



Nonlinear Model Predictive Controller (NMPC) For Surveillance Quadrotor

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Problem Statement

- The objective of project is to capture enemy UAV in a given bounded airspace using quadrotor
- The quadrotor is not allowed to leave the airspace. If the UAV escapes the airspace, then the quadrotor must return back to the nest
- The UAV trajectory is unknown but we can obtain it's current location

Methodology

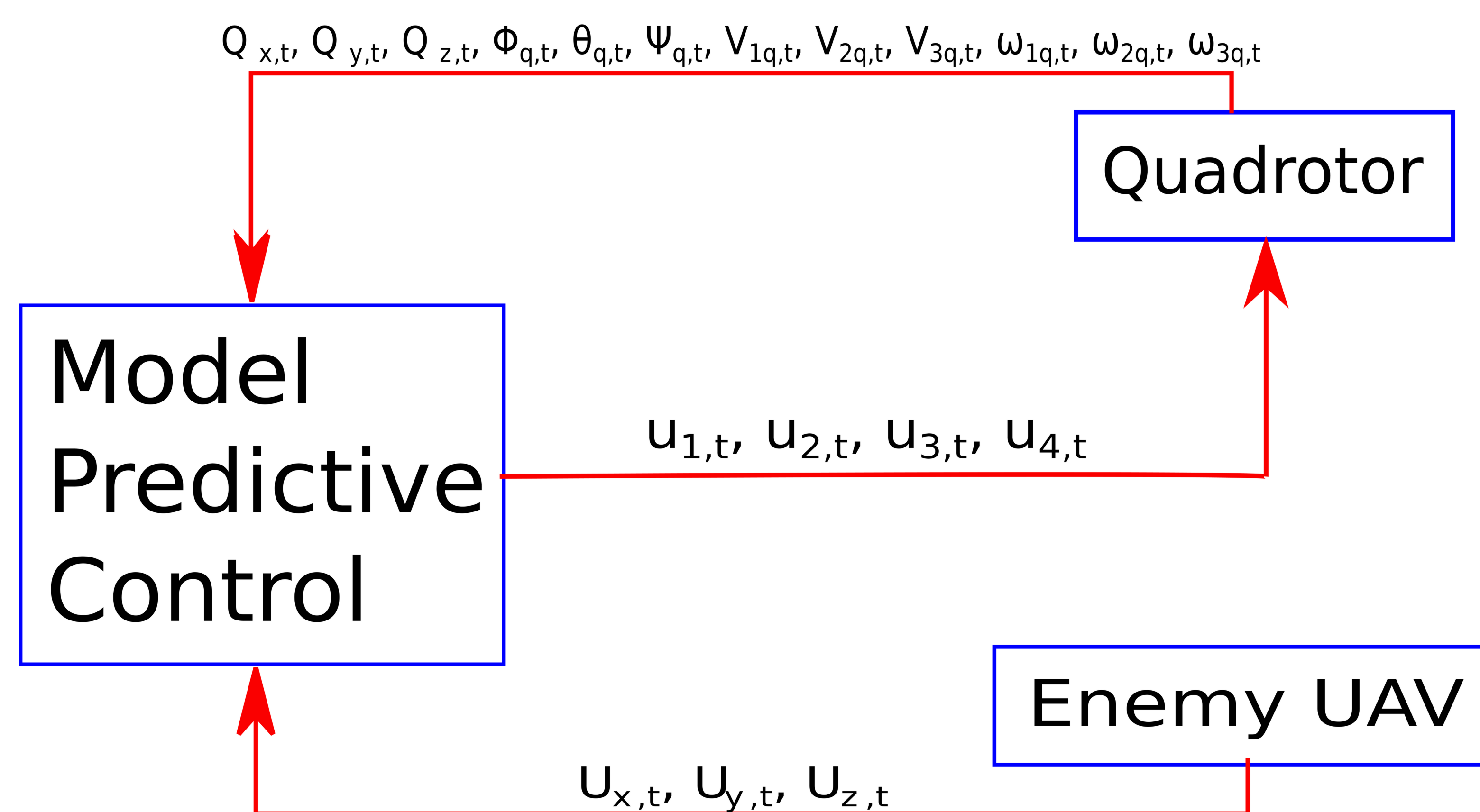


Figure 1: Block Diagram Containing Proposed NMPC Scheme

Proposed Controller

- Nonlinear Model Predictive Controller (NMPC) uses a mathematical model of the system to compute the optimal control actions over a finite prediction horizon (N) by solving a constrained optimization problem (COP)

