Intelligent selection of two-vehicle collision conditions to minimize occupant injuries

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I. INTRODUCTION

Future automated vehicles will be able to detect the surrounding traffic environment and drive autonomously. In an emergency scenario, where a crash is unavoidable, the ideal response would be for the involved vehicles to intelligently select collision conditions in their last-second manoeuvres such that the occupants' injury risks are minimized. A European project, interactIVe, examined the safety strategies available in a two-vehicle collision situation at an intersection [1]. They analyzed various impact locations on the two vehicles and identified less severe collision conditions in a qualitative manner (e.g. avoid colliding directly with the cabin). There have also been some studies on the influence of vehicle speed and impact angle on occupant injury outcomes [2-3]. However, no studies have provided a framework for emergency manoeuvres to minimize injuries in a quantitative manner. In this preliminary study, by computing all possible collision conditions in a typical crash scenario, an injury risk map was generated for the subject vehicle to guide intelligent selection of collision conditions to minimize injuries in dangerous road traffic situations.

II. METHODS

Collision conditions under a typical accident scenario

NHTSA classified 37 accident scenarios in 2007 [4], from which we chose a typical and frequently occurring scenario for this study. (The speeds, moving directions and vehicles' orientations are marked in Fig. 1.) Assuming the subject vehicle (red car) is an automated vehicle, it attempts to manoeuvre itself out of a possible collision or, if a crash is considered unavoidable, to manoeuvre itself by accelerating, braking and/or steering to minimize injury risk for its own occupants.

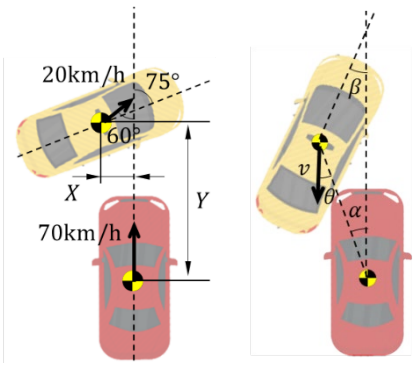

Fig. 1. A typical accident scenario (left) and collision conditions characterization (right).

The kinematics of the vehicles was calculated based on a two-degree-of-freedom vehicle dynamic model [5] and collision risks were computed based on different initial positions. The greater the distance between the encounter and the emergency manoeuvre, the greater the chance of avoiding the collision. In the reference coordinate system set up at the subject vehicle, the collision conditions were described using the following four parameters: the angle of the connection line between the centres of the two vehicles relative to the direction of the subject vehicle (α); the angle between the two vehicles' body directions (β); the speed of the obstacle vehicle (v); and the direction of the obstacle vehicle's velocity (θ). In this characterization, the relative rotation velocity between the two vehicles at the contact moment was ignored (Fig. 1).

Injury risk analysis under the typical scenario

After the collision conditions (the location, velocity and direction of the impact contact) were determined, the finite element (FE) model of a 2012 Honda Accord (https://www.nhtsa.gov/crash-simulation-vehicle-models) was used to obtain the crash pulses of the subject vehicle through simulations of two-vehicle collisions. The acquired two-dimensional crash pulses (two translational and one rotational motion on the X-Y plane) were then used as the load cases on a sled model where a typical vehicle interior and a human body model (HBM) representing the average size of Asian male [6] were used in simulations for injury analysis. The occupant was restrained with seat belt and airbag. The simulation matrix for injury analysis included two seat-belt force levels (2 kN and 5 kN), representing change of restraint stiffness, and a normal sitting posture and a reclined posture, representing

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interior seating diversity in future vehicles [7]. It formed four cases for each of the load cases. The injury outcomes for the skull, brain, neck, chest and femur of the occupant in the subject vehicle were obtained for all the cases in order to formulate whole-body injury risk.

