Drone failure management

This automaton is a model of a 6 propeller drone. The automaton simulates the behaviour of the drone when it tries to remain stable after some of its motors shutdown. Thus, each location corresponds to a failure scenario and the associated flow comprises the equation of the system's dynamic. The model and equation have been taken from . The drone is located by the position and orientation of its center of mass. To describe the system's dynamic, both position and velocities have to be known. The state of the system is described in the vector :

$$S = (x\ y\ z\ \phi\ \theta\ \psi\ u\ v\ w\ p\ q\ s)^T$$

Where (ϕ, θ, ψ) are the Euler angle, (u, v, w) the acceleration and (p, q, r) the angular acceleration. In addition, the variables of the system are the rotation speed of each propeller Ω_i. In , the speed of each controller is supposed to be positive, therefore the change of variable $\Omega_i = \Omega_{r,i}^2$ has been made. In the following, the set of variables will be :

$$V = (\Omega_{r,1}, \Omega_{r,2}, \Omega_{r,3}, \Omega_{r,i4}, \Omega_{r,5}, \Omega_{r,6})^T$$

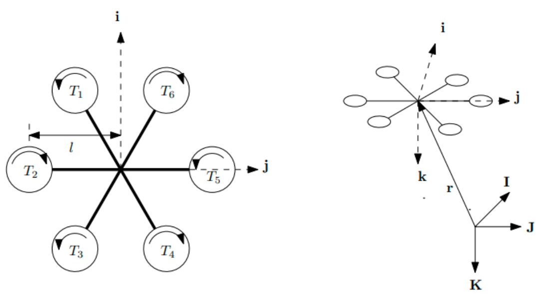

Figure 1: Geometry of studied system

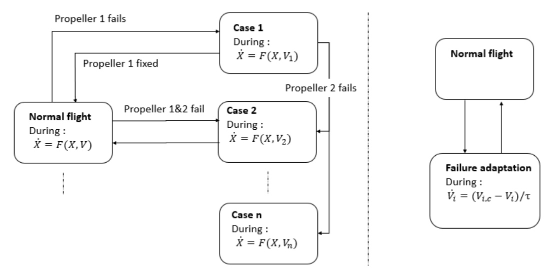

Figure 2: simplified view of the automaton

Hypothesis. The forces exerted on the system are the thrust, the rotor drag, the air resistance and the weight. The moments exerted on the system are the torques due to rotational rate difference between rotors, gyroscopic effect and yaw counter torque. We will use the same notation as in the original paper : J_r is the inertia of one propeller, l is the distance between a propeller and the center of mass, d is the drag factor, b is the thrust factor, K_T and K_D are constants

The system of equations satisfied by velocities and acceleration can be derived from the fundamental principle of dynamic as follow.

$$\left\{ \begin{array}{c} \dot{x} = \cos\theta\cos\psi u + (\cos\psi\sin\phi\sin\theta - \cos\psi\cos\phi)v + (\sin\phi\sin\psi + \cos\phi\cos\psi\sin\theta)w \\ \dot{y} = \cos\theta\sin\psi u + (\cos\phi\cos\psi + \sin\phi\sin\theta\sin\psi)v + (\cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi)w \\ \dot{z} = -\sin\theta u + \cos\theta\sin\phi v + \cos\theta\cos\phi w \\ \dot{\phi} = p + \sin\phi\tan\theta q + \cos\phi\tan\theta r \\ \dot{\theta} = \cos\phi q - \sin\phi r \\ \dot{\psi} = \frac{\sin\phi}{\cos\theta} q + \frac{\cos\phi}{\cos\theta} r \end{array} \right. \tag{1}$$

$$\left\{ \begin{array}{c} \dot{u} = vr - qw - g\sin\theta - \frac{K_T + K_D V}{m} u \\ \dot{v} = pw - ru + g\sin\phi\cos\theta - \frac{K_T + K_D V}{m} v \\ \dot{w} = qu - pv + g\cos\phi\cos\theta - \frac{T_t}{m} - \frac{K_D V}{m} w \\ \dot{p} = \frac{I_{yy} - I_{zz}}{I_{xx}} qr + \frac{M_\phi - J_r q \Omega_R}{I_{xx}} \\ \dot{q} = \frac{I_{zz} - I_{xx}}{I_{yy}} pr + \frac{M_\theta + J_r p \Omega_R}{I_{yy}} \\ \dot{r} = \frac{I_{xx} - I_{yy}}{I_{zz}} pq + \frac{M_\psi - J_r \dot{\Omega}_R}{I_{zz}} \end{array} \right. \tag{2}$$

Where

$$
\begin{aligned}
V &= \sqrt{u^2 + v^2 + w^2} \\
T_t &= b \sum_{i=1}^{6} \Omega_{r,i}^4 \\
M_\phi &= \frac{bl}{2}(2\Omega_{r,2}^4 - 2\Omega_{r,5}^4 + \Omega_{r,1}^4 + \Omega_{r,3}^4 - \Omega_{r,4}^4 - \Omega_{r,6}^4) \\
M_\theta &= \frac{\sqrt{3}bl}{2}(\Omega_{r,1}^4 + \Omega_{r,6}^4 - \Omega_{r,3}^4 - \Omega_{r,4}^4) \\
M_\psi &= d(\Omega_{r,1}^4 - \Omega_{r,2}^4 + \Omega_{r,3}^4 - \Omega_{r,4}^4 + \Omega_{r,5}^4 - \Omega_{r,6}^4) \\
\Omega_R &= \sum_{i=1}^{6}(-1)^i \Omega_{r,i}^2
\end{aligned}
$$

Automaton. The scenarios proposed in have been used to construct the localities. In each scenario, one or more propeller fails, which makes the system switch state by changing the velocity of its propeller in order to remain stable for as long as possible. It is important to note that no feedback loop is implemented, therefore the system unstable and sensitive to small variations.