
  a. Drone Tracking: % of frames with target in shot
  b. Drone Stability: Minimal drone jitter, steady shot

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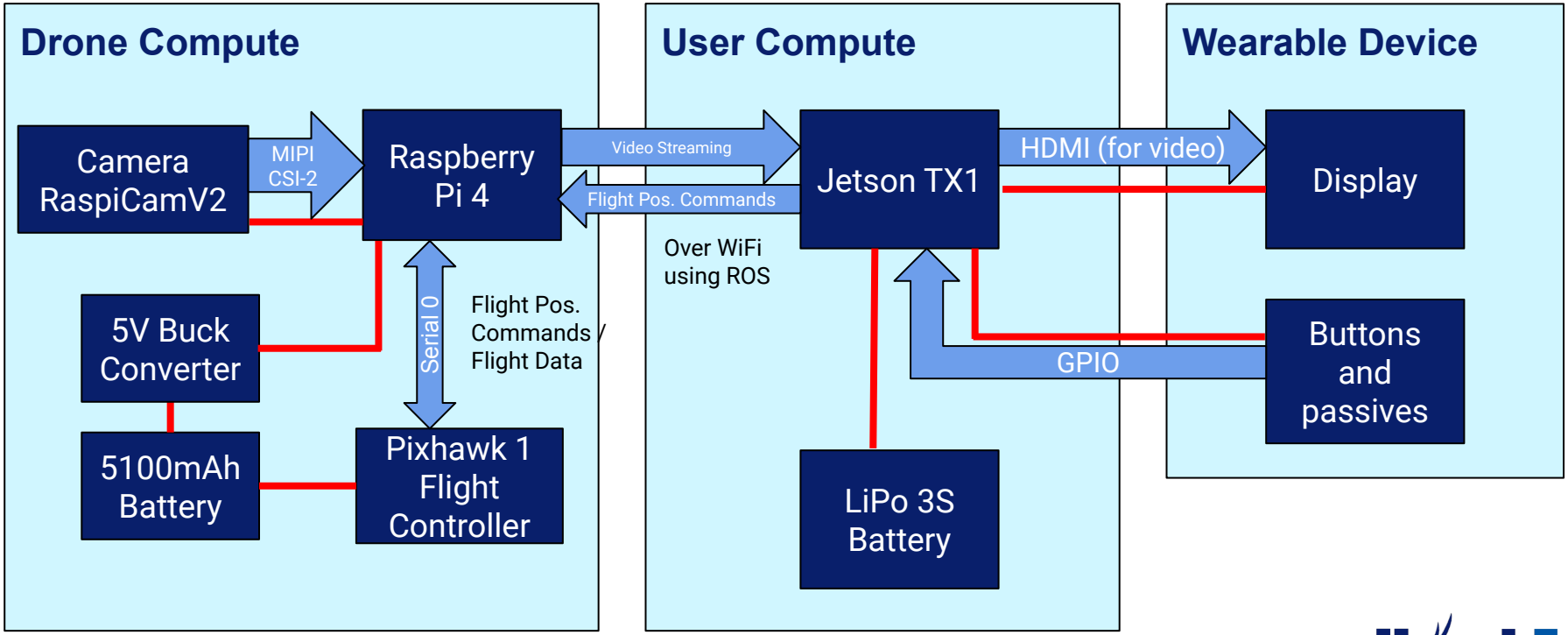
System Specification



