

Propulsion Unit Optimization for Small UAS

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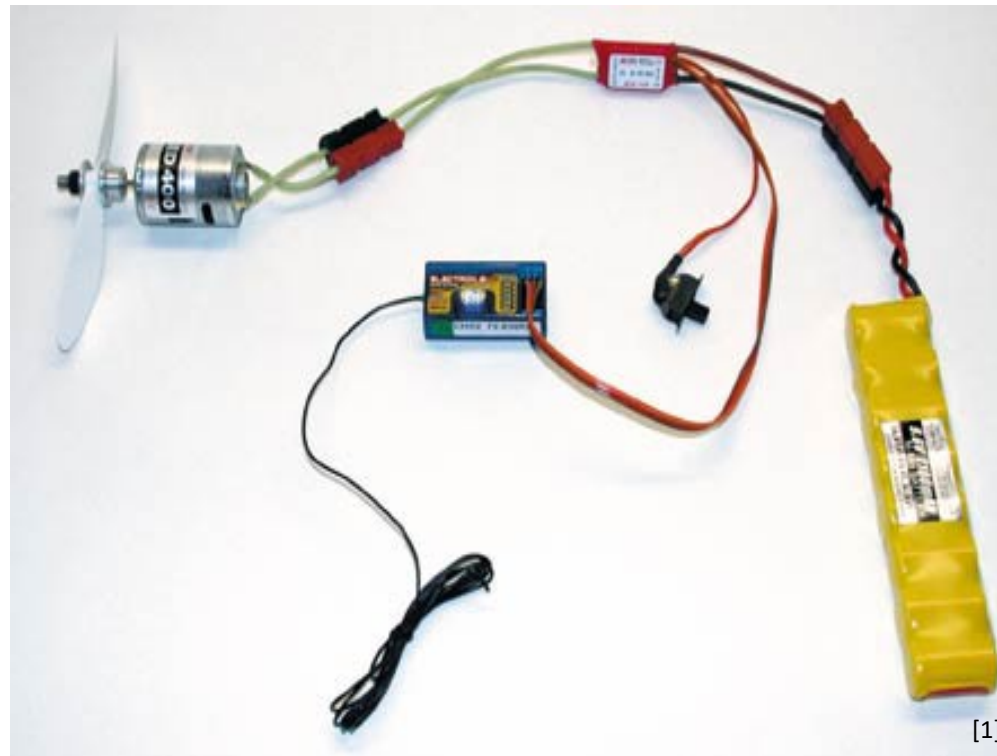


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Research Objective

- Investigate algorithms for optimizing electric propulsion units for small Unmanned Aerial Systems (UAS).



Research Justification

- No literature found for optimizing using commercial, off-the-shelf parts.
 - Examples of optimizing custom propellers [2,3].
- Current modelling software has little to no optimization capability.
- Increasing use of UAS demands efficient tools.

General Motor Cooling: medium # of Rotors: 4 Model Weight: 1500 g 52.9 oz incl. Drive Frame Size: 500 mm 19.69 inch FCU Tilt Limit: no limit Field Elevation: 500 m ASL 1640 ft ASL Air Temperature: 25 °C 77 °F Pressure (QNH): 1013 hPa 29.91 inHg

Battery Cell Type (Cont. / max. C) - charge state: select... - normal Configuration: 3 S 3 P Cell Capacity: 2100 mAh Total Capacity: 6300 mAh Resistance: 0.01 Ohm Voltage: 3.7 V C-Rate: 25 C cont. 57 g 35 C max 2 oz Weight: 25 g 0.9 oz

Controller Type: select... cont. Current: 20 A max. Current: 20 A Resistance: 0.01 Ohm Weight: 25 g 0.9 oz

Motor Manufacturer - Type (KV): Hacker A30-24M UAV (680) KV (w/o torque): 680 rpm/V no-load Current: 0.9 A @ 8.4 V Limit (up to 15s): 350 W Resistance: 0.08 Ohm Case Length: 34 mm 1.34 inch # mag. Poles: 14 Weight: 134 g 4.7 oz

