Active Aerodynamic Disturbance Adaptation

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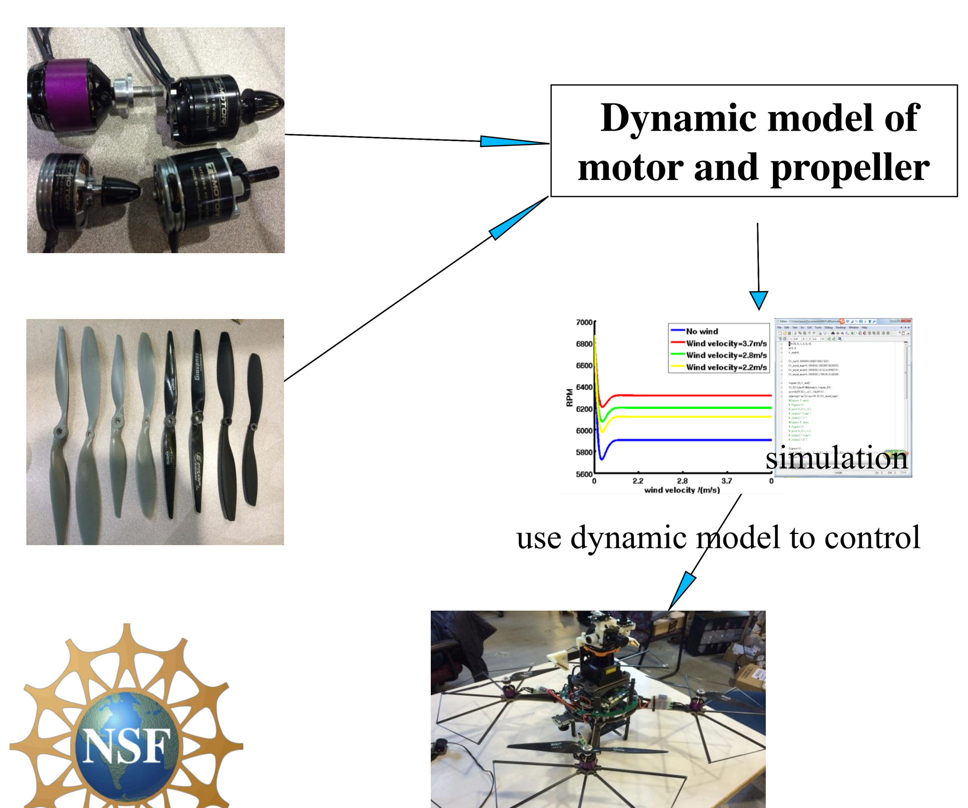
Problem statement:

- A quadrotor is an aerial vehicle popular as a testbed for small UAV development, but existing control approaches often ignore aerodynamic effects
- To improve controllability of the quadrotor, our project builds on the dynamic model of motor and propeller to enable the quadrotor to adapt to changes in the environment wind condition

Method:

- **Building the dynamic model of motor and propeller**
  - Test the static model of propeller and motor
  - Change the wind condition and get the dynamic data.
  - Calculate the strength of wind and build dynamic model
- **Using the dynamic model to control the quadrotor.**
  - Simulate the quadrotor in different wind conditions
  - Test quadrotor.



Aerodynamic model of rotor:

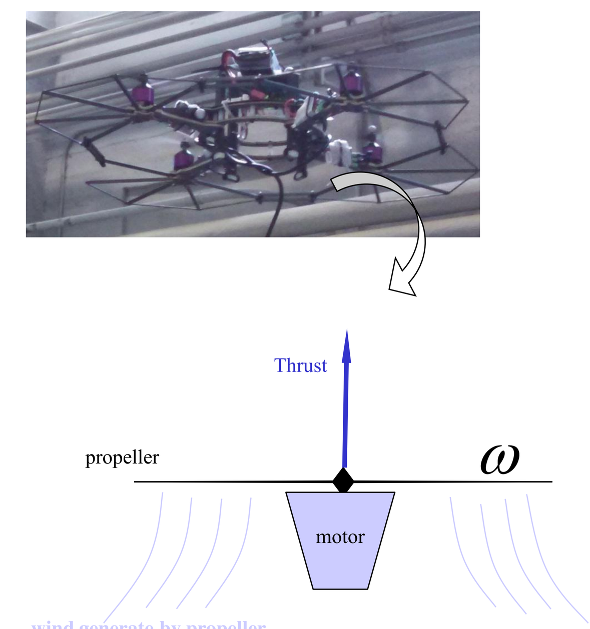
- The thrust generated by the prop: $T = c_T \omega^2$
- The reaction torque acting on airframe: $Q = c_Q \omega^2$

ω is the angular velocity

$c_T = f(V, \omega, D)$

$c_Q = g(V, \omega, D)$

V: vehicle velocity D: propeller diameter



Model calibration result:

- **The motor test setup consist of two components:**
  - Load cell: thrust and torque
  - Prototype rotor
- **Test approach:**
  - Static test: send the motor different voltages and record RPM and thrust. Then according to the curve fit ,get static value of c_T
  - Dynamic test: find c_T when the direction and velocity of wind change.

