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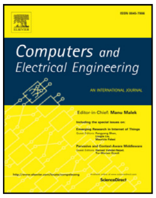

The design of particle swarm optimization guidance using a line-of-sight evaluation method ☆

Kuei-Yi Chen[a,*], Yung-Lung Lee[b], Sheng-Ju Liao[a], Chien-Chun Kung[c]

[a] *School of Defense Science, Chung Cheng Institute of Technology, National Defense University, Taoyuan County 33551, Taiwan, ROC*
[b] *Department of Power Vehicle and Systems Engineering, Chung Cheng Institute of Technology, National Defense University, Taoyuan County 33551, Taiwan, ROC*
[c] *Department of Mechatronic, Energy and Aerospace Engineering, Chung Cheng Institute of Technology, National Defense University, Taoyuan County 33551, Taiwan, ROC*

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ABSTRACT

In this paper, an improved particle swarm optimization guidance (IPSOG) is proposed. The particle swarm optimization guidance (PSOG) is presented to solve nonlinear and dynamic missile guidance problems. However, the miss distance (MD) tends to be large. The objective function of the relative distance in the PSOG leads the missile to the current position of a target. Therefore, the PSOG is similar to pursuit guidance. In the IPSOG, a new objective function for the PSOG is introduced to improve the guidance performance. The line-of-sight (LOS) rate is taken as the objective function. The fitness function is then evaluated according to the defined objective function. Numerical simulation results show that the guidance performance of the IPSOG is better than the PSOG.

1. Introduction

Missiles have already become a weapon of air superiority in air combat, and the core part that guides a missile to its target is the guidance law. Therefore, many guidance laws have been examined, including proportional navigation guidance (PNG) [1], augmented PNG (APNG) [2], and optimal guidance [3].

In recent years, artificial intelligence (AI) algorithms have been applied in many fields, and the study of intelligent guidance laws has become more popular. For example, Mishra et al. [4] designed two kinds of fuzzy-logic-based homing guidance schemes, and showed them to be better than PNG or APNG. Gonsalves et al. [5] developed a neural network guidance law based on the notion of a neighboring optimal adaptive critic. Younas et al. [6] proposed the near optimum navigation constant for PNG by using a modified genetic algorithm. The particle swarm optimization (PSO) algorithm is one kind of AI algorithm, and is utilized to optimize parameters or gains in intelligent guidance law, such as Sang et al. [7] and Fang et al. [8]. In 2013, Kung et al. [9] proposed the particle swarm optimization guidance (PSOG) to solve the missile guidance problem. The PSOG that utilized the PSO algorithm to search for the optimal lateral acceleration made its debut in the research of missile guidance. Although the PSOG technique had been verified, the follow-up studies found that the miss

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[*] Corresponding author. Tel.: +886 933685773.

E-mail addresses: KueiYi.Chen@gmail.com (K.-Y. Chen), dragon0913@yahoo.com.tw (Y.-L. Lee), luking0717@gmail.com (S.-J. Liao), cckung@ndu.edu.tw (C.-C. Kung).

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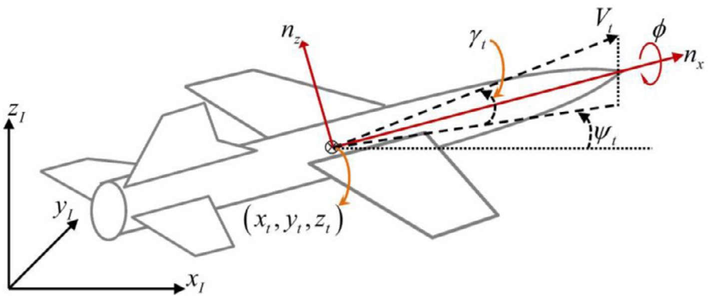

Fig. 1. Definition of a target's aerodynamic vectors.

distance (MD) tended to large. The relative distance was regarded as the objective function in the PSOG. Thus, the lateral acceleration might easily saturate at the final stage.

In this paper, we propose the improved PSO guidance (IPSOG) to improve the guidance performance. The IPSOG uses the line-of-sight (LOS) rate as the objective function. The fitness function is then evaluated according to the defined objective function. The seven elemental maneuvers [10] of evasion scenarios are utilized to verify the guidance performance.

This paper is organized as follows: Section 2 gives a review of mathematical models and the PSO algorithm; Section 3 describes the details of the IPSOG; Section 4 shows simulation results; finally Section 5 presents concluding remarks.

2. Mathematical models

2.1. Dynamic models

Point-mass models are used for a missile and a target. The equations are employed as follows:

2.1.1. Target dynamic

Fig. 1 shows the aerodynamic vectors of a target. The equations of a target dynamic [10] are as follows:

$$\dot{x}_t = V_t \cos\gamma_t \cos\psi_t \tag{1}$$

$$\dot{y}_t = V_t \cos\gamma_t \sin\psi_t \tag{2}$$

$$\dot{z}_t = V_t \sin\gamma_t \tag{3}$$

$$\dot{V}_t = g(n_x - \sin\gamma_t) \tag{4}$$

$$\dot{\gamma}_t = \frac{g}{V_t}(n_z \cos\phi - \cos\gamma_t) \tag{5}$$

$$\dot{\psi}_t = \frac{g n_z \sin\phi}{V_t \cos\gamma_t} \tag{6}$$

where x_t, y_t, z_t are x-, y-, z-coordinates, respectively; V_t is the velocity; γ_t is the flight path angle; ψ_t is the azimuth angle; g is the gravity acceleration; n_x, n_z, and ϕ are three control variables which can be transformed into the thrust force, pitch force, and rolling angle, respectively.

Due to the inertia factor, the dynamic delay model for three control variables (n_x, n_z, and ϕ) are as follows:

$$n_x = \frac{n_{xcom}}{1 + \tau_t s} \tag{7}$$

$$n_z = \frac{n_{zcom}}{1 + \tau_t s} \tag{8}$$

$$\phi = \frac{\omega_n^2}{s^2 + 2\omega_n \xi s + \omega_n^2} \times \phi_{com} \tag{9}$$

where n_{xcom}, n_{zcom}, and ϕ_{com} are the control commands; τ_t is a time constant; ω_n is a natural frequency; and ξ is a damping ratio.

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