Appendices

In this section, we provide the detailed formulas of membership functions and the extracted fuzzy rules in the paper.

Fuzzy Numbers

The membership functions of the fuzzy numbers with respect to collision time are given as follows.

$$E(\Delta T^c) = \begin{cases} 1, & 0 \le \Delta T^c \le t_1 \\ 0, & \Delta T^c > t_1 \end{cases}$$

$$D(\Delta T^c) = \begin{cases} -\frac{\Delta T^c - t_2}{t_2 - t_1}, & t_1 \le \Delta T^c \le t_2 \\ 0, & \text{others} \end{cases}$$

$$S(\Delta T^c) = \begin{cases} 0, & \Delta T^c < t_1 \\ \frac{\Delta T^c - t_1}{t_2 - t_1}, & t_1 \le \Delta T^c \le t_2 \\ 1, & \Delta T^c > t_2 \end{cases}$$

The membership functions of the fuzzy numbers with respect to the speed ratio are given as follows.

$$MA(\alpha) = \begin{cases} 0, & 0 \le \alpha < \alpha_0 \\ \frac{1}{1-\alpha_0}\alpha - \frac{\alpha_0}{1-\alpha_0}, & \alpha_0 \le \alpha \le 1 \end{cases}$$

$$DS(\alpha) = \begin{cases} \frac{1}{\alpha_0}\alpha, & 0 \le \alpha < \alpha_0 \\ \frac{1}{\alpha_0 - 1}(\alpha - 1), & \alpha_0 \le \alpha \le 1 \end{cases}$$

$$DL(\alpha) = \begin{cases} -\frac{1}{\alpha_0}\alpha + 1, & 0 \le \alpha \le \alpha_0 \\ 0, & \alpha_0 < \alpha \le 1 \end{cases}$$

$$SU(\alpha) = \begin{cases} 1, & \alpha = 0 \\ 0, & \text{others} \end{cases}$$

The membership functions of the fuzzy numbers with respect to the orientation change are given as follows.

$$VS(\Delta\theta) = \begin{cases} -\frac{8}{\pi}\Delta\theta + 1, & 0 \le \Delta\theta \le \frac{\pi}{8} \\ 0, & \Delta\theta > \frac{\pi}{8} \end{cases}$$

$$S(\Delta\theta) = \begin{cases} \frac{8}{\pi}\Delta\theta, & 0 \le \Delta\theta \le \frac{\pi}{8} \\ -\frac{8}{\pi}\Delta\theta + 2, & \frac{\pi}{8} < \Delta\theta \le \frac{\pi}{4} \\ 0, & \Delta\theta > \frac{\pi}{4} \end{cases}$$

$$M(\Delta\theta) = \begin{cases} \frac{8}{\pi}\Delta\theta - 1, & \frac{\pi}{8} \le \Delta\theta \le \frac{\pi}{4} \\ -\frac{8}{\pi}\Delta\theta + 3, & \frac{\pi}{4} < \Delta\theta \le \frac{3\pi}{8} \\ 0, & \text{others} \end{cases}$$

$$L(\Delta\theta) = \begin{cases} \frac{8}{\pi}\Delta\theta - 2, & \frac{\pi}{4} \le \Delta\theta \le \frac{3\pi}{8} \\ -\frac{8}{\pi}\Delta\theta + 4, & \frac{3\pi}{8} < \Delta\theta \le \frac{\pi}{2} \\ 0, & \text{others} \end{cases}$$

$$VL(\Delta\theta) = \begin{cases} \frac{8}{\pi}\Delta\theta - 3, & \frac{3\pi}{8} \leq \Delta\theta \leq \frac{\pi}{2} \\ 0, & \Delta\theta < \frac{3\pi}{8} \end{cases}$$

Extracted Fuzzy Rules

For the scenarios where there is only one intruder, the final fuzzy rules are:

1. **IF** $L_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is VS
2. **IF** $L_{\Delta T^c}$ is S, **THEN** v_c is DS and $\Delta\theta$ is S
3. **IF** $F_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is S
4. **IF** $F_{\Delta T^c}$ is S, **THEN** v_c is MA and $\Delta\theta$ is M
5. **IF** $R_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is VS
6. **IF** $R_{\Delta T^c}$ is S, **THEN** v_c is DL and $\Delta\theta$ is L

For the scenarios where there are two intruders in two of the three regions, the generated 12 fuzzy rules are:

7. **IF** $L_{\Delta T^c}$ is D and $F_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is S
8. **IF** $L_{\Delta T^c}$ is D and $F_{\Delta T^c}$ is S, **THEN** v_c is DL and $\Delta\theta$ is VS
9. **IF** $L_{\Delta T^c}$ is S and $F_{\Delta T^c}$ is D, **THEN** v_c is DS and $\Delta\theta$ is S
10. **IF** $L_{\Delta T^c}$ is S and $F_{\Delta T^c}$ is S, **THEN** v_c is MA and $\Delta\theta$ is VS

11. **IF** $R_{\Delta T^c}$ is D and $F_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is S
12. **IF** $R_{\Delta T^c}$ is D and $F_{\Delta T^c}$ is S, **THEN** v_c is DL and $\Delta\theta$ is S
13. **IF** $R_{\Delta T^c}$ is S and $F_{\Delta T^c}$ is D, **THEN** v_c is DS and $\Delta\theta$ is VS
14. **IF** $R_{\Delta T^c}$ is S and $F_{\Delta T^c}$ is S, **THEN** v_c is DS and $\Delta\theta$ is M

15. **IF** $L_{\Delta T^c}$ is D and $R_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is M
16. **IF** $L_{\Delta T^c}$ is D and $R_{\Delta T^c}$ is S, **THEN** v_c is DL and $\Delta\theta$ is S
17. **IF** $L_{\Delta T^c}$ is S and $R_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is VS
18. **IF** $L_{\Delta T^c}$ is S and $R_{\Delta T^c}$ is S, **THEN** v_c is DS and $\Delta\theta$ is S

The fuzzy rules obtained in the scenarios where each region contains an intruder are given as follows.

19. **IF** $L_{\Delta T^c}$ is D and $F_{\Delta T^c}$ is D and $R_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is VL
20. **IF** $L_{\Delta T^c}$ is S and $F_{\Delta T^c}$ is D and $R_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is L
21. **IF** $L_{\Delta T^c}$ is D and $F_{\Delta T^c}$ is D and $R_{\Delta T^c}$ is S, **THEN** v_c is DL and $\Delta\theta$ is L
22. **IF** $L_{\Delta T^c}$ is D and $F_{\Delta T^c}$ is S and $R_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is M
23. **IF** $L_{\Delta T^c}$ is D and $F_{\Delta T^c}$ is S and $R_{\Delta T^c}$ is S, **THEN** v_c is DL and $\Delta\theta$ is M
24. **IF** $L_{\Delta T^c}$ is S and $F_{\Delta T^c}$ is S and $R_{\Delta T^c}$ is D, **THEN** v_c is DL and $\Delta\theta$ is M
25. **IF** $L_{\Delta T^c}$ is S and $F_{\Delta T^c}$ is D and $R_{\Delta T^c}$ is S, **THEN** v_c is DL and $\Delta\theta$ is VS
26. **IF** $L_{\Delta T^c}$ is S and $F_{\Delta T^c}$ is S and $R_{\Delta T^c}$ is S, **THEN** v_c is DS and $\Delta\theta$ is L

Finally, we also introduce three fuzzy rules for emergence.

27. **IF** $L_{\Delta T^c}$ is E, **THEN** v_c is SU
28. **IF** $F_{\Delta T^c}$ is E, **THEN** v_c is SU
29. **IF** $R_{\Delta T^c}$ is E, **THEN** v_c is SU