Indian Institute of Technology Madras

Department of Aerospace Engineering

AS5570

Principles of Guidance of Autonomous Vehicles

Extension to 'All Aspect Approach to A Stationary Target'

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1 Motivation

In the 2pPPN guidance, the orientation phase can be attained with different trajectories. We computed the cost requirement as $\int a_p^2 dt$. The minimum lateral acceleration requirement gives the best trajectory. Also, we have analyzed the phase after the orientation phase for $N > 2$ values and concluded an optimum N for that phase.

2 Procedure

- The pursuer has to reach the target with finite bounded lateral acceleration.
- The pursuer takes the orientation phase to reach the $N = 2$ line in the $\alpha_P - \theta$ plane. Then, it follows the $N = 2$ line to reach the target.
- The initial conditions in our case are - $(\alpha_{P_0}, \theta_0) = (\pi/4, 0)$. The desired approach angle is -150°. The orientation gain is found by -

$$N = \frac{\alpha_P - \alpha_{P_0}}{\theta - \theta_0} \tag{1}$$

  We have considered the gains from (-2, 1) during this phase.

- The lateral acceleration is found as -

$$a_p = \frac{N V_p V_\theta}{R} \tag{2}$$

  Here $a_{p_{(ori)}}$ is when N=N_{ori} and $a_{p_{(end-phase)}}$ is when $N = 2$.

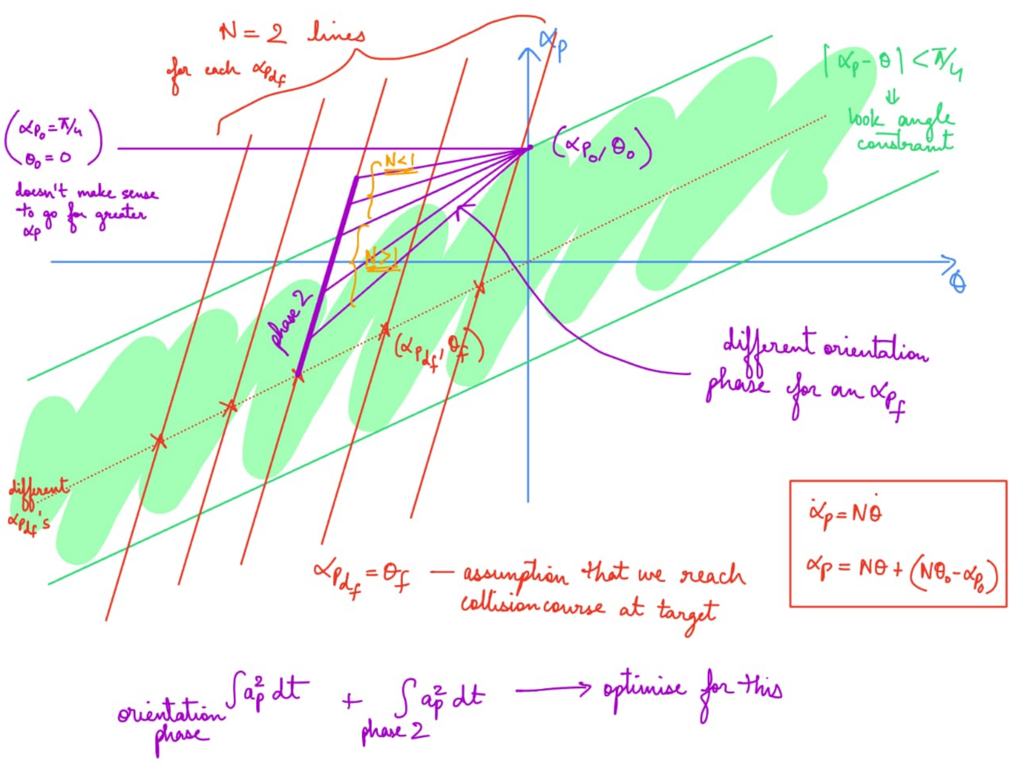
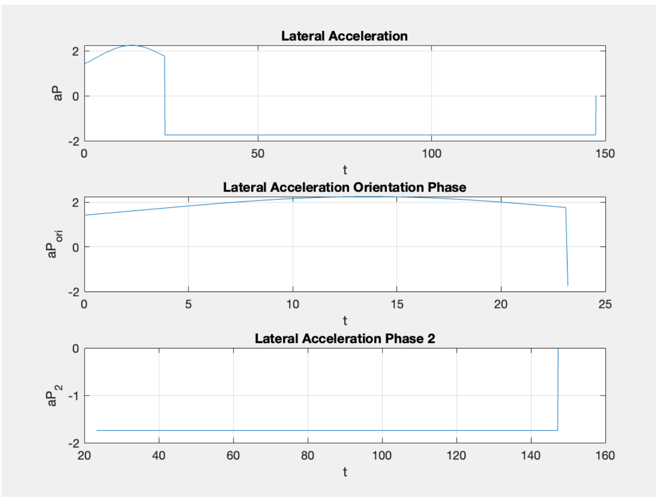