III. INITIAL FINDINGS

Figure 2 shows the collision risk area of the two vehicles. When the initial location of the obstacle vehicle falls within the red area (the distances in the X and Y directions marked in Fig. 1), a collision cannot be avoided, no matter what manoeuvres the two vehicles undertake. Beyond that red area, collision can be avoided if the vehicles manoeuvre correctly.

A specific area in Fig. 2 was further selected for injury analysis. This area is where the obstacle vehicle is located at 7.6–8.4m ahead of the subject vehicle and 0–1m to the left. In this area, the collision cannot be avoided, but the subject vehicle still has sufficient space and time to manoeuvre itself to select a collision condition to minimize the injury risk of its own occupants. Figure 3 shows the injury risks of MAIS3+ for all the possible collisions that may occur in this area, depending on the manoeuvres of the two vehicles (i.e. possible sets of the four parameters defined in Fig. 1), as well as the cases under the two restraint levels and two sitting postures. For example, crashes that occur at the middle of the obstacle vehicle carry a 10% higher risk of MAIS3+ injury than crashes at the rear (causing greater rotation and thus lower crash severity), and an impact angle (between vehicles' body directions, β) of 65° is 7% safer than an impact angle of 85°, and a reclined posture is generally more risky. Such results may offer manoeuvre strategies to automated vehicle(s) in dangerous road traffic situations.

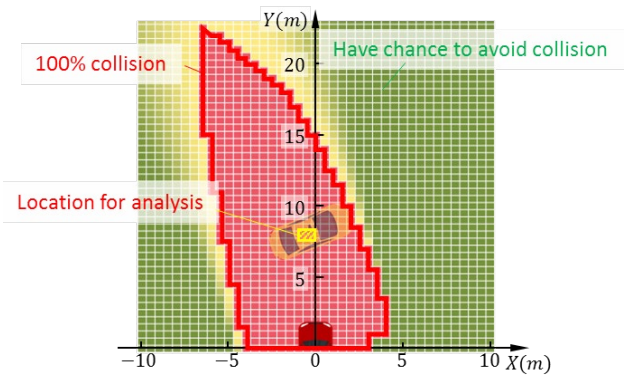

Fig. 2. Collision risk envelope for various initial states.

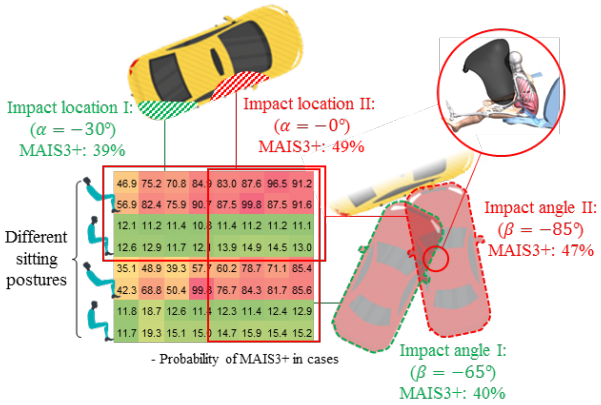

Fig. 3. Map of injury risks.

IV. DISCUSSION

The collision risk envelope developed in this study can be used to judge whether automated vehicles can avoid a crash in emergency near-collision situations. Automated vehicles may refer to the collision risk map for the timing of the transition from normal driving [8] to intelligent protection state. Furthermore, the capability of predicting injury risk demonstrated in this study may support algorithm development for intelligently selecting collision conditions to minimize injuries when a collision becomes unavoidable. In the future, to realize intelligent protection, this preliminary study can be improved and expanded to those situations where all involved vehicles are automated vehicles, where more restraint parameters are adjustable, and where more occupant statures and postures are included. Moreover, injury risk minimization can be considered among all involved vehicles, instead of self-vehicle only. More complex situations will certainly bring in greater challenges in achieving reliable and robust results.

V. ACKNOWLEDGEMENTS

This study was supported by National Key R&D Program of China (Grant Number 2017YFE0118400).

VI. REFERENCES

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