Algorithm 1: Kernel Disturbance Observer algorithm using dynamic regression for parameter estimation

Input: $\mathbf{p_M} = [p_M(t_k-\delta) : p_M(t_k-\delta)]$, $\Theta_M[\Theta_M(t_k-\delta) : \Theta_M(t_k)]$

Output: $\hat{d_p}(t_k)$, $\hat{d_\Theta}(t_k)$

1 Set $\mathbf{w}_1^0 = [1,1,1,1]$, $k=1$

2 Obtain Full State Estimate

for $\zeta \in [x, y, z, \phi, \theta, \psi]$ **do**

3 **Parameter Estimate for Local Surrogate Model:** Compute $\mathbf{w}_{\zeta_k}$

$$\hat{\mathbf{w}}_{\zeta_k} = \underset{\mathbf{w}_{\zeta_k}}{\operatorname{argmin}}\left\{\gamma||\mathbf{w}_{\zeta_k} - \hat{\mathbf{w}}_{\zeta_{k-1}}||_2^2 + \lambda||\mathbf{w}_{\zeta_k}||_2^2 + ||\zeta_M - \zeta_{est}||_2^2\right\}$$

4 **State Estimation:** Compute state estimate $\hat{\zeta}(t_k)$

$$\hat{\zeta}(t_k) = \frac{1}{((t_k)-(t_k-\delta))^4}\int_{t_k-\delta}^{t_k} K_{DS}(t_k,\tau)\zeta_M(\tau)\mathrm{d}\tau$$

5 **Higher Order Derivatives:** Compute the higher order derivatives $\dot{\hat{\zeta}}(t_k)$ and $\ddot{\hat{\zeta}}(t_k)$ using (**??**)-(**??**) in Section **??** of Appendix.

6 **end**

7 Compute External Disturbances $\hat{d_p}(t_k) = [d_x, d_y, d_z]$ and $\hat{d_\Theta}(t_k) = [d_\phi, d_\theta, d_\psi]$:

$$\hat{d_\phi} = \ddot{\hat{\phi}} - (r_1\dot{\hat{\theta}}\dot{\hat{\psi}} - r_2\dot{\hat{\theta}}w + q_1U_2); \quad \hat{d_x} = \ddot{\hat{x}} - \left((C_{\hat{\phi}}S_{\hat{\theta}}C_{\hat{\psi}} + S_{\hat{\phi}}S_{\hat{\psi}})\frac{1}{m}U_1\right)$$

$$\hat{d_\theta} = \ddot{\hat{\theta}} - (r_3\dot{\hat{\phi}}\dot{\hat{\psi}} + r_4\dot{\hat{\phi}}w + q_2U_3); \quad \hat{d_y} = \ddot{\hat{y}} - \left((C_{\hat{\phi}}S_{\hat{\theta}}S_{\hat{\psi}} - S_{\hat{\phi}}C_{\hat{\psi}})\frac{1}{m}U_1\right)$$

$$\hat{d_\psi} = \ddot{\hat{\psi}} - (r_5\dot{\hat{\theta}}\dot{\hat{\phi}} + q_3U_4); \quad \hat{d_z} = \ddot{\hat{z}} - \left(-g + (C_{\hat{\phi}}C_{\hat{\theta}})\frac{1}{m}U_1\right)$$

8 Set $k \leftarrow k+1$ and go to Step 2.