Figure 1: $\alpha_P - \theta$ plane

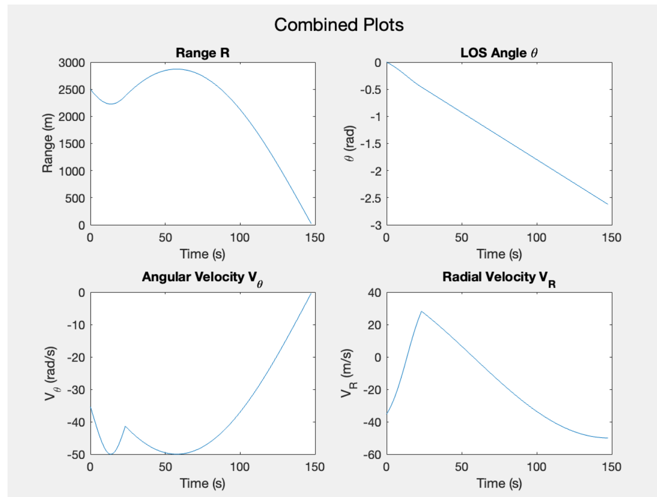
3 Interpretation

The initial conditions in our case are - $(\alpha_{P_0}, \theta_0) = (\pi/4, 0)$. The desired approach angle is -150°. The final phase gain or N_f is 2 for the plots shown.