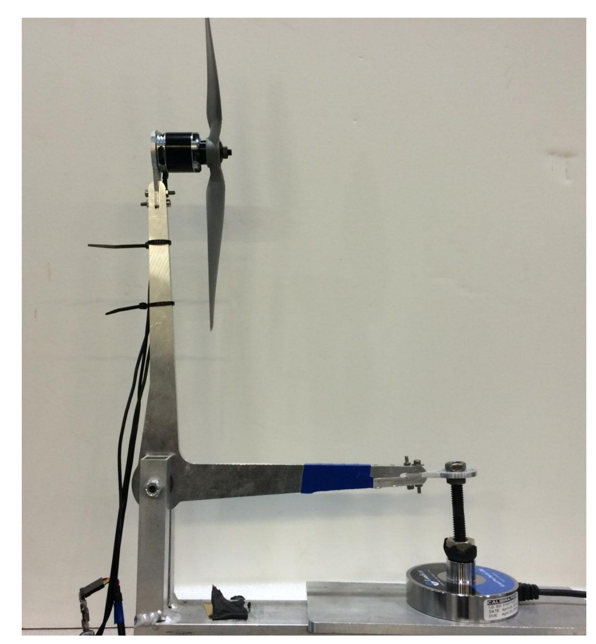


Figure 3. Thrust and torque test setup which can record data of RPM,current and voltage from speed controller ESC32.

Result

All the results use T-MOTOR MT2216 with APC 10*5E propeller.

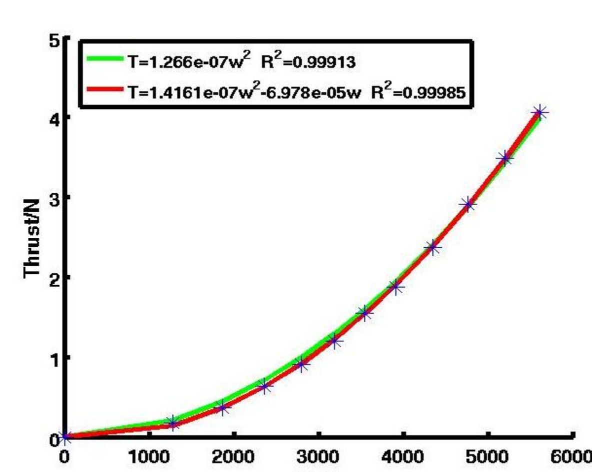


Figure 4. c_T fitting curve when wind Condition doesn't change

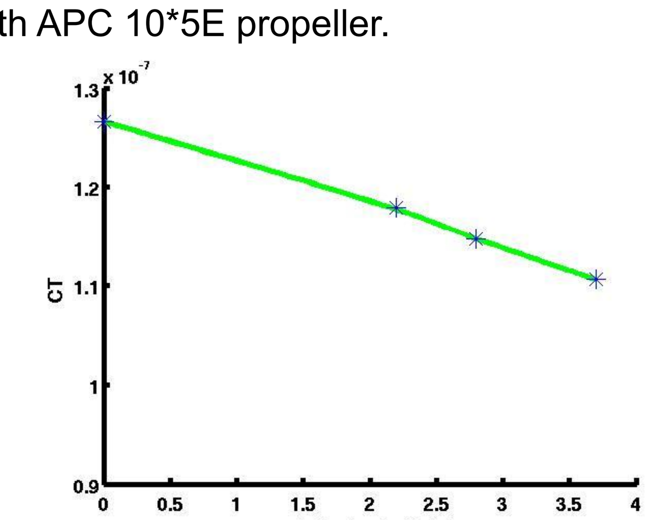


Figure 5. different value of c_T in four different wind conditions

- In different wind conditions, model of rotor changes.
- When the velocity of wind increase, the value of c_T decrease.

