UAV Evasive Maneuver Algorithm based on Moth Natural Behavior

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Abstract

This initial work proposes UAV evasive maneuver algorithm which inspired by natural moth movement. A quad-rotor UAV autonomously evades dynamic threat during mission flight which has been evaluated in real environment. In order to evaluate the proposed system, a threat rate which is risk percentage of UAV successfully attacked by enemy has taken as performance measure. The threat rate values are aimed when attacker is initially detected and after the moth evasive maneuver is performed. Based on the experiment result, the proposed system successfully reduce the threat rate by 31,62%.

I. Introduction

The evasive maneuver for autonomous UAV during mission flight (particularly in military environment) has gained a huge interest among researchers. The possibility for autonomous evasive maneuver has shown through those previous works. A protective maneuver against missile threat using proportional-navigation (PN) guidance law has been proposed by Yomchinda, et al. [1]. Furthermore, an approach of model predictive control for avoiding collision is presented by David, et al. [2]. The angle of attack and UAV speed information are assumed to be known for threat prediction in their proposed system. Kemal, et al. [3] introduces an evasive maneuver in battlefield scenario using autonomous control of unmanned combat air vehicles. However, an issue about real-time dynamic threat has not been addressed based on author's knowledge.

A bio-inspired firefly evasive maneuver algorithm which allocated for dynamic threat has been proposed in author's previous work [4]. Nevertheless, that evasive maneuver is predictable if the attackers are in reconnaissance mode which will become a serious issue.

As a solution for mentioned issue, this work presents an advanced evasive maneuver algorithm for UAV that inspired by natural behavior of moth. It solves the predictable maneuver issue. The proposed system is built and tested based on a real condition to validate its effectiveness.

II. System Configuration and Experimental Result

A. System Configuration

A reconnaissance attacker scenario has been considered in this proposed system. UAV evasive maneuver which inspired by moth movement is proposed to increase survivability of UAV. The essential attitude of moth when evading enemy is by flying in random direction [5]. This unique behavior able to deceive enemy with its unpredictable movement. In this situation, the enemy will be hard to approach the moth and survivability is increase. The unpredictable maneuver from moth is adopted into UAV. When the attacker is detected during mission flight and the percentage of threat risk is calculated, the moth evasive maneuver is automatically executed. The flowchart of proposed system can be seen in Figure 1.

Percentage of threat risk can be calculated by Eq. 1 and Eq. 2.

$$\delta_{ij} = (\delta_0 e^{\alpha d_{ij}^2}(p_j - p_i)) \times 100\% \quad (1)$$

$$d_{ij} = \|p_i - p_j\| \quad (2)$$

Percentage of threat risk at distance d_{ij} is denoted by δ_{ij}. Meanwhile, δ_0 denotes a threat risk at d_{ij} = 0. Position of the attacker and agent UAV are represented as p_j and p_i respectively. Moreover, distance between the attacker and agent is expressed by d_{ij}.

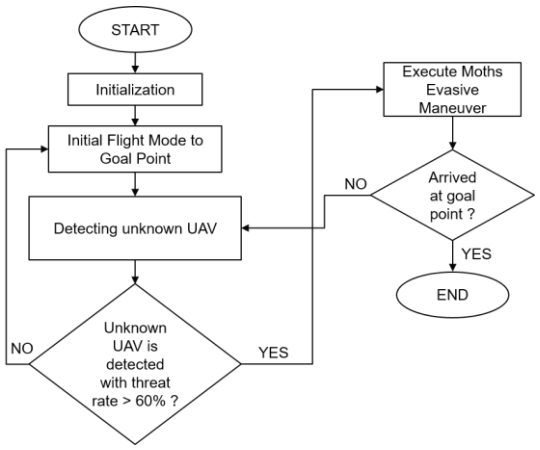

Figure 1. Moth evasive maneuver algorithm

B. Experimental Result

In order to show the effectiveness, the proposed algorithm is tested on physical quad-rotor UAV with real environment. The experiment is executed in outdoor using UAV agent and attacker UAV that represents real scenario as can be seen in Figure 2.

Figure 2. Flight test environment in free obstacle outdoor with Bebop 2.0 quad-rotor

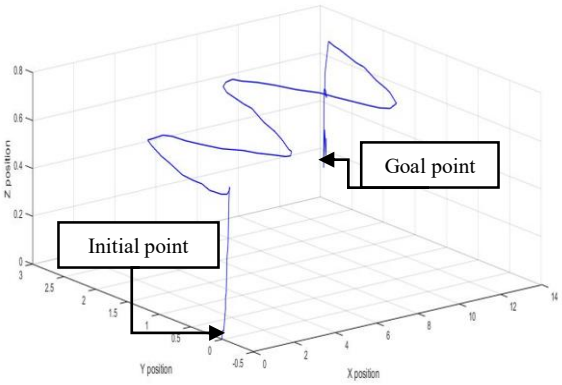

Figure 3. UAV flight path based experimental result

Figure 3 shows flight path of UAV agent which performed moth evasive maneuver. In accordance with experimental result, UAV agent able to deceive the attacker by executed evasive maneuver which has unpredictable movement. As shown in Table 1., the agent evaded attacker UAV at threat risk 67,83% and able to maintain the risk at 36,21% after maneuver.

Table 1. Experimental result

	Pre-evasive maneuver	Post-evasive maneuver
Percentage of threat risk	67.83%	36.21%

III. Conclusion

This paper presents advanced evasive maneuver algorithm which inspired by natural behavior of moths. The proposed evasive algorithm is tested with real-time dynamic threat. UAV is successfully evaded the attacker using moth evasive maneuver and reduced the threat risk by 31,62%. In the future, the proposed algorithm will be tested in various conditions for further validation.

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