Cost Function:

$$\min_{U_t} J(X_t, U_t) = \sum_{i=t}^{t+N} W_1 * G(X_{Q,i}, X_{U,i})$$

Subject to:

$$\begin{aligned} X_{Q,i+1} &= f(X_{Q,i}, U_{Q,i}), \\ X_{Q,i} &\in [X^-, X^+], \\ U_{Q,i} &\in [U^-, U^+] \end{aligned}$$

Where,

$$G(X_{Q,i}, X_{U,i}) = \sqrt{(Q_{x,i} - U_{x,i})^2 + (Q_{y,i} - U_{y,i})^2 + (Q_{z,i} - U_{z,i})^2}$$

Moreover, bounds on states and controls are as follows:

$$\begin{aligned} Q_x, Q_y &\in [-5m, +5m], \\ Q_z &\in [0m, +10m], \\ U_{Q,i} &\in [0N, 3N], i \in [1, 2, 3, 4] \end{aligned}$$

Simulation Setup

- We used given dynamic model of the quadrotor
- For the enemy UAV we used Fixed-Wing UAV with randomly generated angular yaw and pitch with constant linear velocity
- Enemy UAV can enter randomly from any possible plane of airspace

Simulation Parameters of the Quadrotor:

- Distance from center of mass to the each rotor (L) = 0.2 m
- Total mass of quadrotor (m) = 0.5kg
- Mass moment of inertia about global X, Y axis (I11, I22) = 1.24 kg.m²
- Mass moment of inertia about global Z axis (I33) = 2.48 kg.m²
- g (The gravitational acceleration) = 9.8m/s²
- ||r||₂ ≤ 2N and, ||n||₂ ≤ 1N added after catch of Enemy UAV

Simulation Parameters of Nonlinear Model Predictive Controller (NMPC):

- Discrete Time Step (T_s) = 0.2s
- Prediction Horizon (N) = 20 iterations = 20*0.2 s = 4 sec

Simulation Results

Catch Scene:

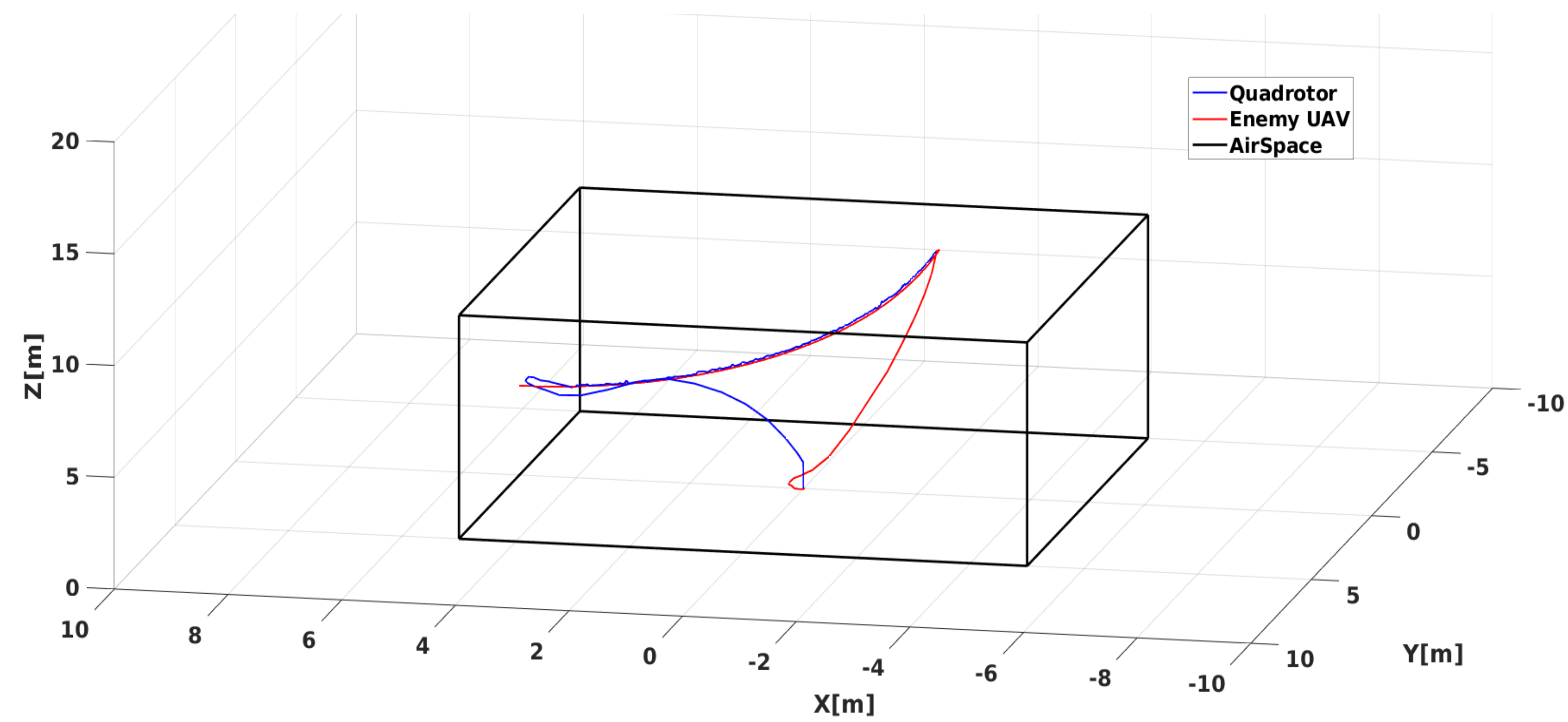


Figure 2: NMPC Performing Catch Scene

Escape Scene:

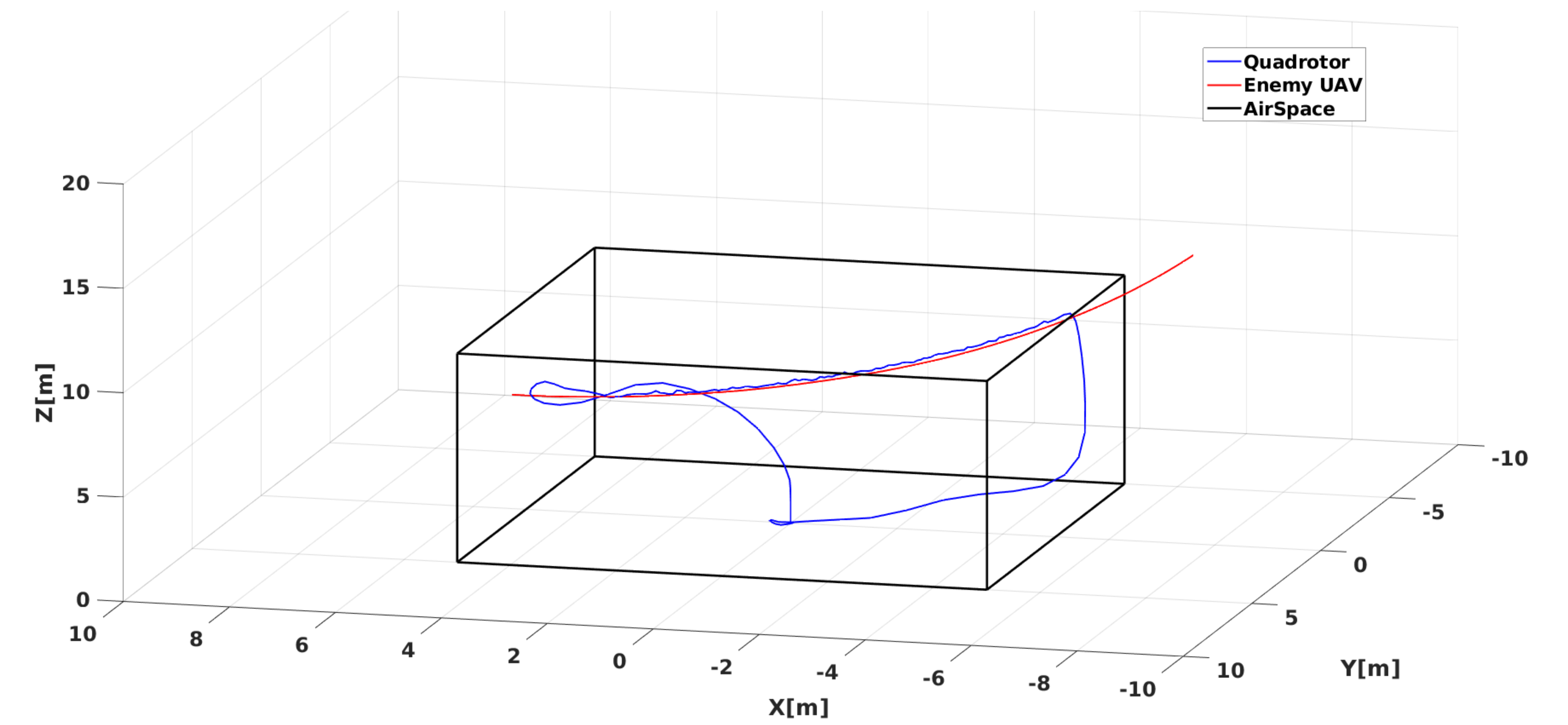


Figure 3: Enemy Escaped, Quadrotor Returning to Base

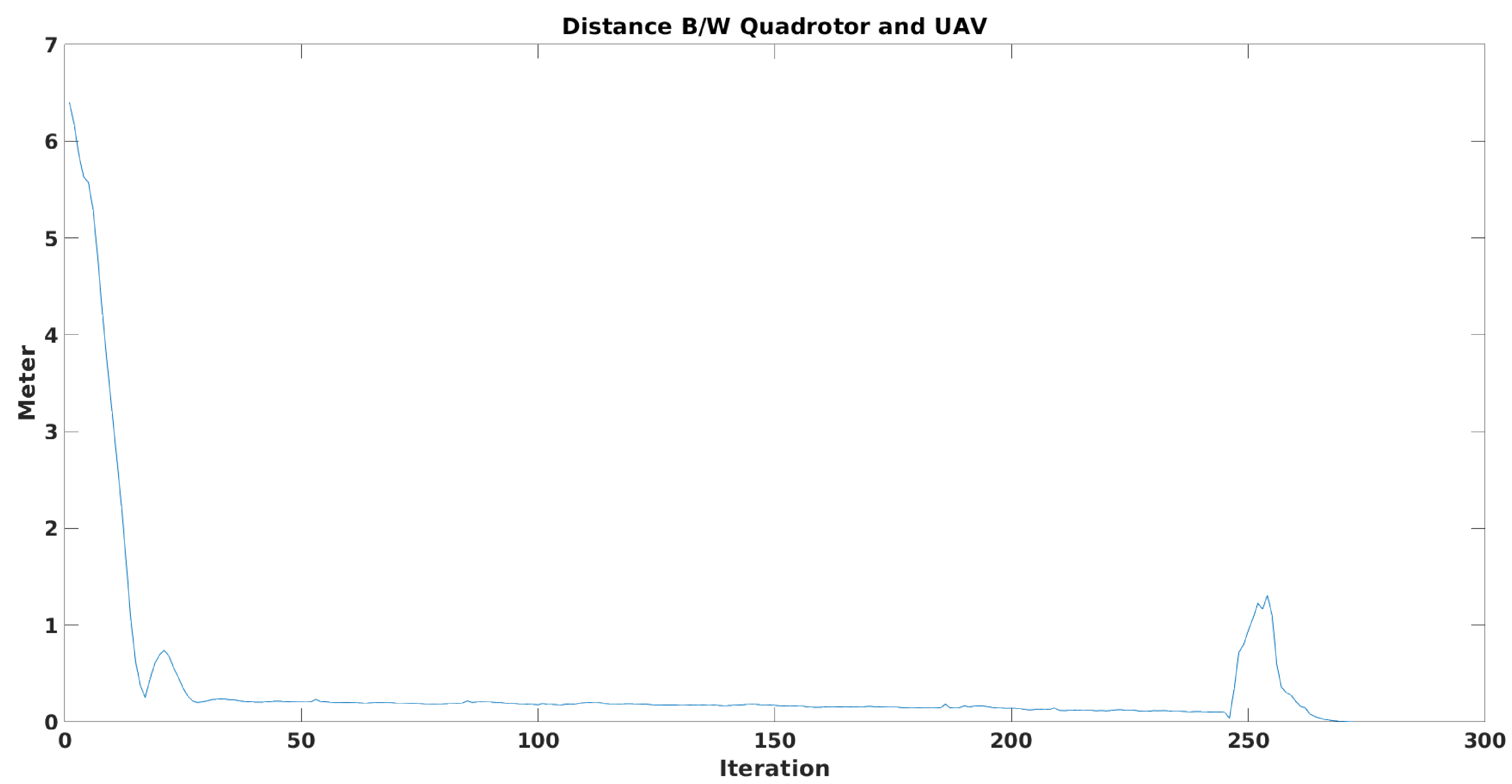