Propeller Type - yoke twist: custom - +5.0° Diameter: 12 inch Pitch: 4.7 inch # Blades: 2 PConst / TConst: 1.18 / 1.0 Gear Ratio: 1 : 1 calculate

Load: 10.68 C Hover Flight Time: 18.6 min electric Power: 172.5 W est. Temperature: 43 °C Thrust-Weight: 2.3 specific Thrust: 7.98 g/W

Remarks:

Battery		Motor @ Optimum Efficiency		Motor @ Maximum		Motor @ Hover		Total Drive		Multicopter	
Load:	10.68 C	Current:	10.79 A	Current:	16.82 A	Current:	4.32 A	Drive Weight:	1264 g	All-up Weight:	1500 g
Voltage:	10.43 V	Voltage:	10.56 V	Voltage:	10.26 V	Voltage:	10.88 V	Thrust-Weight:	44.6 g	add. Payload:	52.9 oz
Rated Voltage:	11.10 V	Revolutions*:	6543 rpm	Revolutions*:	5983 rpm	Revolutions*:	3429 rpm	Current @ Hover:	17.27 A	max. Tilt:	60 °
Capacity:	6300 mAh	electric Power:	114.0 W	electric Power:	172.5 W	Throttle (log):	39 %	Pi(in) @ Hover:	191.7 W	max. Speed:	49 km/h
Energy:	69.93 Wh	mech. Power:	94.6 W	mech. Power:	139.9 W	Throttle (linear):	53 %	Pi(out) @ Hover:	148.6 W	est. rate of climb:	8.3 m/s
Flight Time:	5.6 min	Efficiency:	83.0 %	Efficiency:	81.1 %	electric Power:	47.0 W	Efficiency @ Hover:	77.5 %	with Rotor fail:	1634 ft/min
Mixed Flight Time:	13.2 min			est. Temperature:	43 °C	mech. Power:	37.2 W	Current @ max:	67.27 A		
Hover Flight Time:	18.6 min				109 °F	est. Temperature:	30 °C	Pi(in) @ max:	746.7 W		
Weight:	513 g					est. Temperature:	86 °F	Pi(out) @ max:	559.5 W		
	18.1 oz					specific Thrust:	7.98 g/W	Efficiency @ max:	74.9 %		
							0.28 oz/W				

