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Driving Scenario Design for Driving Simulation Experiments Based on Sensor Trigger Mechanism

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Abstract: This study presents the method and principle of driving scenario design using BJTU driving simulator. The scenario design method is based on a sensor trigger mechanism which can activate critical traffic events under controlled conditions. The BJTU driving simulator provides different sensors with various functions to realize the triggered events. To illustrate the scenario design method, a preliminary precrash scenario is designed and the corresponding test sample data depict the subject's response time to a potential collision with pedestrian and vehicle's parameters of acceleration and brake pedal force during the simulation process. The study show that the simulation scenario could reflect the driving behavior pattern realistically and effectively.

Key words: Driving simulator, scenario design, sensor, precrash

INTRODUCTION

In recent years, driving simulators have become a popular tool applied to many areas, including traffic engineering, vehicle engineering, psychology and medical science. Especially in the traffic research fields, driving simulators are used for investigating complex interaction between drivers, vehicles and roadways. Researchers have fulfilled a large number of driving simulation experiments, such as evaluation on traffic signal displays (Knodler *et al*., 2005), weather influence analyses for driving behavior (Konstantopoulos *et al*., 2010), impacts of cell phones on driving performance (Beede and Kass, 2006), etc. In these experiments, it's critical to build realistic driving scenarios for testing subjects' behaviors in driving simulators. How to design proper driving scenarios to meet research purposes plays an important role in the success of the simulation experiment. Presently, there exit many types of driving simulators all over the world and their driving scenario design methods are diverse but their principle of scenario design is similar which is focused on ease of design procedure and high-reality of simulation result.

This study presents an effective driving-scenario design method based on a sensor trigger mechanism in the BJTU driving simulator. In this study, a pedestrian-vehicle precrash scenario is chosen as a typical example to illustrate how to use triggers to fulfill the purpose of simulation experiment and reflect the driving behavior realistically.

DRIVING SCENARIO DESIGN USING SENSORS

Overview of BJTU simulator: The BJTU simulator is a high performance, high fidelity driving simulator, as shown in Fig. 1. It can realize the interactive driving simulation experiments under lab-control conditions and is used to conduct scientific research such as driver behavior characteristics, vehicle dynamics and transportation facility evaluation. The BJTU simulator is composed of 300° forward view visual simulation system, 150° backward view visual simulation system, full-size vehicle cabin with real operation interface, environmental noise and shaking simulation system, digital video replay system, vehicle dynamic simulation system and two DOF motion platform. The software in the simulator lab is provided for driving scenario design, virtual traffic environment simulation and virtual road modeling, including Simvista, Simcreator, Multigencreator, Sketchup, or other 3D modeling tools.

How to design scenario: In the BJTU driving simulator, before designing a driving scenario, the first step is to develop a model for driving scenario occurrence process. Then it's necessary to add traffic signal controls, pedestrians, vehicles and other dynamic elements into the traffic scenario. Next, a set of special objects called scenario control objects including sensors, markers, paths, start points and stop points should be added to control the actions and behaviors of the vehicles, pedestrians and other controllable features within the

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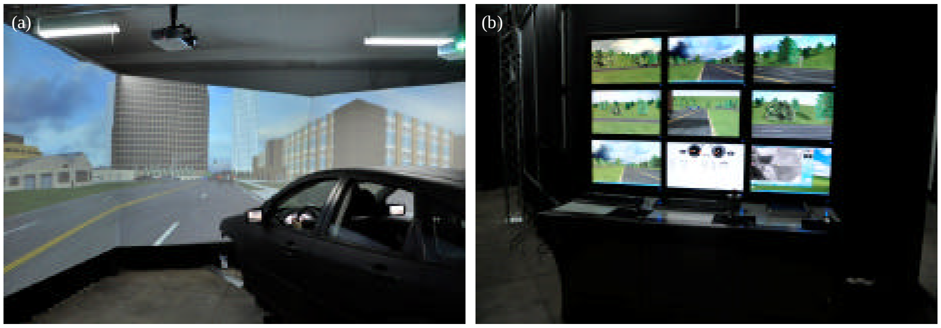

Fig. 1(a-b): The BJTU driving simulator

simulator. The last step is editing script commands attached to sensors to make specific traffic events occur.

