Supplementary:

Proof of Theorem 1: For the estimated error subsystem (11), we choose the Lyapunov function

$$V_e = e^T P^{-1} e, \tag{17}$$

where $P = (p_{ij})(t)$ is a solution of the Riccati equation (10), then its derivative along the solution of (11) satisfies

$$\begin{aligned} \dot{V}_e &= \dot{e}^T P^{-1} e + e^T P^{-1} \dot{e} + e^T \dot{P}^{-1} e \\ &\leqslant -\frac{1}{2} e^T P^{-2} e + z_1^2 + 4h^2(t). \end{aligned} \tag{18}$$

Substituting $\alpha_1 = -Kp_1^* p_2^* z_1$ in to (12), the z_1 dynamics can rewritten as

$$\dot{z}_1 = \left(-\frac{\dot{u}_0}{u_0} - Kp_1^* p_2^*\right) z_1 + e_2 + \sigma_1. \tag{19}$$

Selected a Lyapunov function candidate

$$V_1 = V_e + \frac{1}{2} z_1^2. \tag{20}$$

The derivative along the solution of (20) satisfies the following inequality

$$\begin{aligned} \dot{V}_1 \leqslant & -\frac{1}{2} e^T P^{-2} e + z_1^2 + \left(-\frac{\dot{u}_0}{u_0} - Kp_1^* p_2^*\right) z_1^2 \\ & + z_1 e_2 + z_1 \sigma_1 + 4h^2(t) \\ \leqslant & \left(-\frac{1}{2} + \epsilon_1\right) e^T P^{-2} e + \sigma_1^2 + 4h^2(t) \\ & + \left(-\frac{\dot{u}_0}{u_0} - Kp_1^* p_2^* + 1 + \epsilon_2\right) z_1^2, \end{aligned} \tag{21}$$

where ϵ_1 is a sufficiently small positive constant, while ϵ_2 is a suitable positive constant satisfying $z_1 e_2 + z_1 \sigma_1 \leqslant \epsilon_1 e^T P^{-2} e + \epsilon_2 z_1^2 + \sigma_1^2$. According to the second equation of the extended Kalman observer, i.e., equation (13), we have

$$\begin{aligned} \dot{\sigma}_1 &= \dot{\widehat{z}}_2 - \dot{\alpha}_1 \\ &= d_1(t) \widehat{z}_3 - p_{21}(t) \widehat{z}_2 + Kp_1^* p_2^* \dot{z}_1 + u \\ &= d_1(t) \widehat{z}_3 - p_{21}(t) \widehat{z}_2 - Kp_1^* p_2^* \frac{\dot{u}_0}{u_0} z_1 \\ &\quad -(Kp_1^* p_2^*)^2 z_1 + Kp_1^* p_2^* (e_2 + \sigma_1) + u. \end{aligned} \tag{22}$$

Therefore, the control law

$$\begin{aligned} u = & -d_1(t) \widehat{z}_3 + p_{21}(t) \widehat{z}_2 + Kp_1^* p_2^* \frac{\dot{u}_0}{u_0} z_1 \\ & - L_1 sgn(\sigma_1) K |p_1^* p_2^* z_1| - L_2 \sigma_1, \end{aligned} \tag{23}$$

with choice of the parameters as

$$\begin{aligned} & L_1 > Kp_1^* p_2^*, \quad Kp_1^* p_2^* e_2 \sigma_1 \leqslant \epsilon_3 e^T P^{-2} e + \epsilon_4 \sigma_1^2 \\ & L_2 > Kp_1^* p_2^* + \epsilon_4 + 2, \end{aligned} \tag{24}$$

for a sufficiently small ϵ_3 and a proper large ϵ_4, renders

$$\sigma_1 \dot{\sigma}_1 \leqslant \epsilon_3 e^T P^{-2} e - 2\sigma_1^2. \tag{25}$$

Consider the Lyapunov function candidate

$$V_2 = V_e + \frac{1}{2} z_1^2 + \frac{1}{2} \sigma_1^2. \tag{26}$$

From (22) and (26), we obtain the time derivative of V_2 satisfies

$$\begin{aligned} \dot{V}_2 \leqslant & \left(-\frac{1}{2} + \epsilon_1 + \epsilon_3\right) e^T P^{-2} e - \sigma_1^2 + 4h^2(t) \\ & + \left(-\frac{\dot{u}_0}{u_0} - Kp_1^* p_2^* + 1 + \epsilon_2\right) z_1^2. \end{aligned} \tag{27}$$

Since the adjustable parameters K, L_1, L_2 and ϵ_i, $i = 1, 2, 3, 4$, can be set as required, while $\dot{u}_0 / u_0$ is bounded, therefore, if

$$-\frac{\dot{u}_0}{u_0} - Kp_1^* p_2^* + 1 + \epsilon_2 < 0, \quad -\frac{1}{2} + \epsilon_1 + \epsilon_3 < 0,$$

is guaranteed, then the inequality (27) yields

$$\dot{V}_2 \leqslant -\beta V_2 + 4h^2(t), \quad \beta > 0. \tag{28}$$

Noting that $h(t) \in l_2$, it can be proved that V_2 converges to zero asymptotically, which implies that the signals e, z_1 and σ_1 verge to zero as time tends to infinity. By the definitions of $e_i = z_i - \widehat{z}_i$ $(i = 1, 2, 3)$, $\sigma_1 = \widehat{z}_2 - \alpha_1$ and the fact that $\alpha_1 = -Kp_1^* p_2^* z_1$, it is derived that $\widehat{z}_2$ and z_2 go to zero. Moreover, noting that $\dot{z}_3 = h(t)$ and $h(t) \in l_2$, it concluded that z_3 as well as $\widehat{z}_3$ is bounded. Therefore, the control law given in (23) is bounded, and moreover, as time tends to infinity, $u + d_1 \widehat{z}_3$ tends to zero. As a result, from the inverse transformations of coordinate/state, we can obtain that x_1, x_2 converge to zero. This together with the design of (2) indicates that (x_l, y_l, θ_l) converges to the equilibrium $(0, 0, -\varepsilon)$.