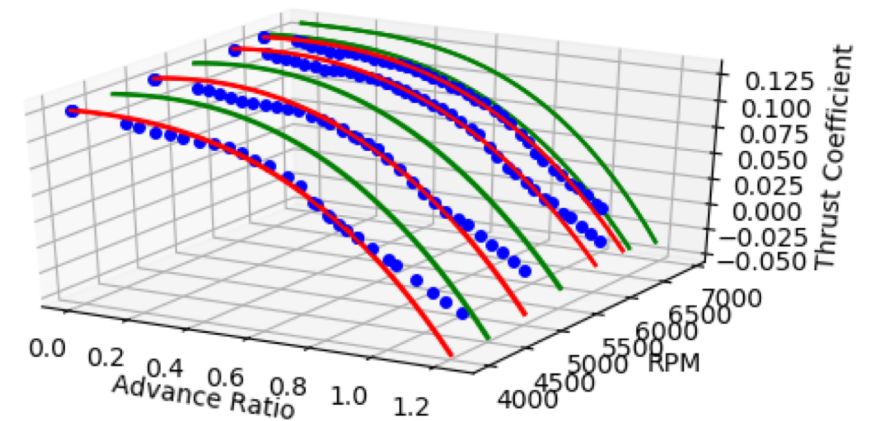
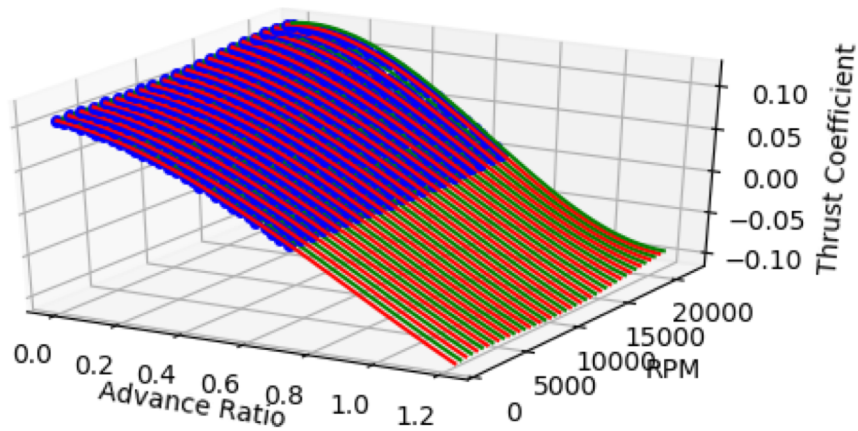
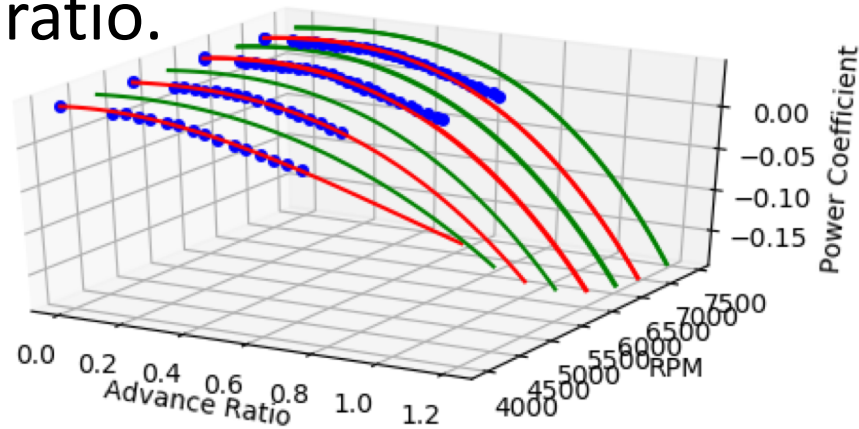
Database Creation

- Assembled a database of commercial components from databases available online.



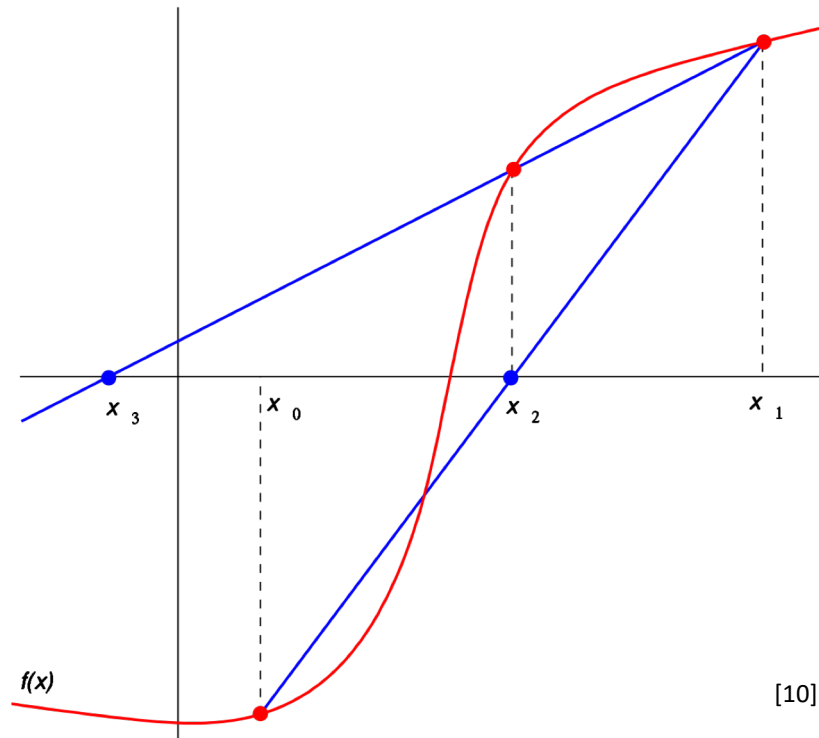
Propeller Modelling

- Created polynomial fits of thrust and power as functions of angular velocity and advance ratio.



