Building a Posture Incorporated Dataset of Occupant Injuries in Vehicle Collisions Based on Multi-source Data Fusion

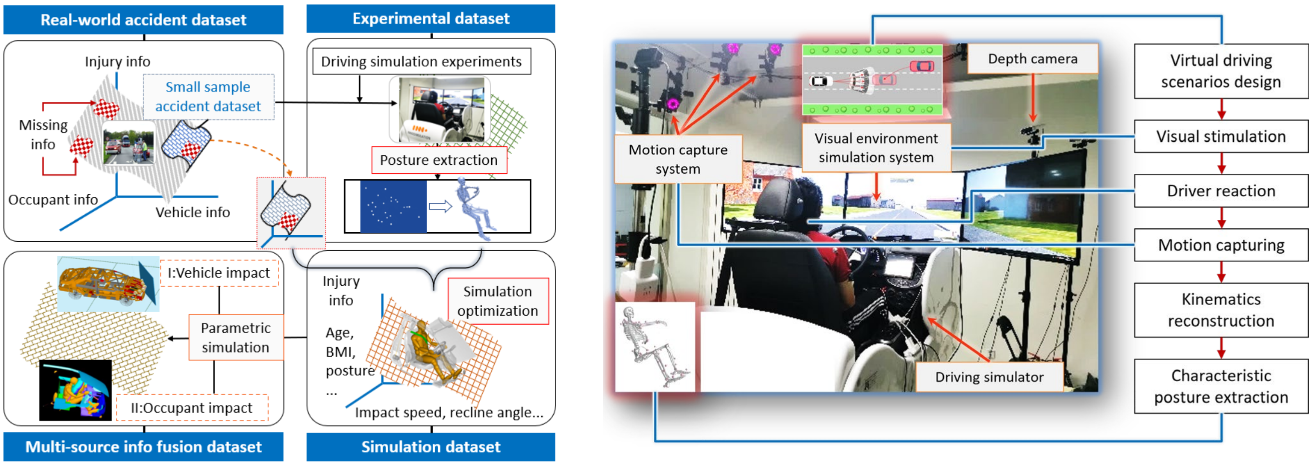
Shi Shang, Xizhe Pei, Quan Li, Bingbing Nie

I. INTRODUCTION

Occupants account for 29% of the fatalities in motor vehicle accidents each year, which is 391,500 fatalities [1]. Quantitatively characterizing the risks of vehicle occupants in the complex and dangerous conditions of the human-vehicle system and implementing accurate and real-time predictions can provide references for trajectory planning and occupant restraint optimization. A collision accident database with comprehensive coverage of crucial information is the basis for developing injury risk prediction algorithms [2]. In-depth accidents, computation and/or analytical simulation and naturalistic driving are the most common sources of the current training database. Each has its inherent pros and cons for providing essential information. For example, the real-world in-depth accident database serves as an origin for subsequent research and analysis of injury mechanisms, while, owing to equipment constraints during the collection of accident information, some critical influencing factors (e.g. occupant posture and muscle activation level [3-4]) are unrealistic to collect and largely lacking. This study aims to capture driver posture at collision moments and then combine the posture information with the available collected impact parameters to form a comprehensive injury dataset based on multi-source data fusion.

II. METHODS

The overall proposal framework for building a multi-source information dataset is illustrated in Fig. 1(a).



(a) (b)

Fig. 1. Demonstrations of (a) proposal framework and (b) driving simulator and experimental procedure.

(Step 1) The boundary conditions of a small sample accident dataset were analysed and extracted as references for virtual driving scenarios design. In addition, they are also the essential parameters of the fusion dataset. (Step 2) A set of driving simulation experiments (10 scenarios x 24 volunteers = 240) was conducted to capture occupant postures during virtual crash scenarios. Figure 1(b) demonstrates the driving simulation platform and the experimental procedure of volunteer tests. A driving simulation system was employed to generate customized dangerous-driving scenarios based on the boundary conditions of real-world accidents. To represent drivers' emergency avoidance behaviours and their accompanying postures, the virtual extreme (almost inevitable) driving scenarios were designed to simulate the accidents caused by speeding, driver inattention, traffic violation, etc. Due to the visual stimuli, the volunteer drivers engaged in active avoidance behaviours in a natural response to perceived dangers. Meanwhile, the motion-capture system and the depth cameras recorded the kinematics of markers attached to body regions. Joint positions, velocities and