3.1 Gain = -2



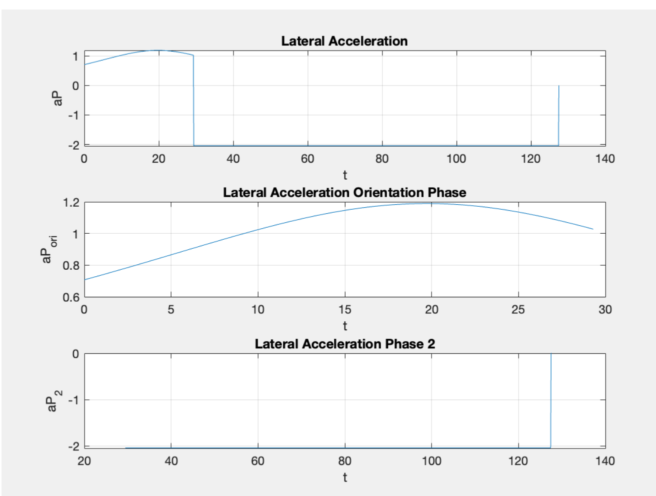
(a) Lateral acceleration



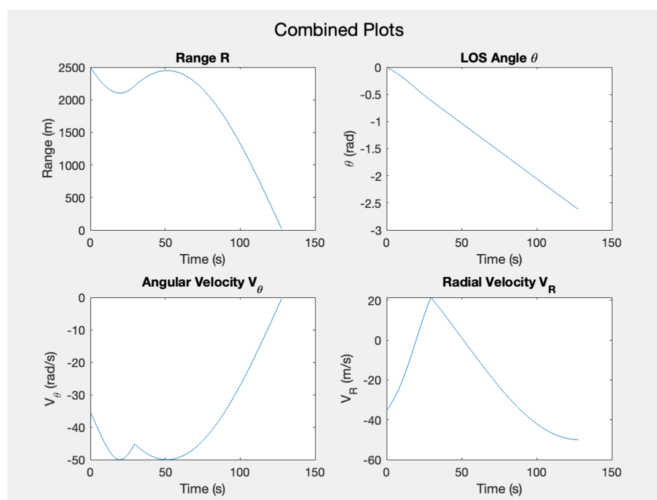
(b) Combined plots

Figure 2: Comparison of plots

3.2 Gain = -1



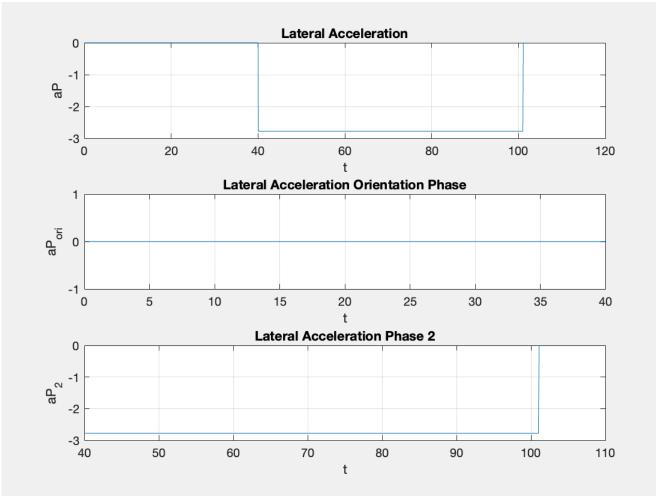
(a) Lateral acceleration



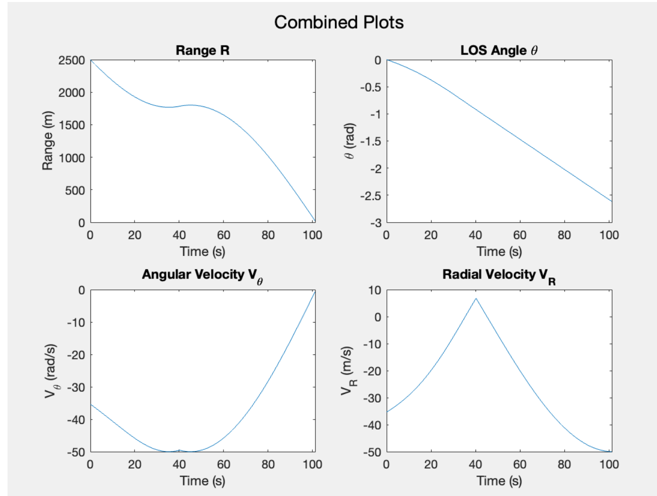
(b) Combined plots

Figure 3: Comparison of plots

3.3 Gain = 0



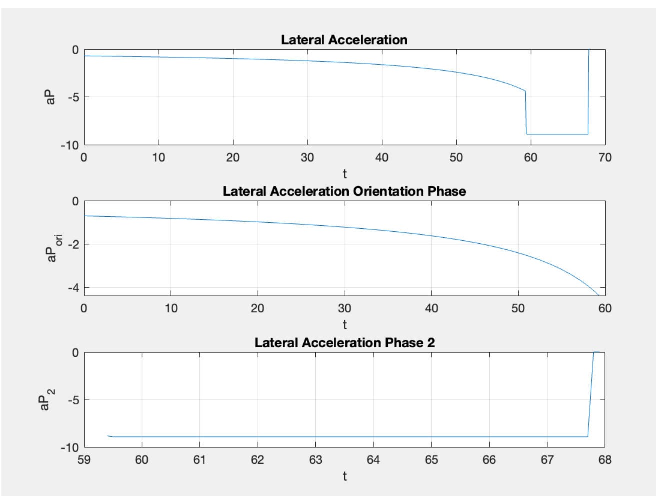
(a) Lateral acceleration



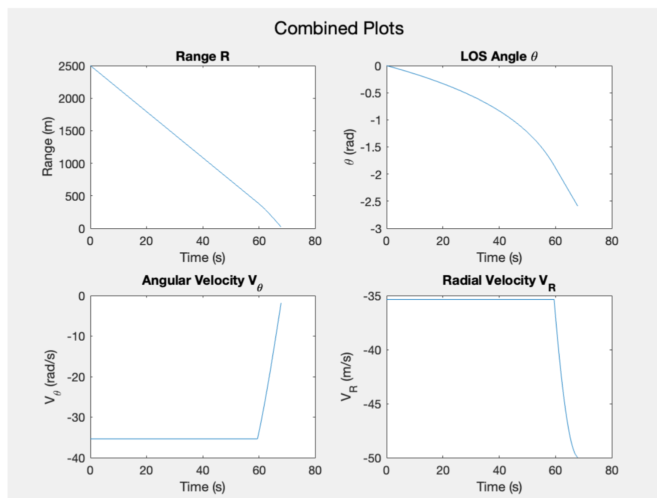
(b) Combined plots

Figure 4: Comparison of plots

3.4 Gain = 1



(a) Lateral acceleration



(b) Combined plots

Figure 5: Comparison of plots

3.5 Cost and Time to reach

We can observe from the plots that time to reach decreases with increase in N_{ori}. The cost variation and trajectories for different N_{ori} is also shown.

