# Surface Effects Mapping of a Multirotor in Close Proximity to the Ground, Ceiling, and Walls

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## Research Question

**What is the comprehensive model of Surface Effects (SE) on multirotor performance, with a focus on ground effect and wall effects, and how can this model be leveraged to develop energy-efficient navigation algorithms for unmanned aerial vehicles in close-proximity flights near surfaces?**

## Methodology

- Utilized UR5 robot with an inbuilt force-torque sensor.
- Collected data from the multirotor at various distances from surfaces.
- Gathered 10 sets of 1-minute-long flight data for each effect (ground and wall) and in free space as a control.
- Recorded force-torque data for analysis.
- Logged RPM data from each of the six motors for thrust calculations.
- Total thrust (T) determined by the equation:
  $T = t_c * (\omega_1^2 + \omega_2^2 + \omega_3^2 + \omega_4^2 + \omega_5^2 + \omega_6^2)$
- $t_c$ is a constant related to motor and propeller characteristics and was calculated using the control dataset.
- $\omega_1$, $\omega_2$, $\omega_3$, $\omega_4$, $\omega_5$, and $\omega_6$ represent motor angular velocities.

## Data Processing

- Initial raw data: High noise, sensor drift offsets
- Sensor offset removal: Subtract average of first 50 points with motors off
- Noise reduction: Apply lowpass filter, followed by 250-point moving average