Figure 4: Distance B/W Quadrotor and Enemy UAV

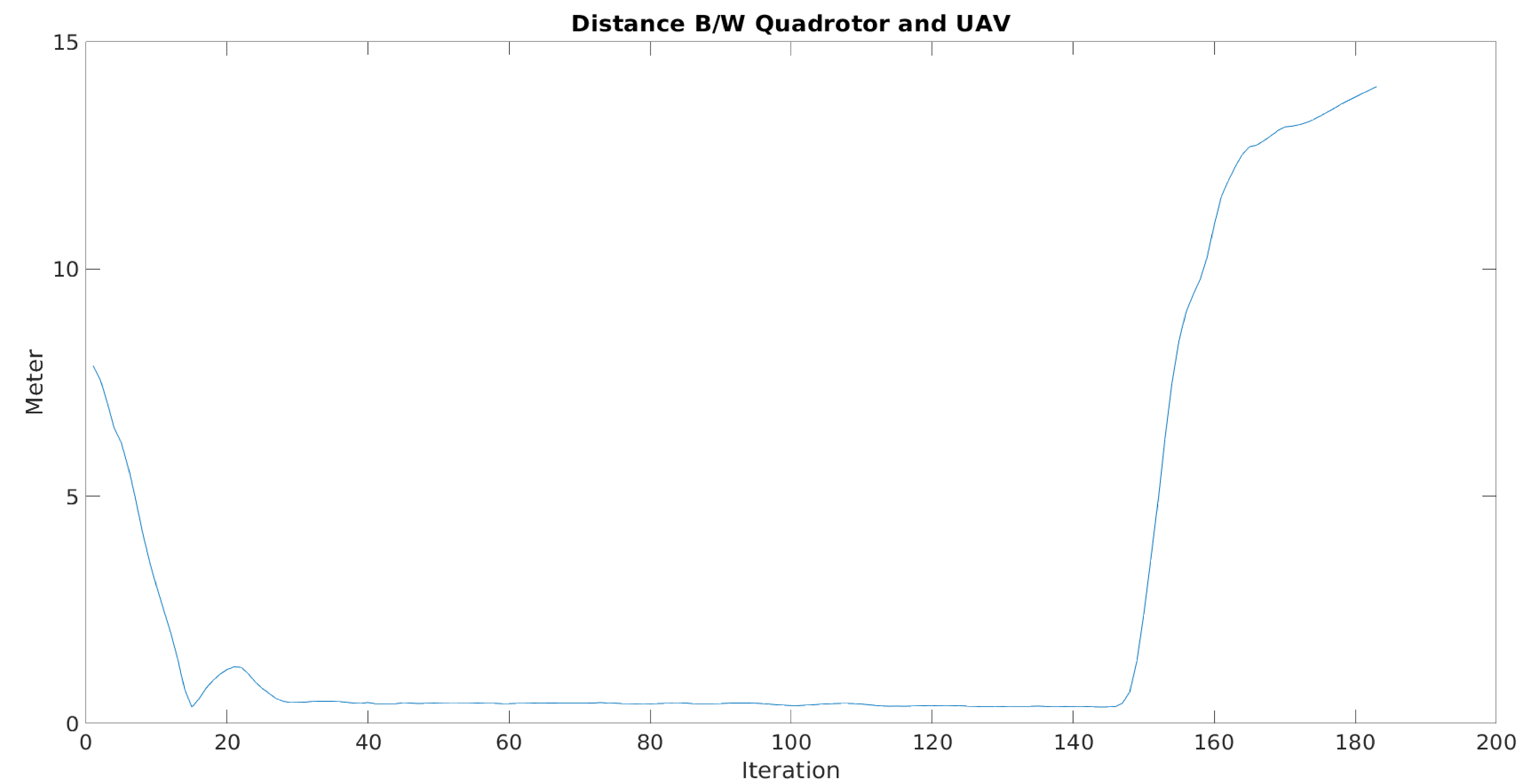


Figure 5: Distance B/W Quadrotor and Enemy UAV