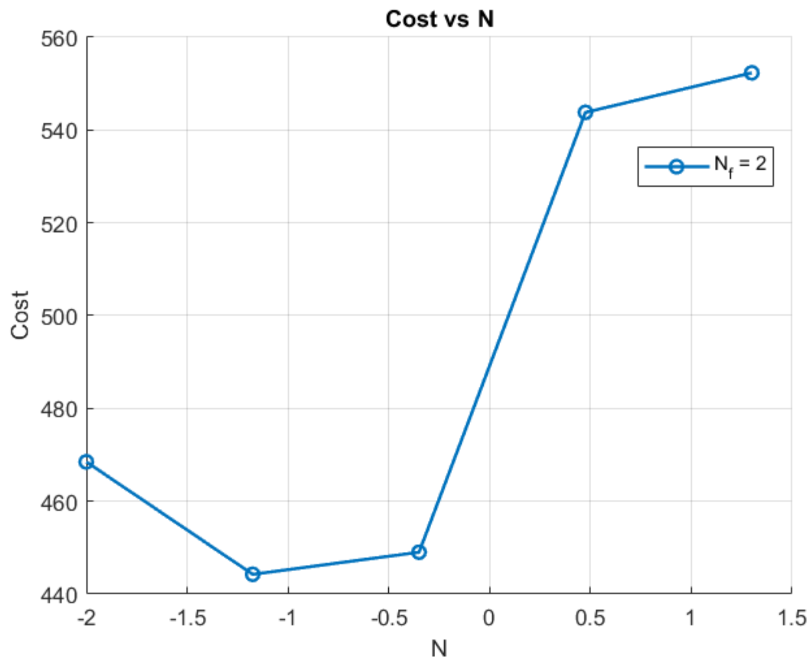


Figure 6: Cost v/s N_{ori}

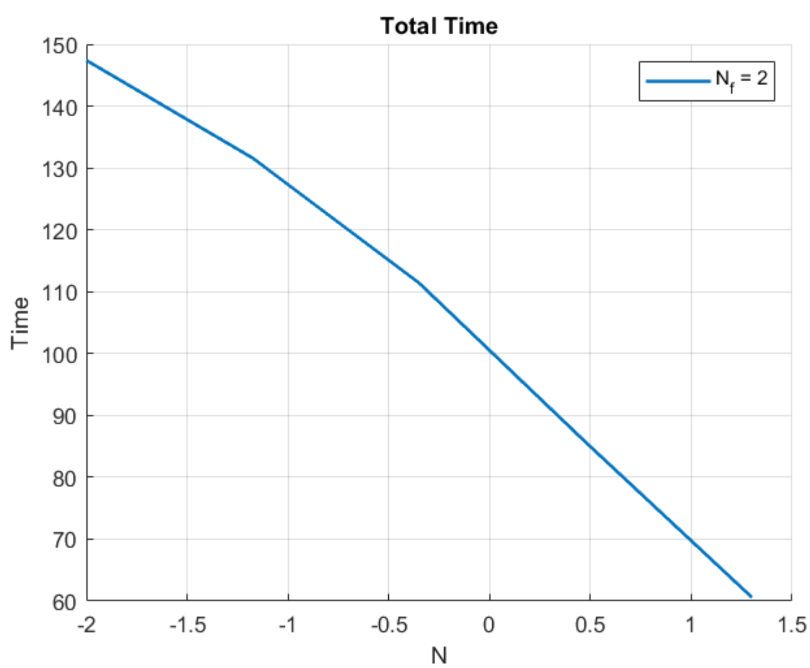


Figure 7: Time to reach v/s N_{ori}

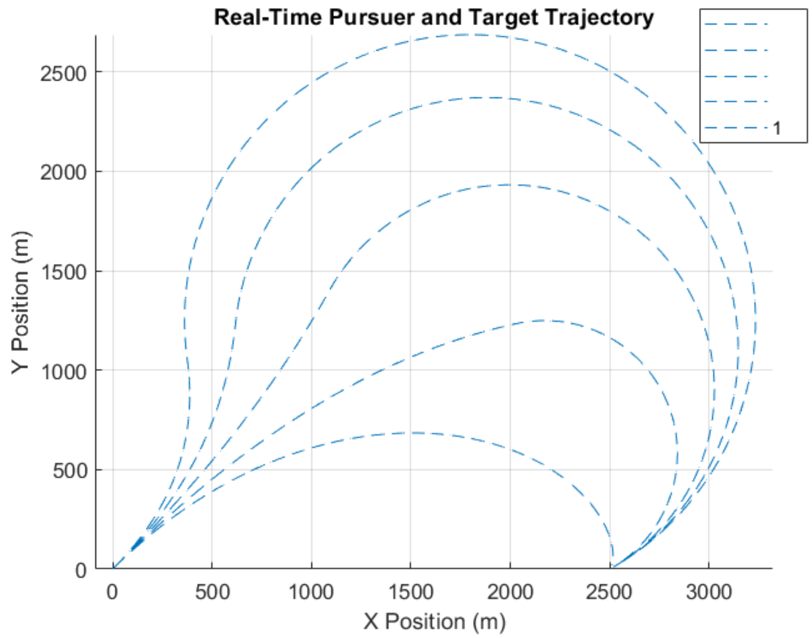


Figure 8: Trajectories

4 Optimising Cost

