Collision Risk Model for Unmanned Aerial Systems

Junichi Naganawa[1)†] and Ryota Mori[2)]

[1)]*Electronic Navigation Research Institute, National Institute, Maritime, Port and Aviation Technology, Japan*
[2)]*Kobe University, Japan*
[†]*email: naganawa@mpat.go.jp*

This research addresses the methodology to ensure the safety of the operation of unmanned aerial systems. Historically, manned aviation has relied on quantitative calculations of collision probability to guarantee safety. This study begins by reviewing the collision risk model used in manned aviation and explores ways to adapt this model for application in unmanned aerial systems.

Key Words: collision probability, drones, safety

1. Introduction

The rapid growth of Unmanned Aerial Systems (UAS), commonly referred to as drones, has transformed various industries and aspects of modern life. UAS have proven to be versatile tools with numerous benefits, such as delivery services. However, as the usage of UAS continues to grow, so does the need for ensuring their safe operation. The increasing complexity and uncertainty surrounding UAS operations necessitate a comprehensive approach to safety analysis. Currently, there is no standardized framework to evaluate the safety of UAS operations nor determine the separation standards.

The safety has been a top priority in manned aviation, where separation standards have been determined through collision risk modelling approach. This research aims to apply existing risk modelling techniques to UAS systems, and develop a methodology for determining separation standards under UAS operations.

2. Collision risk model (CRM) in aviation

To assess the safety of the manned aviation, the collision probability between two aircraft is calculated over a certain period. This calculated collision probability is then compared to the target level of safety (TLS). TLS is defined as the level of risk which is considered acceptable in particular circumstances, and it is often expressed as accidents per flight hour or accidents per flight. Recognizing that the TLS for manned aviation and UAS should differ, this paper focuses on developing a method to calculate collision probability rather than determining the TLS itself.

The Reich model is a renowned CRM in aviation, which is briefly described here. Consider two aircraft flying in parallel on the same flight level. Due to various errors such as navigation error and flight technical error, the aircraft cannot strictly adhere to their prescribed tracks. The probability density function of the lateral deviation is defined as $p_y(y)$, and the lateral overlap probability of two aircraft with a separation of S_y can be calculated using the following expression.

$$P_y(S_y) = \int_{S_y-\lambda_y}^{S_y+\lambda_y} \int_{-\infty}^{\infty} f(u+v) f(u) du dv \tag{1}$$

where λ_y is the aircraft width. Similarly, P_x and $P_z(0)$ can be calculated. Once these parameters are determined, the Reich model can calculate the collision probability per flight hour using the following expression.

$$N_{ay} = 2P_y(S_y)P_z(0)P_x\left(\frac{v_x}{2\lambda_x} + \frac{v_y}{2\lambda_y} + \frac{v_z}{2\lambda_z}\right) \tag{2}$$

The pure product of 3-dimensional overlap probability refers to the ratio of overlapping time rather than the collision frequency itself. The Reich model takes into account that the collisions can occur in any of the three dimensions (nose-to-tail, side-to-side, and top-to-down), and calculates collision frequency (probability) is calculated by considering the average overlap time in each dimension.

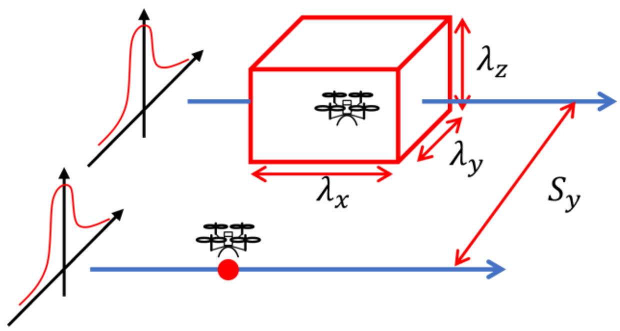

Fig. 1 Schematic image of Reich model.

3. Application of CRM to UAS systems

Although the Reich model is can also be effectively applied to determine the separation of UAS systems, the lack of shared flight trajectory data poses significant challenge in directly determining the parameters above. We present a methodology for applying the Reich model even when associated data are not available.

Acknowledgment

The results were obtained as a result of work commissioned by the New Energy and Industrial Technology Development Organization (NEDO) (JPNP22002).