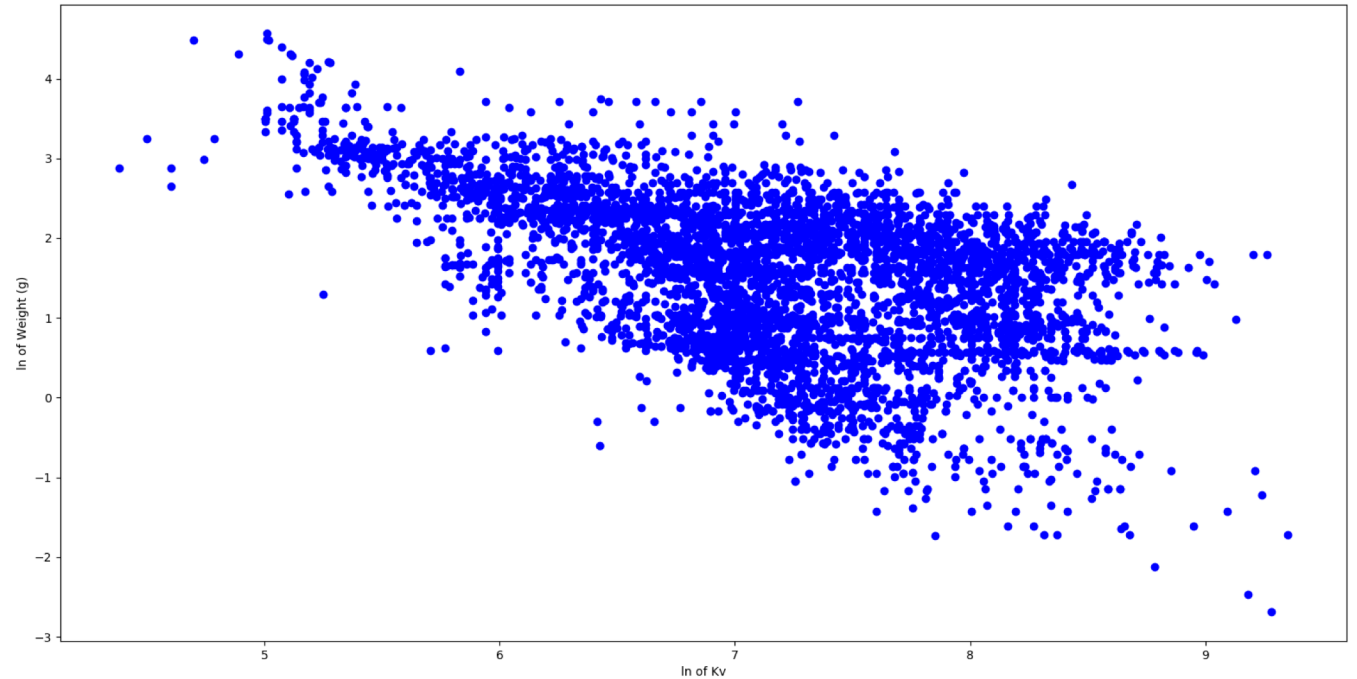
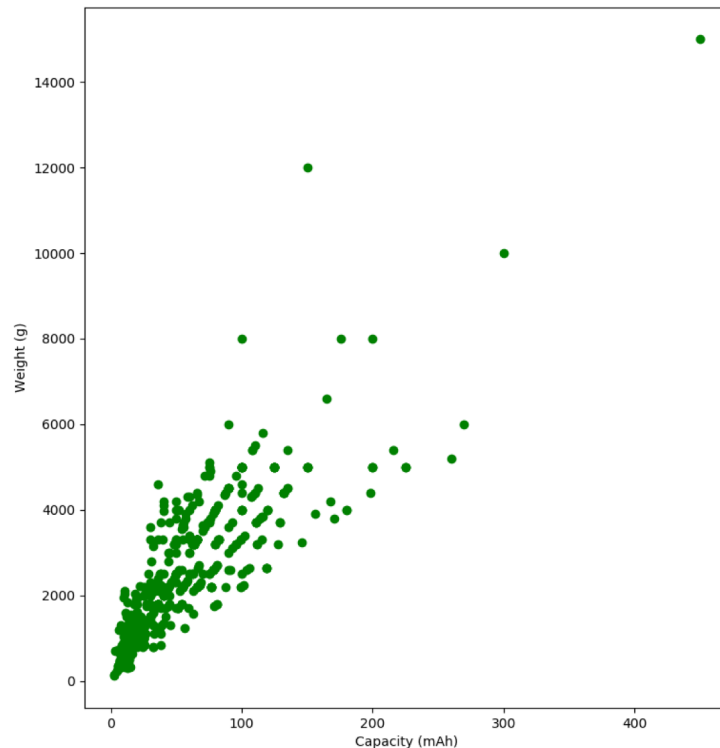
Unit Modelling