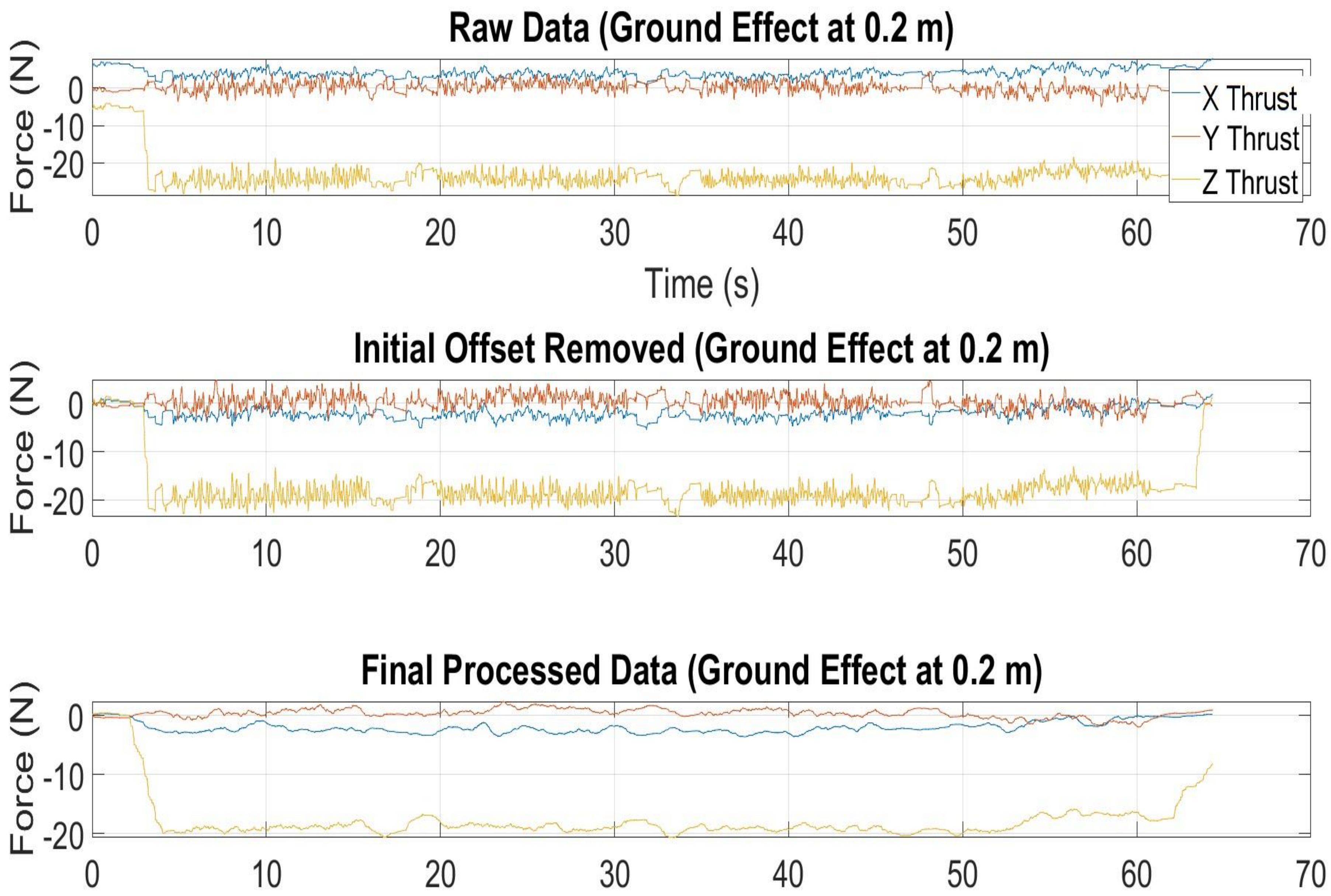


Fig. 1. Data Processing

## Data Collection Architecture

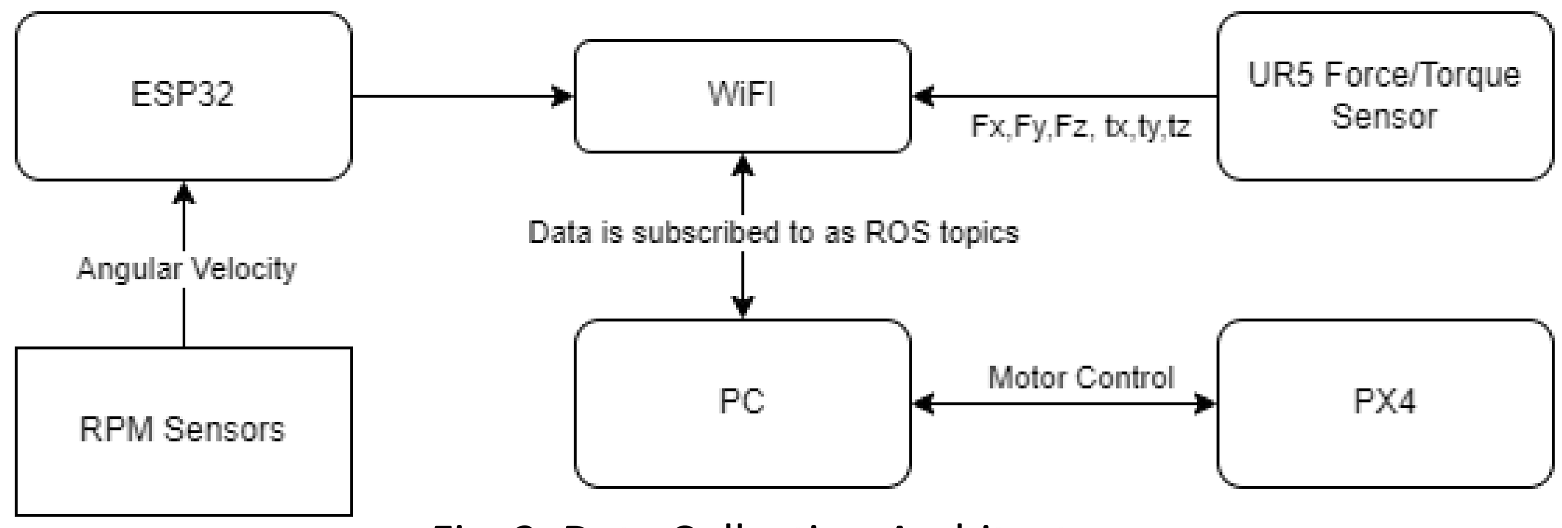


Fig. 2. Data Collection Architecture

Fig. 3. Experiments setup for Ground Effect

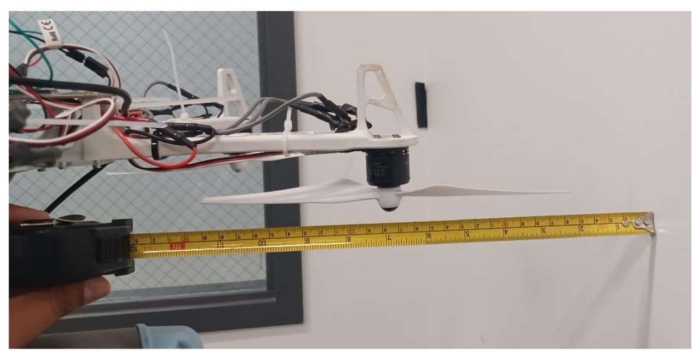

Fig. 4. Measurement of Distance of the Multi Rotor from Wall (18 cm)

