

Multi-Agent System (MAS) Dynamics

State & Measurement

$$x_i(k+1) = Ax_i(k) + Bu_i(k) + Ew_i(k)$$

Battery State-of-Charge Dynamics

Energy drained by control & propulsion

$$\text{soc}_i(k+1) = \text{soc}_i(k) - \eta_{\text{ctrl}} \|u_i(k)\|_2^2 - \eta_{\text{prop}} \|p_i(k)\|_2^2$$

SOC-Dependent Interaction Weight

Attenuates effort as either agent's SOC drops

$$w_{ij}(k) = \exp\left(-\alpha \left\{ \frac{1}{\text{soc}_i(k)} + \frac{1}{\text{soc}_j(k)} \right\}\right)$$

LMI-based Observer & Controller Synthesis

H_∞ observer gain, polytopic LMI controller gain

$$u_i(k) = K \sum_{j \in \mathcal{N}_i} w_{ij}(k) \{\hat{x}_i(k) - \hat{x}_j(k)\}$$

Control Input bound

$$\|u_i(k)\|_2^2 \leq u_{\max}^2$$

C-rate Bound

$$C_{\text{rate},i}(k) = \eta_{\text{ctrl}} \|u_i(k)\|_2^2 \leq C_{\text{rate},\max}$$

Safe Operation Horizon

$$\text{soc}_i(k) \geq \text{soc}_{\min}, \forall k \leq T_{\text{safe}}$$

Safe & Energy-Efficient MAS Consensus

Certified end-to-end via LMI-based synthesis; T_{safe} computed a posteriori from the Lyapunov matrix