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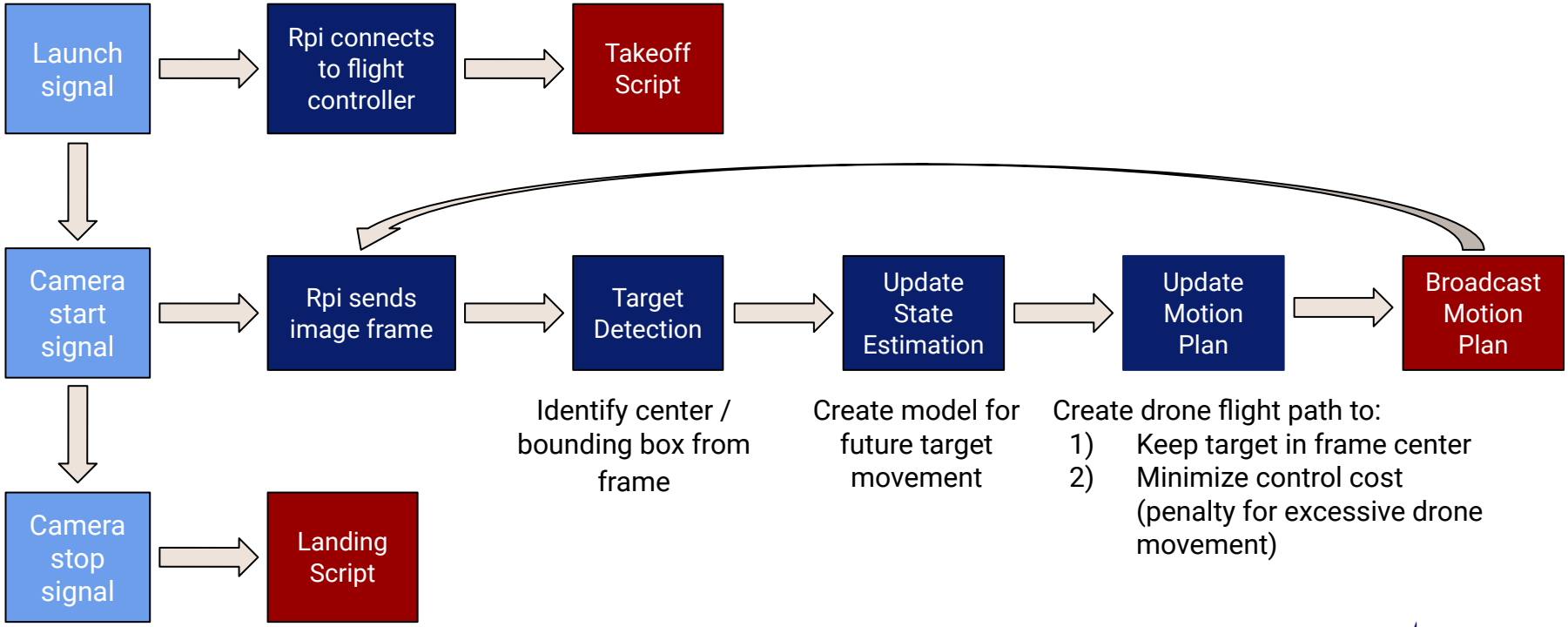
System Specification - Software



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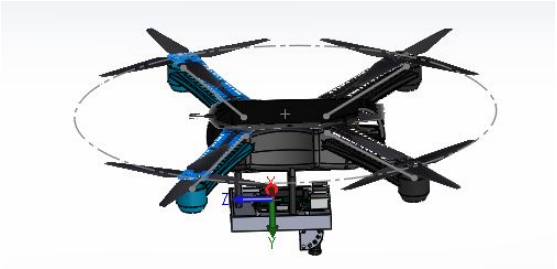
Complete solution

- We will show:
  - Drone manually taking off and streaming video to wearable device
  - Live display of target detection and state estimation results along with the resulting planned flight path
    - Flight path will not be broadcasted back to the drone
    - Drone will be guided manually
  - Full demonstration of autonomous motion in simulation
    - Drone will follow the given flight path



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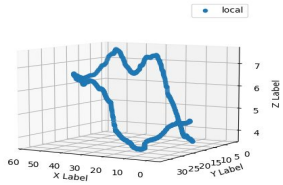
Challenges

Local Position Error:

- Flight controller's internal x,y,z local position estimates are very off
- When still, positions drift within +/- 3 m every few seconds
- Seemingly random where the drone ends up when given the same positional waypoint