## Results

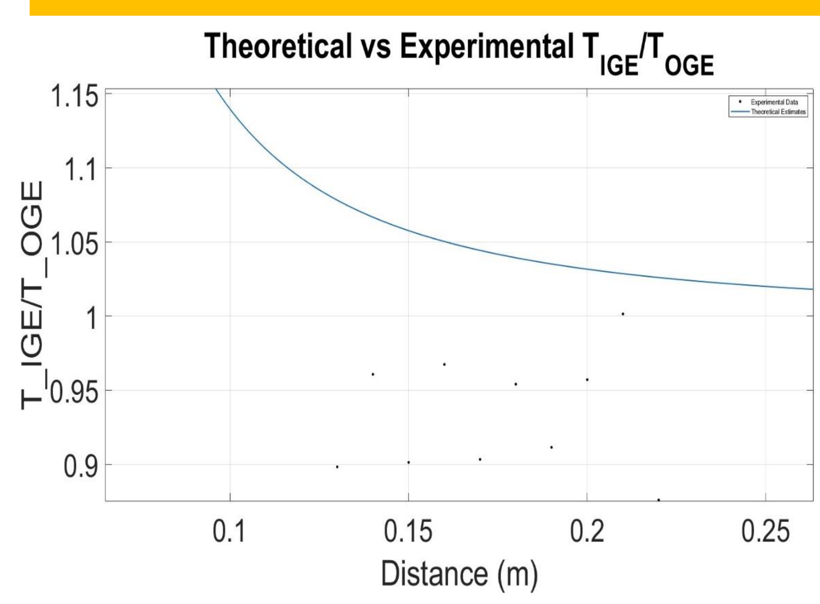


Fig. 5. $T_{IGE}/T_{OGE}$

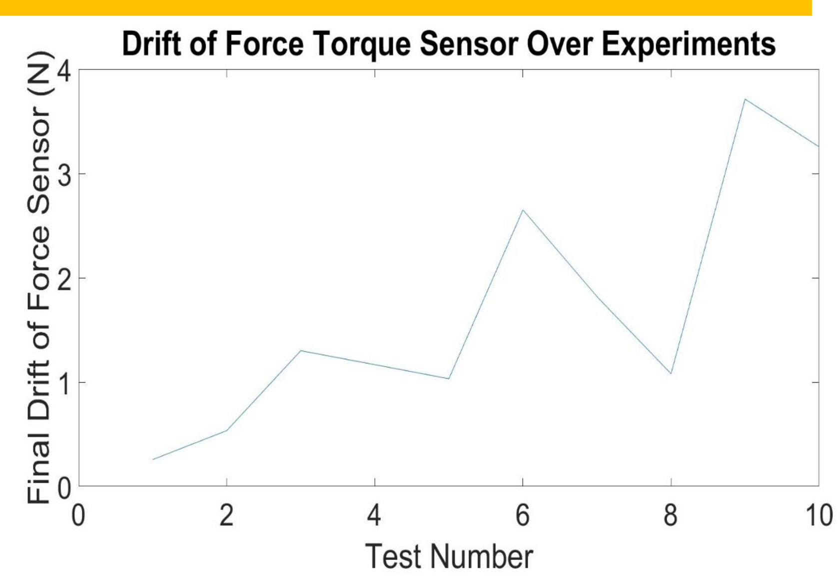


Fig. 6. End Sensor Drift over Experiments

- The model does not align with the expected results for ground effect as per [1]. Instead of observing an increase in thrust, we are experiencing a decrease.
- Noted a substantial sensor drift of up to 25% (4N) in observed values. This drift in sensor readings can explain the discrepancy, where forces are decreasing by 4 percent at 0.2 m instead of increasing by the expected 3 percent.
- To address this issue, we plan to adopt more accurate and less-drifting sensors for improved data reliability and alignment with expected results.

## Acknowledgements and References

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[1] Conyers, Stephen A. Empirical evaluation of ground, ceiling, and wall effect for small-scale rotorcraft. Diss. University of Denver, 2019.