Quadrotor model:

2D case (x-z plane)

- Position and attitude model

$$m\ddot{x} = -F\sin\theta$$
$$m\ddot{z} = F\cos\theta - mg$$
$$J\ddot{\theta} = M$$

- Rotor model

$$\begin{bmatrix} F \\ M \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ L & -L \end{bmatrix} \begin{bmatrix} c_T\omega_1^2 \\ c_T\omega_2^2 \end{bmatrix}$$

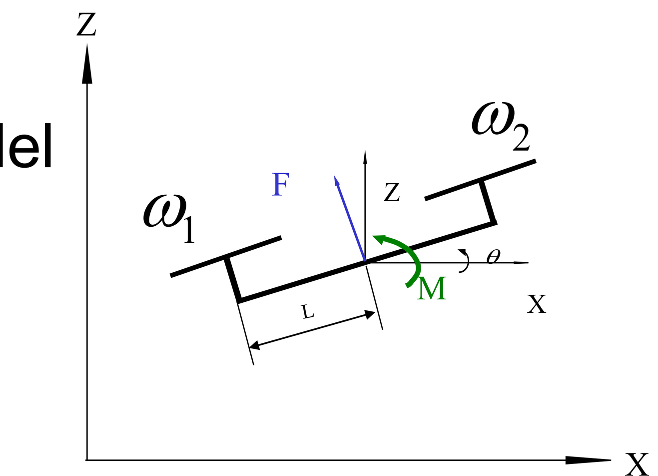


Figure 6. 2D state configuration of quadrotor in the X-Z place. ω_1 and ω_2 are angluar velocity of propeller

Simulation result:

- Four different wind conditions
- Command quadrotor's position from (5,1) up to (5,1.5). Desired velocity of X and Z axis are 0 m/s. Desired angular is 0 rad and angular velocity is 0 rad/s.

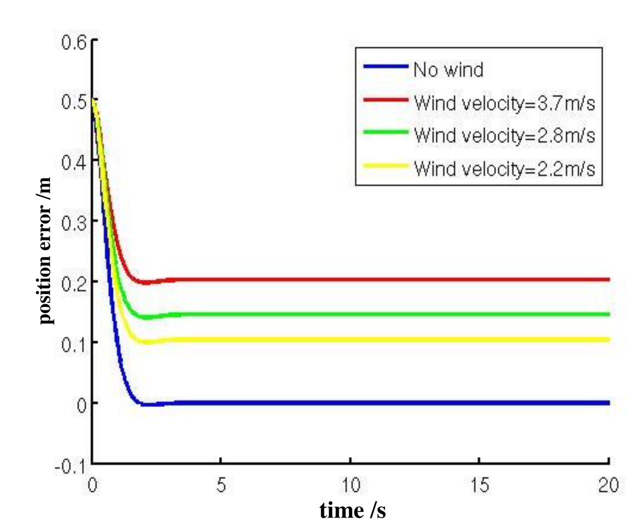


Figure 7. step response of position error for four different wind conditions

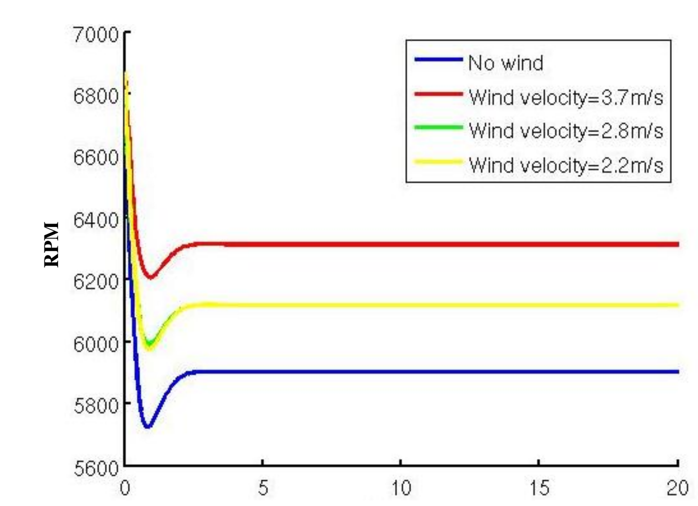


Figure 8. step response of RPM for four different wind conditions

In this simulation,we use T-MOTOR MT2216 with APC 10*5E propeller.

- In different wind condition, if we do not change the model of the rotor, the change of c_T results in large position errors.
- If c_T decrease, the final RPM for hovering increases.

Future work:

- Simulate the behavior when we use the dynamic model of the rotor to adapt to a change in wind condition
- Testing adaptation on the real quadrotor