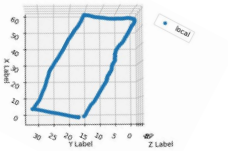


FIgure: Local position estimates for the path walked above

Extreme Sensitivity to Wind:

- Drone topples sideways in even slight wind gusts

Dealing w/ the Issues:

- Cannot fly drone safely fully autonomously
- Instead, we can demonstrate target detection / motion planning while flying drone manually rather than having the drone follow the resulting motion plan
- Autonomy demonstrated on simulated flight controller with exact same interface as real flight controller

FIgure: Drone flailing wildly while trying to hold position during mild wind

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Testing: Image Processing

Operation	Average Time Taken (s)	FPS	
Capture Image	0.344	2.91	Bottleneck
Stream Image to TX1	0.25	4	
Convert Image to Cv2	7.14e-5	14006	
Detect Target	2.67e-4	3745	
Estimate 3D Position + Kalman Filter	6.50e-4	1538	
Motion Planning	0.0135	74.07	
Overall	**0.344**	**2.91**	
Desired		**5 - 10**	

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Testing: Target Detection

False Positive Rate: #Images with detection / No target present
False Negative Rate: #Images without detection / target is present
Average Pixel Error: Distance from predicted target center to actual center

$$\frac{1}{N}\sum_{i}^{N}\sqrt{(\hat{x}_i - x_i)^2 + (\hat{y}_i - y_i)^2}$$

	FP Rate	FN Rate	Avg. Pixel Error
Actual	0%	14.78%	11.87
Desired	2%	10%	(N/A)

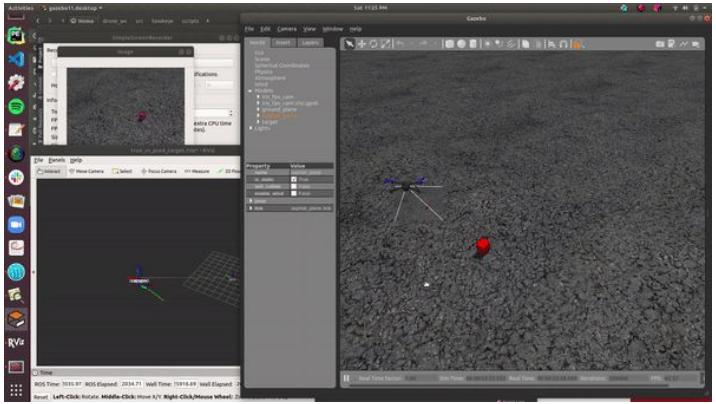
Figure: Predicted vs. actual target center

Figure: Example false negative

Testing: Drone Stability and Tracking (simulation)

Drone Tracking: % of frames where the target is within frame
Drone Stability: % of 3 second windows where drone position is stable

Testing Condition	Tracking	Stability
Walking Only	100%	100%
Running Only	88%	100%
Walking + Running	97%	93.75%
Desired	90%	90%



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Trade-Offs

Motion Planning

- Balancing control cost vs. tracking accuracy
- More control cost = more stable/minimal movement
- Less control cost = jerky movement but higher tracking accuracy

	Current Design	Higher Control Cost	Lower Control Cost
Tracking	**97%**	47%	84.58%
Stability	**93.75%**	100%	43.75%

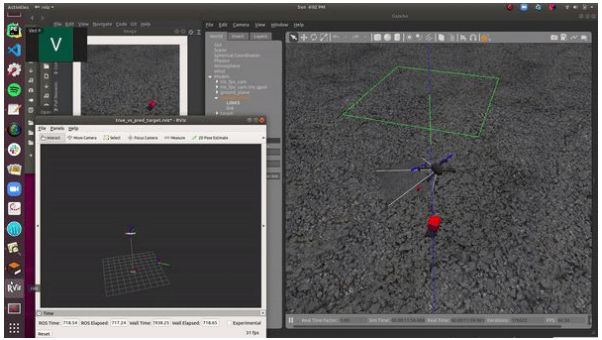

Figure: Motion planner with very high control cost (stable but can't adapt to changes in target motion)

