Mechatronic Design and Characterization of an Optimized Quadrotor for Collaborative Transportation

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Motivation

Challenge: Designing high-performance aerial robots, especially for demanding tasks like collaborative transportation (e.g., **FlyCrane**), requires accurate dynamic models. Off-the-shelf component data is often insufficient or inaccurate.

Need: Precise knowledge of motor and propeller characteristics (**Thrust Coefficient Kt, Torque Coefficient Kq**) is crucial for:

- Model-based control design.
- Realistic simulation.
- Optimized component selection and mechatronic design.

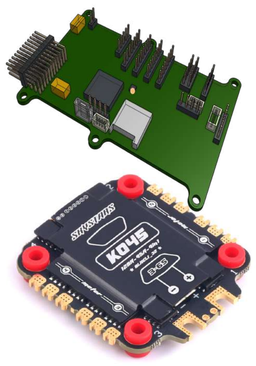
Goal: To design and validate a quadrotor optimized for collaborative transport, starting with accurate characterization of its propulsion system.

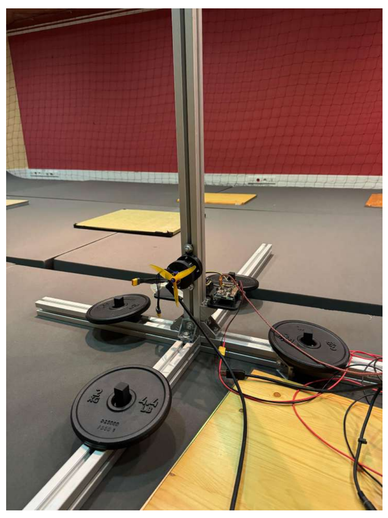
Propulsion System Characterization

Objective: Experimentally determine the Kt and Kq coefficients for selected motor-propeller combinations.

Methodology: Custom Test Bench

Developed a test bench to accurately measure thrust and torque.

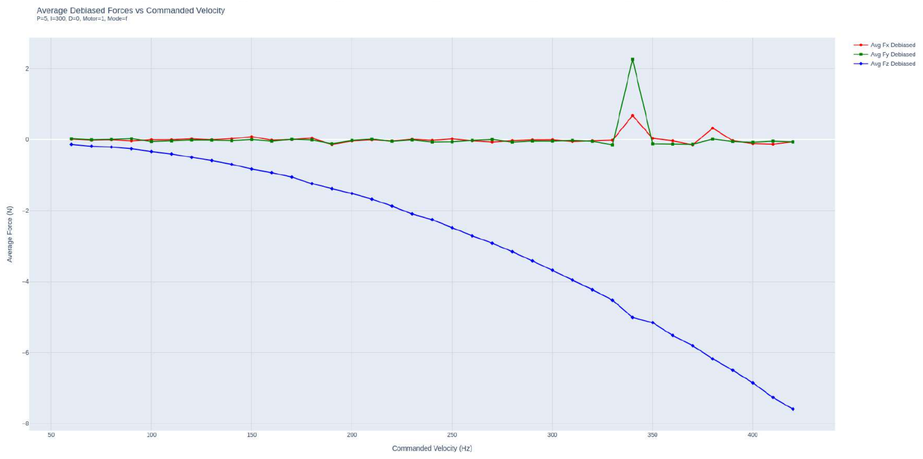




Components: Chimera Flight Controller, Skystars KO45A ESC, Medusa Botasys sensor, motor mount, aluminium profiles, controllable power supply.

Procedure: Systematically vary motor command (velocity) and record thrust, torque and RPM.

Data Processing: Calculate Kt = Thrust / ω^2 and Kq = Torque / ω^2



Design Objective

Develop a quadrotor specifically optimized for the **FlyCrane** collaborative transportation platform.

Focus on:

- High Thrust-to-Weight Ratio (**TWR**) for payload capacity.
- Structural integrity for carrying loads.
- Appropriate size and mounting points for FlyCrane integration.
- Efficient power usage.