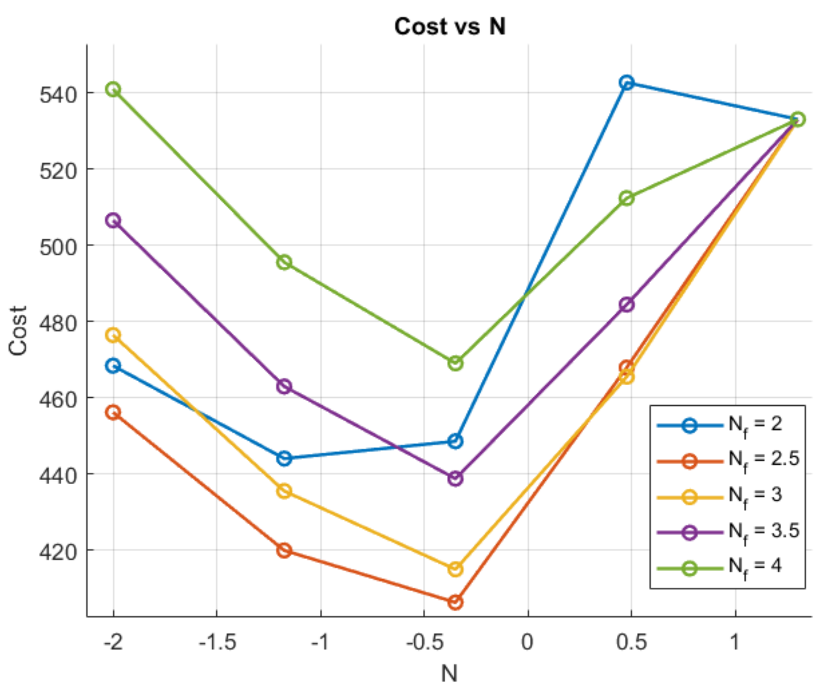


Figure 9: Cost Comparison

As we can see cost has an overall minima compared to the rest at $N_f = 2$, and then increases after. Hence, **optimum N_f is 2.5** and **optimum N_{ori} for it is -0.35** for $\alpha_{P_{d_f}} = -150°$