- Calculated flight time at a given thrust for a given combination of propeller, motor, ESC, and battery [9].



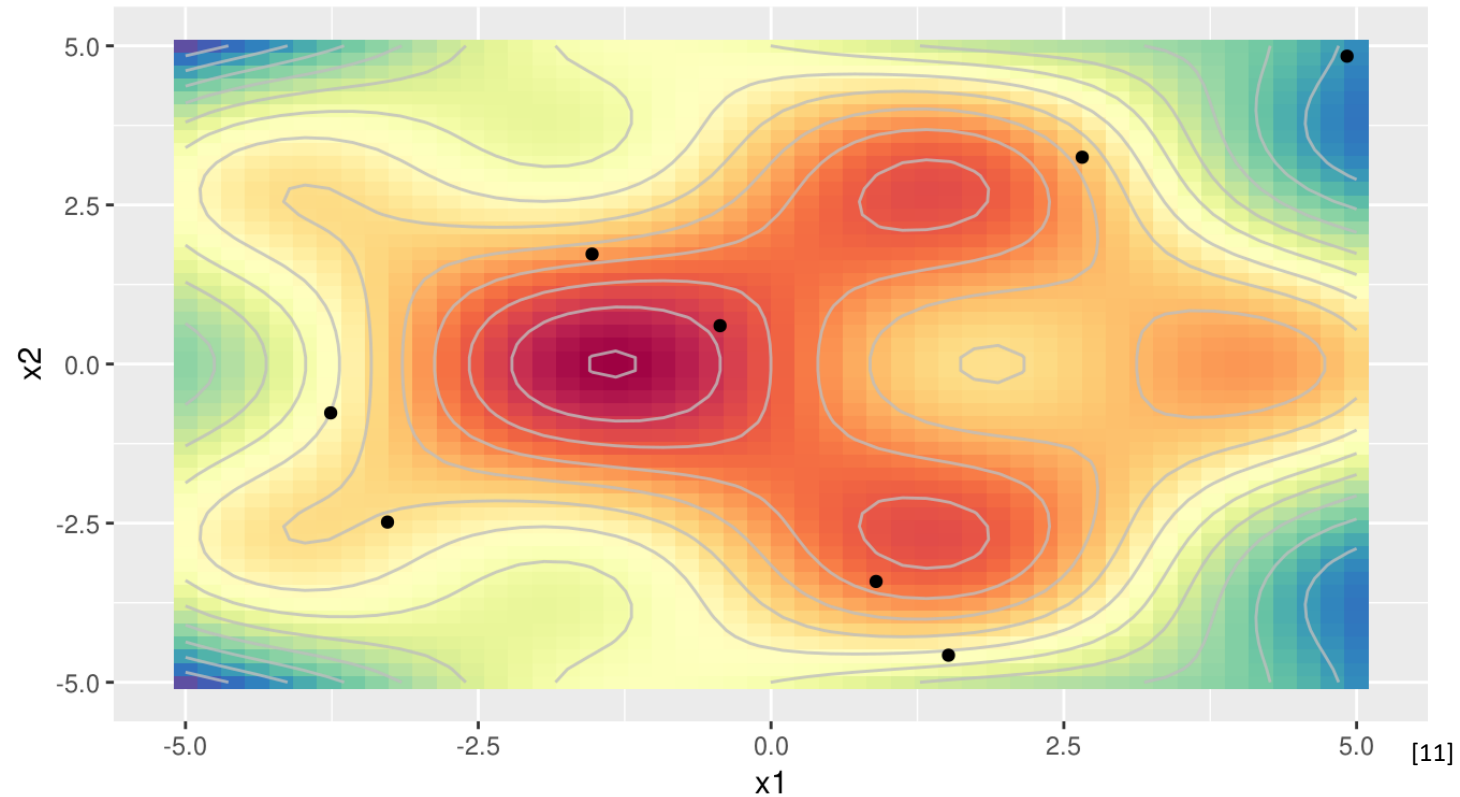
Discrete vs Continuous Optimization

- Some parameters can be modelled as continuous functions; however, this is inaccurate for commercial, off-the-shelf parts.