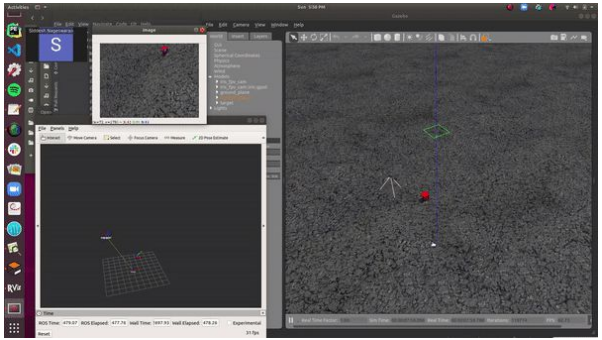

Figure: Motion planner with very low control cost (jerky movement)

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Trade-Offs

Image Streaming

- Uncompressed Images (what we use) vs. Compressed Images
  - Bottleneck -> camera capture
    - Uncompressed: 2.91 FPS, Compressed: 2.94 FPS
  - There IS a difference in streaming (4 FPS vs. 6.67 FPS), but that's irrelevant since it isn't bottleneck
  - No benefit to loss of quality from compression

State Estimation

- New target detection data vs. Current target model
  - The more that new data is weighted, the noisier the predicted path potentially becomes
  - The more the current model is weighted, the more the predicted path drifts from the actual one
- Model of target's acceleration
  - Modeling a higher potential for acceleration makes path jerkier
  - But modeling a lower potential for acceleration may cause predicted path to lag behind actual one

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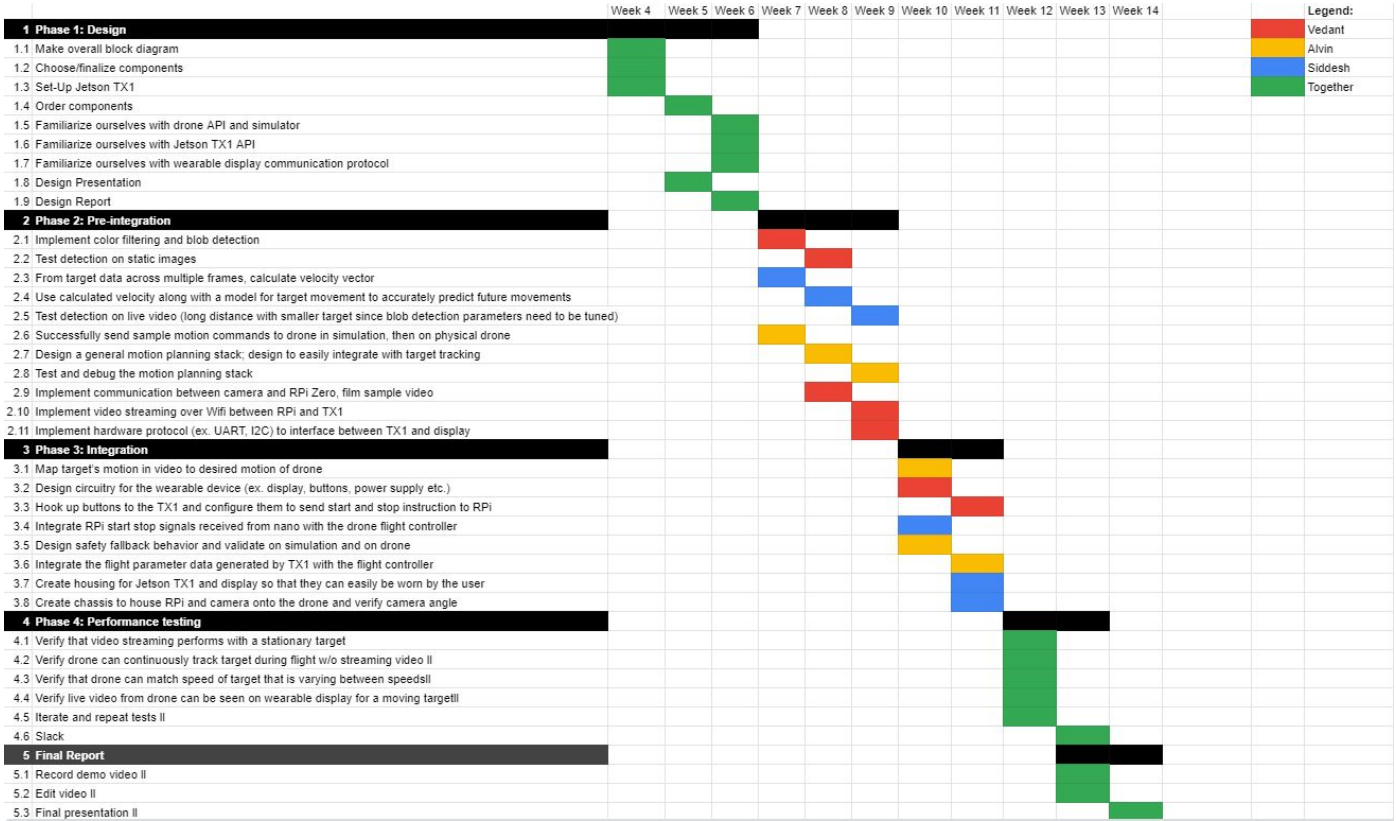
Updated Schedule