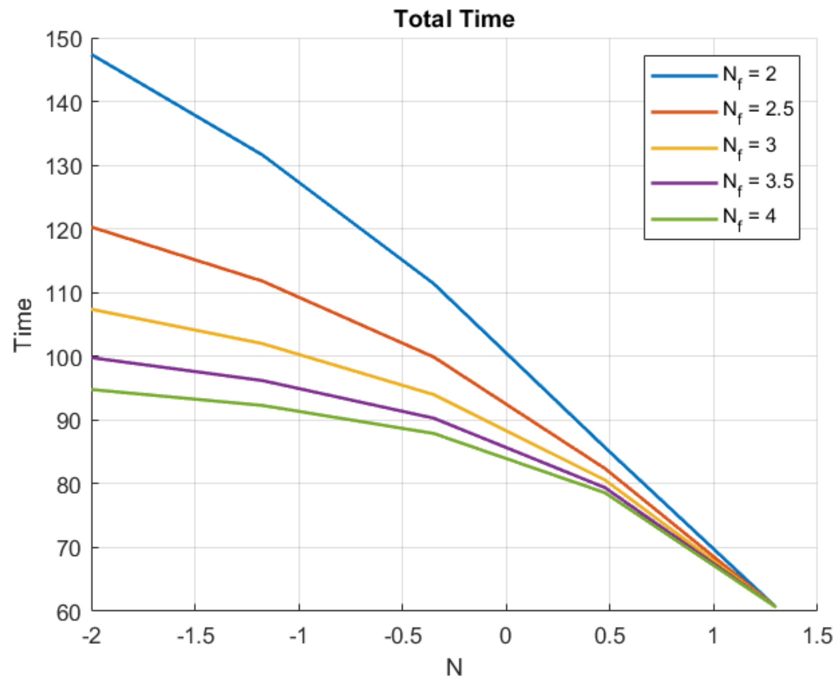


Figure 10: Time to Reach

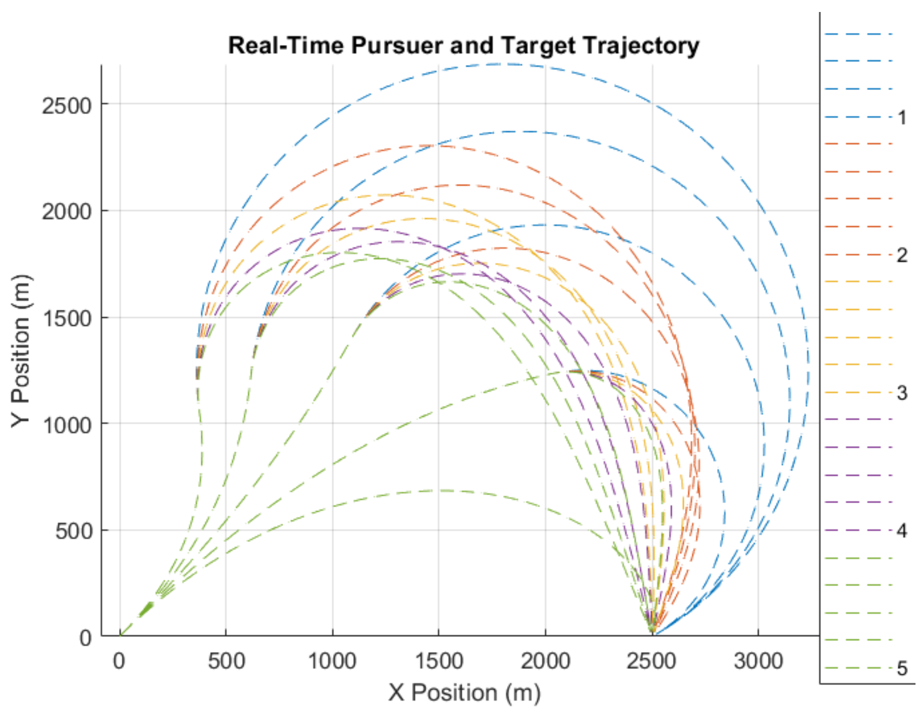
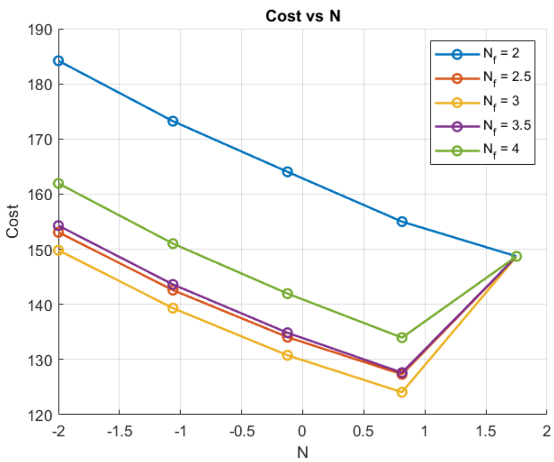
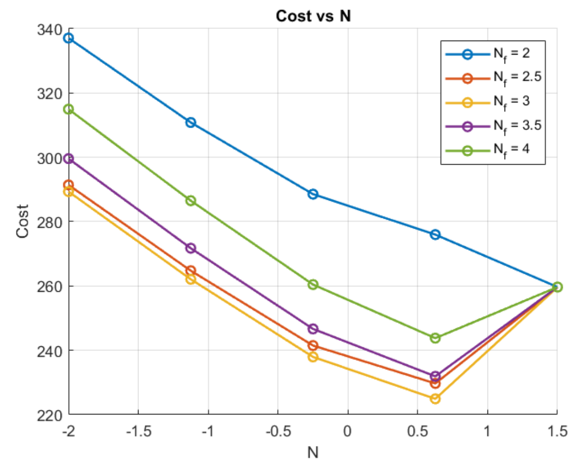