Mechatronic Design Process

Design Choice: Testin various CAD taking in consideration the minimum distance between the COM and the bottom part of the platform.

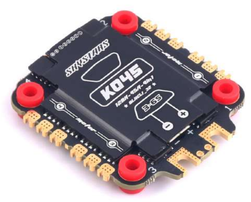
Component Selection:

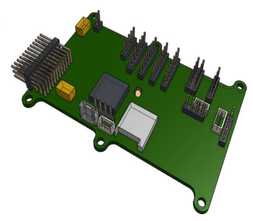
Motors & Propellers: Chosen based on costructor data

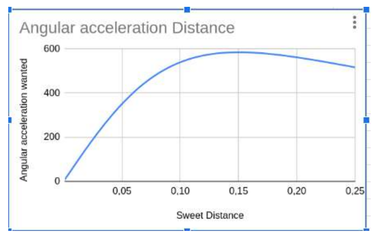
Prop（inch）	Voltages（V）	Throttle（%）	Load Currency（A）	Pull(g)	Power(W)	Efficiency(g/W)	Temperature(in full throttle load 5's)
GF5136R	21	50%	10.0	839	210.0	3.995	76℃
		100%	49.6	2184	1041.6	2.097	
	24	50%	11.9	1006	285.6	3.522	84℃
		100%	59.4	2521	1425.6	1.768	
GF51466R	21	50%	10.1	861	212.1	4.059	76℃
		100%	51.0	2278	1071.0	2.127	
	24	50%	12.1	1040	290.4	3.581	84℃
		100%	60.7	2547	1456.8	1.748	
HQ R36	21	50%	9.4	811	197.4	4.108	69℃
		100%	44.7	2025	938.7	2.157	
	24	50%	11.7	997	280.8	3.551	79℃
		100%	54.4	2236	1305.6	1.713	
HQ R38	21	50%	9.8	806	205.8	3.916	75℃
		100%	47.2	1941	991.2	1.958	
	24	50%	12.2	981	292.8	3.350	83℃
		100%	57.7	2279	1384.8	1.646	
DAL T5148.5	21	50%	8.9	759	188.9	4.061	72℃
		100%	43.9	1967	921.9	2.134	
	24	50%	10.4	920	249.6	3.686	80℃
		100%	54.3	2311	1303.2	1.773	
■Airplane			☐Helicopter			■Vtol	

Frame: Off-the-shelf design choosen for weight, stiffness, component mounting and minimum dimension needed. Material choice, Carbon Fiber and costum 3D printed parts.

Flight Controller (FC) & 4in1 ESCs: Selected for compatibility, processing power, and required current handling.



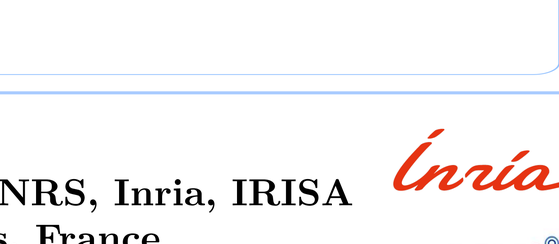




Power System: Battery selected based on voltage, capacity, weight, and discharge rate to meet flight time and power demands predicted using characterization data.

Comparison between various setup with predicted performances

Final Design



Future Work

Prototyping: Fabricate/3D print frame components and assemble the quadrotor prototype.

System Integration: Integrate FC, ESCs, motors, power system.

Simulation: Develop a simulation model using the measured Kt and Kq values.

Experimental Validation:

- Bench testing of the assembled quadrotor
- Flight testing in the drone arena to validate flight dynamics and performance.
- Integration and testing within the FlyCrane collaborative transport system.

How would be the new drone?

Research Environment & Tools

Rainbow Team, Inria Rennes: Access to expertise and collaborative environment.

Tools Used: Custom test bench, OnShape, Python, Excel, 3D Printers.

Future Testing: Drone arenas with motion capture systems available for validation.

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