1	**Phase 1: Design**
1.1	Make overall block diagram
1.2	Choose/finalize components
1.3	Set-Up Jetson TX1
1.4	Order components
1.5	Familiarize ourselves with drone API and simulator
1.6	Familiarize ourselves with Jetson TX1 API
1.7	Familiarize ourselves with wearable display communication protocol
1.8	Design Presentation
1.9	Design Report
2	**Phase 2: Pre-integration**
2.1	Implement color filtering and blob detection
2.2	Test detection on static images
2.3	From target data across multiple frames, calculate velocity vector
2.4	Use calculated velocity along with a model for target movement to accurately predict future movements
2.5	Test detection on live video (long distance with smaller target since blob detection parameters need to be tuned)
2.6	Successfully send sample motion commands to drone in simulation, then on physical drone
2.7	Design a general motion planning stack; design to easily integrate with target tracking
2.8	Test and debug the motion planning stack
2.9	Implement communication between camera and RPi Zero, film sample video
2.10	Implement video streaming over Wifi between RPi and TX1
2.11	Implement hardware protocol (ex. UART, I2C) to interface between TX1 and display
3	**Phase 3: Integration**
3.1	Map target's motion in video to desired motion of drone
3.2	Design circuitry for the wearable device (ex. display, buttons, power supply etc.)
3.3	Hook up buttons to the TX1 and configure them to send start and stop instruction to RPi
3.4	Integrate RPi start stop signals received from nano with the drone flight controller
3.5	Design safety fallback behavior and validate on simulation and on drone
3.6	Integrate the flight parameter data generated by TX1 with the flight controller
3.7	Create housing for Jetson TX1 and display so that they can easily be worn by the user
3.8	Create chassis to house RPi and camera onto the drone and verify camera angle
4	**Phase 4: Performance testing**
4.1	Verify that video streaming performs with a stationary target
4.2	Verify drone can continuously track target during flight w/o streaming video II
4.3	Verify that drone can match speed of target that is varying between speedsII
4.4	Verify live video from drone can be seen on wearable display for a moving targetII
4.5	Iterate and repeat tests II
4.6	Slack
5	**Final Report**
5.1	Record demo video II
5.2	Edit video II
5.3	Final presentation II

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