Reliability of Experimental Results

Duong Dinh Tran, Takashi Tomita, and Toshiaki Aoki
Japan Advanced Institute of Science and Technology, Ishikawa 923-1292, Japan

TABLE I
SECOND RUN OF CUT-OUT EXPERIMENTS.

Mode	ID	Config Ve, Vo	First Run			Second Run		
			Actual Ve	Collision	Min TTC	Actual Ve	Collision	Min TTC
Lidar	20-1	5.56	5.55	N	2.61	5.55	N	2.59
	20-2	5.56	5.56	N	2.74	5.55	N	2.74
	30-1	8.33	8.31	N	1.59	8.35	N	1.47
	30-2	8.33	8.34	N	1.38	8.28	N	1.37
	40-1	11.11	11.12	N	1.89	11.11	N	1.84
	40-2	11.11	11.12	N	1.88	11.12	N	1.90
	50-1	13.89	13.71	Y		13.72	Y	
	50-2	13.89	13.71	Y		13.63	Y	
Camera -lidar fusion	20-1	5.56	5.56	N	2.19	5.55	N	2.39
	20-2	5.56	5.55	N	2.48	5.55	N	2.29
	30-1	8.33	8.32	N	1.25	8.35	N	1.47
	30-2	8.33	8.29	N	2.09	8.34	N	1.39
	40-1	11.11	11.12	N	1.08	11.11	N	1.73
	40-2	11.11	11.12	N	1.41	11.12	N	1.42
	50-1	13.89	13.72	Y		13.72	Y	
	50-2	13.89	13.71	Y		13.67	Y	

TABLE II
SECOND RUN OF DECELERATION EXPERIMENTS.

Mode	ID	Config Ve, Vo	First Run			Second Run		
			Actual Ve	Collision	Min TTC	Actual Ve	Collision	Min TTC
Lidar	20	5.56	5.55	N	1.54	5.55	N	1.70
	30	8.33	8.33	N	1.59	8.34	N	1.57
	40	11.11	11.11	Y		11.08	Y	
	50	13.89	13.77	Y		13.75	Y	
Camera -lidar fusion	20	5.56	5.55	Y		5.55	Y	
	30	8.33	8.33	N	1.25	8.34	N	1.28
	40	11.11	11.12	Y		11.12	Y	
	50	13.89	13.76	Y		13.79	Y	

Although it is inherently impossible to reproduce identical traces across experimental runs, our experimental results presented in the paper are reliable. To demonstrate this reliability, we conducted a second set of experiments for the cut-out and deceleration scenarios, with results presented in Tables I and II (the cut-in scenario was skipped due to the time and effort required).

The key results—collision and non-collision—were consistently preserved across the two runs. For non-collision cases, the minimum TTC values from the second runs were generally close to those from the first runs.

Factors contributing to the non-determinism. The first factor contributing to the non-determinism of the experimental results originates from the Autoware side. As shown in the two tables, the ego vehicle's speeds at the moment when the cut-out and deceleration starts (**Actual Ve**) occasionally differed between the two runs.

Another contributing factor to the non-determinism of the traces was the behavior of the `Update` function in the Unity-based AWSIM-Labs source code. Unlike the deterministic `FixedUpdate` function, the timing and frequency of the `Update` calls depend on the computing performance during execution[1]. This variability can result in non-deterministic outcomes due to inconsistencies between runs.

In the cut-out experiments, larger deviations in the minimum TTC values were observed in the camera-lidar fusion perception mode. This is likely due to the additional non-determinism introduced by the fusion and camera-based object detection systems.

[1]https://docs.unity3d.com/6000.0/Documentation/ScriptReference/MonoBehaviour.html