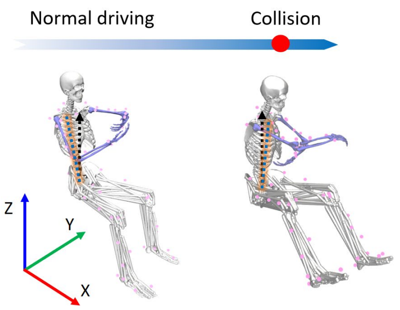
B. Nie (e-mail: nbb@tsinghua.edu.cn; tel: +86-10-6278-8689) is an Associate Professor, S. Shang is a Research Associate, X. Pei is a MSc student, Q. Li is a PhD student, all in School of Vehicle and Mobility at Tsinghua University, China.

accelerations at the virtual crash moments were extracted with inverse kinematics approaches at the OpenSim platform. (Step 3) After a simulation optimization that fused occupant posture of experimental data with the crash parameters of accident data, the injury indices were compared to estimate the most likely occupant posture in real-world accidents. (Step 4) A fully parametric simulation, including two-phase collision (vehicle-to-vehicle and occupant-to-vehicle interior), was carried out to generate a large-scale occupant injury dataset with sufficient critical information. We established the data matrix based on a co-simulation platform composed of a virtual crash system (Visual Crash Studio, VCS) and multi-body dynamics software (MADYMO). In the first stage, VCS was used to simulate the vehicle-to-vehicle crash. Then, the obtained collision accelerations of the cockpit were employed as a bridge to reconstruct the collision of the occupant-to-vehicle interior on the MADYMO platform. Finally, posture data from experiments, crash information from accident data, and the injury outcomes from simulations were fused as parameters of the dataset for injury risk prediction.

III. INITIAL FINDINGS

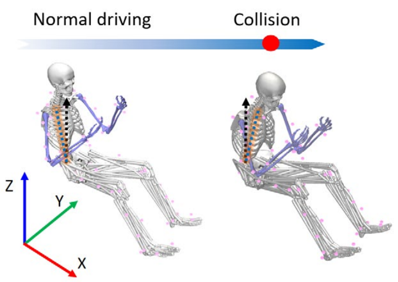
The dataset under construction takes advantage of real-world accident data authenticity, experimental data compensation, and simulation parametric modelling. Core information, including collision pattern, vehicle impact speed/position/angle, driver physical characteristics, age, postures, seat position/recline angle, injury with its accompanying AIS level, etc., are fused via simulation, forming the data matrix. As a result, the dataset volume could be two orders of magnitude higher than a similar dataset [2]. Besides, the postures extracted from driving simulation experiments are more complex but realistic.

In the real-world accident dataset, four typical patterns are frontal, side, rear-end collisions, and collisions with stationary vehicles. Based on these patterns, designed driving simulation experiments showed that most drivers had a noticeable change in posture when facing danger compared with those in normal driving phases. Specifically, sudden braking and turning the steering wheel resulted in the driver's trunk leaning forward and the torso bending and twisting. Figure 2(a) illustrates a visual comparison between "steering left" and normal driving postures. Figure 2(b) shows a "deceleration" versus normal driving posture. The torso angles at different stages of driving behaviour were compared (Fig. 2).



	Normal	Collision
Bending (°)	-8.1	5.3
Lateral bending (°)	-2.4	4.6
Twisting (°)	-2.7	-15.2

(a) "Steering left" posture versus normal driving posture.



	Normal	Collision
Bending (°)	-10.3	9.8
Lateral bending (°)	-2.6	-1.8
Twisting (°)	-1.0	-2.4

(b) "Deceleration" posture versus normal driving posture.

Fig. 2. Examples of comparing postures and torso angles of the driver at collision moment versus normal driving phase. "+/-" of the torso angles denote "forward/backward"bending, "left/right" lateral banding, and "clockwise/counterclockwise" twisting, respectively.

IV. DISCUSSION

Preliminary insight into occupant kinematics in driving simulation experiments indicates that collision posture diversity and unpredictability range far beyond the current dataset [2]. The existing training datasets lack occupant posture information at collision moment, making the accuracy of the occupant injury prediction doubtful. Multi-source data fusion could mitigate the limitation of single-source data. Furthermore, incorporating the occupant collision posture into the dataset as a parameter would contribute to improving injury risk prediction accuracy. This study will continue to (a) analyse the potential estimated posture that the driver presented at the collision moment in the real-world crash, and (b) conduct a full parametric simulation to build a large-scale injury dataset for occupant injury risk prediction.

V. ACKNOWLEDGEMENTS

This work was in part supported by National Key R&D Program of China (2018YFE0192900) and National Natural Science Foundation of China (52072216).

VI. REFERENCES

[1] WHO, 2018.
[2] Bance, I., *et al*. *IRCOBI*, 2019.
[3] Bose, D., *et al*., *Accid Anal Prev*, 2010.
[4] Östh, J., *et al*., *Traffic Inj Prev*, 2012.