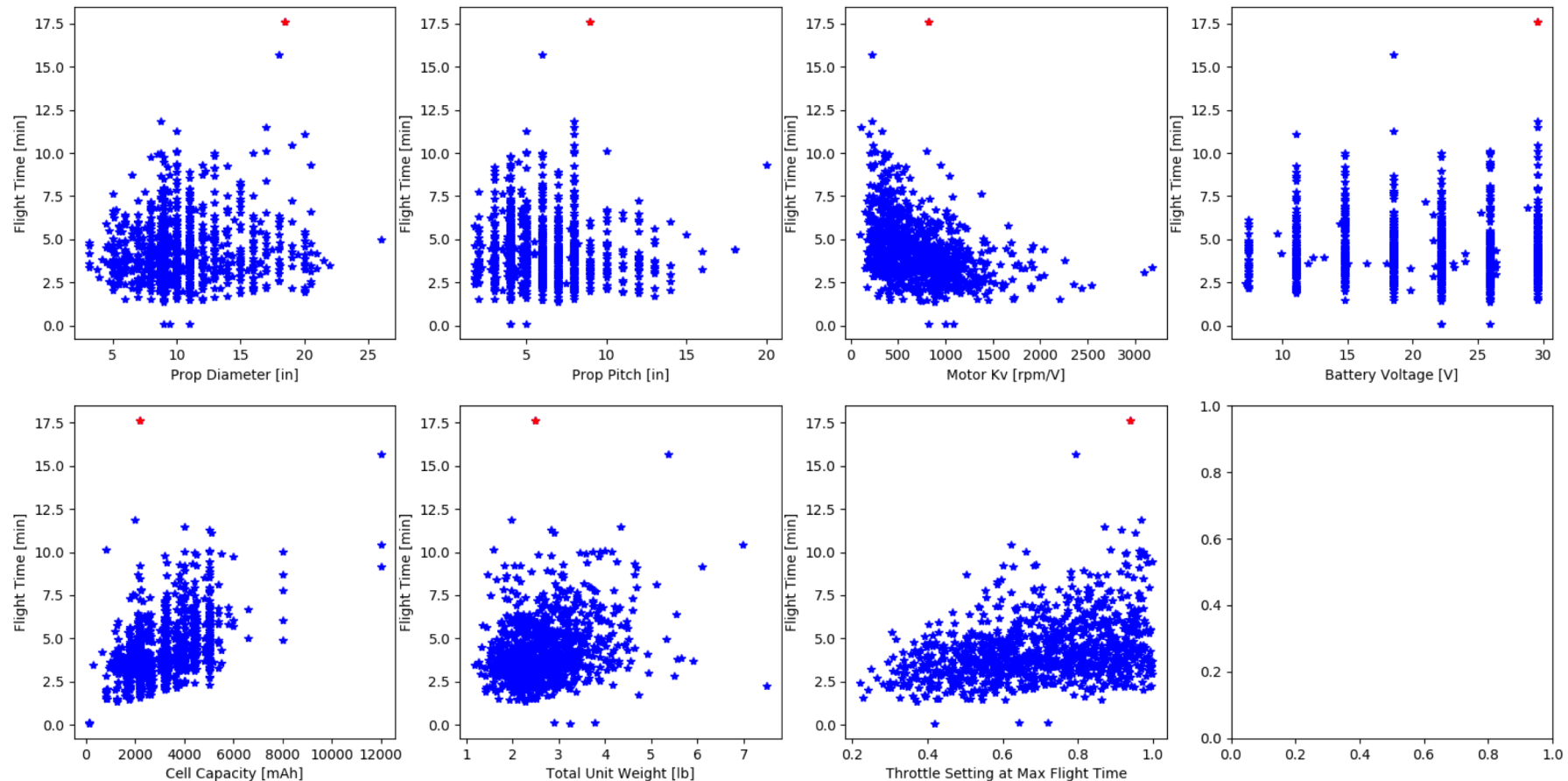
Random Search Method

- Simplest choice for discrete optimization.



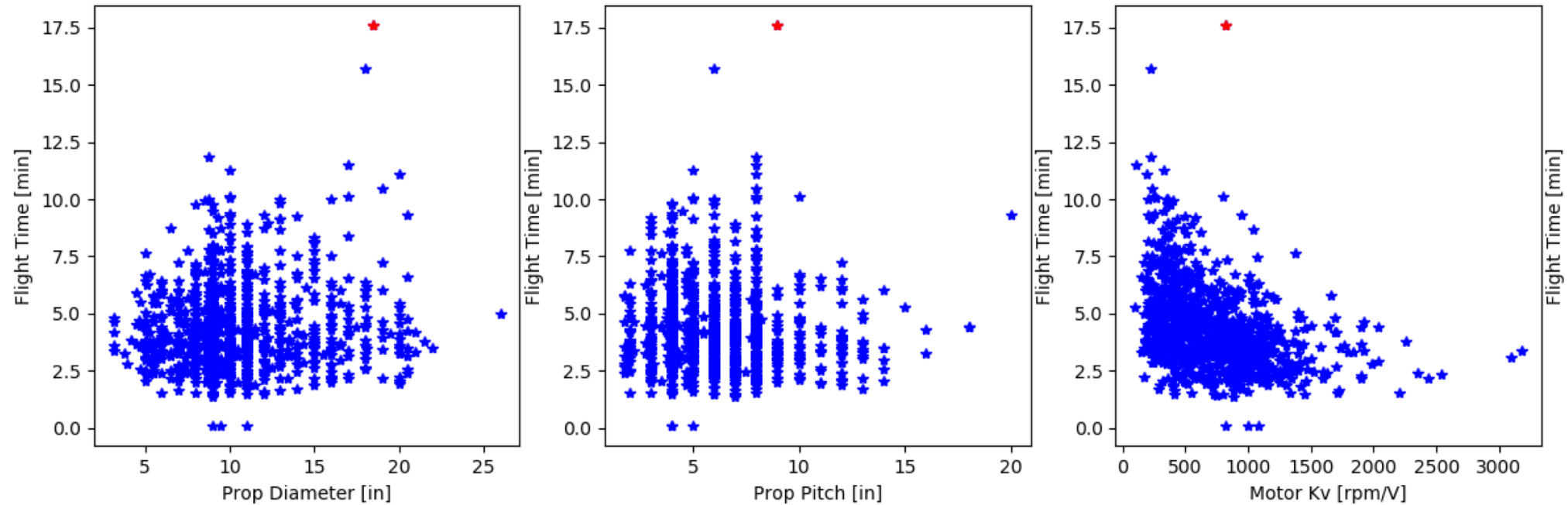
Performance Trends

- Identify trends in the design space for optimizing flight time.



Algorithm Weaknesses

- Very susceptible to outliers.
- Computationally inefficient.



Future Work

- Improve quality of database.
- Analyze other discrete optimization techniques:
 - Genetic
 - Simulated annealing
 - Branch and cut
- Research how to effectively constrain the optimization.

- [1] <https://newatlas.com/laser-powered-stalker-uas/23283/>
- [2] Gur, O. *Optimization of Propeller Based Propulsion System*, Journal of Aircraft, 2009.
- [3] Gur, O. *Optimizing Electric Propulsion Systems for UAVs*, AIAA/ISSMO Conference, 2008.
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