Figure 11: Trajectory Comparison

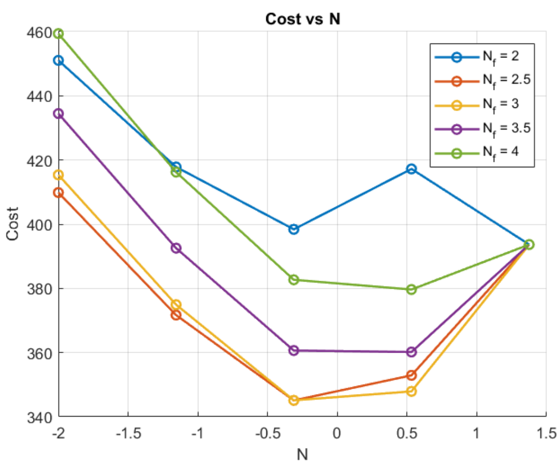
4.1 Variation of Cost with change in Desired Approach Angle



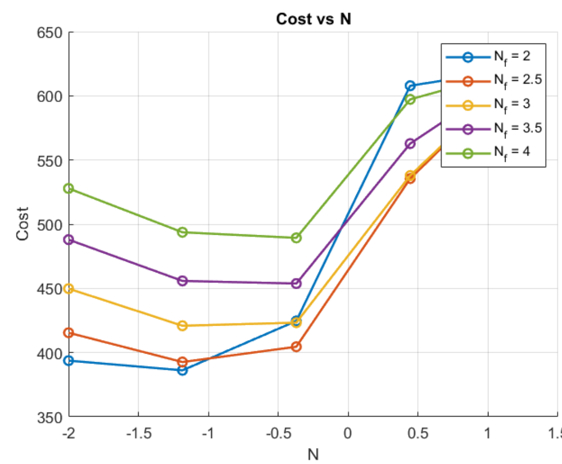
(a) $\alpha_{P_{d_f}}$ = -60°



(b) $\alpha_{P_{d_f}}$ = -90°



(c) $\alpha_{P_{d_f}}$ = -120°



(d) $\alpha_{P_{d_f}}$ = -175°

Figure 12: Comparison for different $\alpha_{P_{d_f}}$

We can clearly see a shift in the optima value with change in $\alpha_{P_{d_f}}$

5 Conclusion

- The minima of the cost function was observed at N_{ori} = **-0.35** for different N_f. Hence, it is the optimum orientation phase for our given conditions.
- As the N_{ori} increases from 0, the cost increases, and the time to reach the target decreases. Hence, it is a **tradeoff between lateral acceleration requirement and time to reach here**.
- Based on the Cost vs N plot, we can conclude that **optimum N_f is 2.5**. We could use a finer array of N values around optimum N_f to check for a better optimal final phase N.
- The range of angles which can be attained using PPN is [-45°, 0°), but we want to optimise a_P over both phases. So, we ran the simulations for different final approach angles like [-60°, -90°, -120°, -175°]. As we increase the angle from -45° to -180°, the optimal orientation gain decreases. Also, the optimum

gain for the final phase decreases ($3 -> 2.5 -> 2$). But for all approach angles, the time to reach decreases as N_{ori} increases.

- There is some anomalous behavior for $N_f = 2$, for a certain $\alpha_{P_{d_f}}$ it does not follow a similar trend compared to the other higher N values. We can associate this behaviour to it being the minimum bound for finite missile latax.