APPENDIX

A. Quadcopter Equations of Motion (EoM)

In this study, we use a linearized dynamic model of quadcopter multi-rotors in simulations in which the dynamics of different Euler angles are decoupled and the body and propeller gyroscopic effects are neglected [**?**], as represented in (A.1). It is good to mention that this dynamic model is only effective and reliable around the hovering point of the multi-rotor MAV where the rolling (ϕ) and pitching (θ) angles are relatively small.

$$\bar{x} := \begin{bmatrix} \phi \\ \theta \\ \psi \\ Z \\ X \\ Y \\ \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \\ \dot{Z} \\ \dot{X} \\ \dot{Y} \end{bmatrix} \rightarrow \dot{\bar{x}} = \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \\ \dot{Z} \\ \dot{X} \\ \dot{Y} \\ \frac{l}{I_{xx}}(U_2 + \mathrm{T_X}) \\ \frac{l}{I_{yy}}(U_3 + \mathrm{T_Y}) \\ \frac{1}{I_{zz}}(U_4 + \mathrm{T_Z}) \\ g - \frac{u_z}{m}U_1 + \frac{1}{m}\Lambda_Z \\ \frac{u_x}{m}U_1 + \frac{1}{m}\Lambda_X \\ \frac{u_y}{m}U_1 + \frac{1}{m}\Lambda_Y \end{bmatrix} \qquad (A.1)$$

where T_X, T_Y, T_Z, and Λ_X, Λ_Y, Λ_Z are the elements of the $\bar{\mathrm{T}}$ and $\bar{\Lambda}$ vectors in (12), (13). The definitions of the other parameters are mentioned in the table below.

TABLE II

PARAMETER DEFINITIONS OF QUADCOPTER MULTI-ROTOR DYNAMIC MODEL USED IN SIMULATIONS

Par.	Definition	[Unit]
I_{xx}	drone moment of inertia about x-axis	$kg.m^2$
I_{yy}	drone moment of inertia about y-axis	$kg.m^2$
I_{xx}	drone moment of inertia about z-axis	$kg.m^2$
l	drone rolling/pitching arm length	m
m	drone total mass	kg
g	gravity $= 9.81$	m/s^2
u_z	$= cos(\phi)cos(\theta)$	[]
u_x	$= cos(\phi)sin(\theta)cos(\psi) + sin(\phi)sin(\psi)$	[]
u_y	$= cos(\phi)sin(\theta)sin(\psi) - sin(\phi)cos(\psi)$	[]
U_1	drone resultant input thrust along body z-axis $U_1 = C_L(\mathbb{T}_1 + \mathbb{T}_2 + \mathbb{T}_3 + \mathbb{T}_4)$	N
U_2	drone resultant input torque about the body x-axis $U_2 = lC_L(\mathbb{T}_1 - \mathbb{T}_2 - \mathbb{T}_3 + \mathbb{T}_4)$	$N.m$
U_3	drone resultant input torque about the body y-axis $U_3 = lC_L(\mathbb{T}_1 + \mathbb{T}_2 - \mathbb{T}_3 - \mathbb{T}_4)$	$N.m$
U_4	drone resultant input torque about the body z-axis $U_4 = lC_D(\mathbb{T}_1 - \mathbb{T}_2 + \mathbb{T}_3 - \mathbb{T}_4)$	$N.m$

*$\mathbb{T}_i$: thrust force of the i-th propeller N

**C_L : propeller Lift coefficient

***C_D : propeller Drag coefficient

One can realize that the matrices A, B, D, and the vector $\bar{a}$ (from (3)) representing the autonomous dynamics of the system can readily be obtained from (A.1).