

Classification of Minimal Risk Maneuver for Automated Driving

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The development of automated driving vehicles has been active in recent years, and research and development of minimal risk maneuver (MRM) are also in progress. The MRM stops a vehicle in a case when the driver does not respond to a request to intervene (RTI) delivered from the system of Level 3 (L3) or lower driving automation or in a case when Level 4 automated driving vehicle (L4) will go out of the operational design domain (ODD). The MRM of L4 is targeted for the case when it is desirable to stop an L4 vehicle because of crew members' or passengers' unwellness, and the case of system malfunction and sudden changes in the surrounding environment. There is no systematic definition of the appropriate stopping method, while various MRM triggers are possible. The MRM is triggered when some malfunction that requires the automated vehicle to stop happens. It judges the vehicle location, the surrounding traffic flow, and the available function of the vehicle. Finally, it determines the appropriate stopping method for each situation based on the results. Figure 1 describes the MRM execution process. According to this process, this study classifies the MRM trigger, driving location (road), and traffic flow and then classifies appropriate MRMs according to the available functions in each situation.

Considering the MRM trigger such as system malfunction or sudden changes in the surrounding environment can be applied to the discussion of required functions and the verification of use cases when expanding ODD for L3 driving automation. Therefore, the target of this study is an L4 vehicle and assumes that the system configuration is divided into the following four modules: Vehicle control, Sensing, Remote monitoring, and V2X Communication.

In selecting the MRM method, this study considers the case in which all four modules are available and the case in which one of the modules is unavailable. If multiple triggers occur and multiple modules become unavailable, the multiple applicable cases are extracted, and the stopping method for the more severely constrained case is selected from the stopping methods corresponding to each trigger.

Figure 2 shows that the detailed triggers are classified into three elements of the L4 operation: people, system, and external environment. This study considers a road as a path for traffic and divides it into a motorway and a general road according to road users. It also classifies traffic conditions into a congestion flow and a free flow based on the vehicle traveling speed on a given section of road, referring to the criteria used in the road traffic information by JARTIC in Japan.

This study classifies the stop positions and stopping methods by MRM and the types of MRM used to realize those stopping methods. The classification of the stop positions and stopping methods is derived from ideal stopping methods based on the regulation in Japan. The restrictions are tightened step by step, starting with the usual parking and stopping methods, with priority given to those elements that contribute the most to safety. The classification of the MRM is divided into two types: autonomous type and infrastructure cooperative type.

Based on the above classification, this study selects a stopping method that could be adopted for each MRM trigger in the autonomous and infrastructure cooperative types, respectively. The classification results show that the infrastructure cooperative type becomes effective to perform safer stopping in the cases of software malfunction and sensing malfunction. The validity of the classification proposed in this paper has not all been technically proven, and therefore it is necessary to verify whether the stopping methods and types of MRM proposed as optimal for each case are helpful in practice.

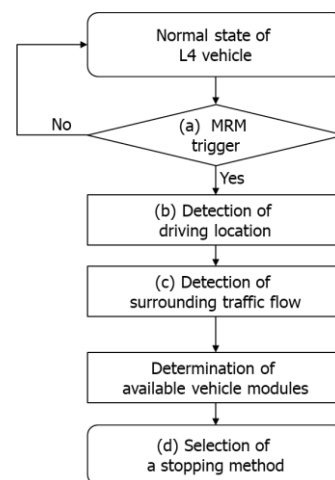


Fig.1 MRM execution process

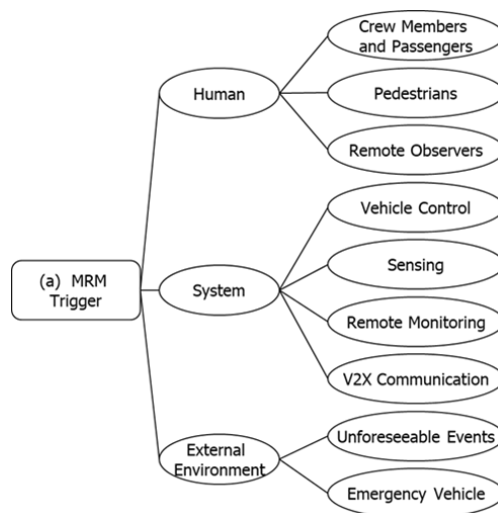


Fig.2 Factors that may trigger MRM