Commonly, it needs three basic simulation components in the scenario design which are traffic control devices regulation, lighting and weather conditions control and simulated vehicles manipulation. Traffic control devices are used for regulating traffic to form a smooth traffic flow. The most critical control device in an intersection is traffic light. The traffic light signal timing should be controlled to suit for the required scenario by using script commands. The controllable elements include the cycle time, each phase time and each direction state (red, yellow, or green). Lighting and weather conditions are external environments which cannot be lacked in the scenario. The lighting conditions include day, night, headlight of vehicle and shadows and the weather conditions consist of fog, rain and snow. These conditions could be modified to accommodate different scenario demands such as density of fog or precipitation. Simulated vehicles manipulation is the core of the scenario design. The simulated vehicles can be divided into ambient and target vehicles. The ambient vehicles that generally run in an autonomous mode are not involved in the driving scenario and only used to create a live and realistic scene. The target vehicles are the elaborate simulated vehicles, whose behaviors significantly influence the subject's driving performance in an experiment. Typically, the subject-driving vehicle (simulator) is used to examine its interaction with the target vehicles through a scenario design. Figure 2 displays a model for the mechanism of controlling simulated vehicles.

In this model, the vehicle embodies vehicle's driving behaviors including velocity, acceleration and deceleration rates, lane offset, desired headway and tailway relative to other traffic and desired lane selection. The scenario module is responsible for creating and destroying autonomous vehicles. The road module assigns a default of speed limit, steers the vehicle module to keep a vehicle on the road and compares the position

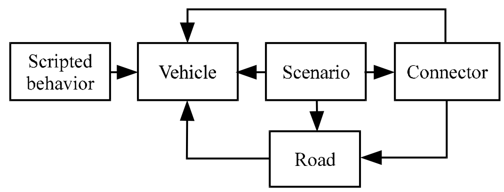

Fig. 2: The control mechine of simulated vehicles

and velocity of all vehicles on the road to determine if lanes should be changed. The connector module represents connections between lanes of roads that can be a merge or split on the highway as well as turns or straights at signalized intersections. It is responsible for assigning a vehicle to the four approaches and deciding which approach should control steering. The scripted behavior allows overriding the road module to set vehicles' velocities and default properties for the road or connector module to use.

Sensor trigger mechanism: In a driving scenario, the events required in the experiment are realized through Javascript commands. These commands are attached to different types of sensors provided by BJTU simulator. These sensors are responsible for various events' occurrence including trigger time.

Every sensor has its own trigger condition. When a trigger entity, such as the subject vehicle, satisfies the sensor's trigger conditions, the sensor will trigger a series of events controlled by the JavaScript commands. The mechanism is shown in Fig. 3.

Trigger events in the scenario are various and often require different trigger conditions based on time, location. According to the requirement of trigger conditions, the sensor can be classified as proximity sensor, planar Time-to-collision (TTC) sensor, time sensor and maneuver sensor.

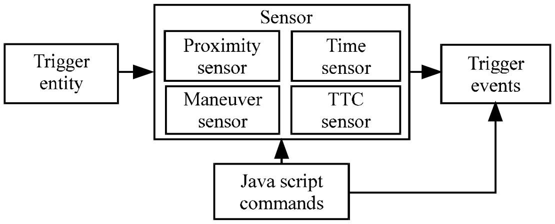

Fig. 3: The sensor trigger mechanism

Proximity sensor: Proximity sensor defines a 3D geometry space. According to the shape, proximity sensors can be spherical, cylindrical, rectangular or planar. Their geometry parameters such as radius, height, width and length could be set according to different scenario requirements.

The proximity sensor's trigger conditions are based on space location, commonly include:

- Enter the geometry
- Within the geometry
- Leave the geometry

When the trigger entity satisfies one of three conditions, a series of trigger events associated with corresponding conditions will occur, as shown in Fig. 4.

Planar time to collision sensor: Planar TTC sensor defines a planar geometry and its related geometry parameters including width and height could be set. TTC sensor only responds to the entity whose heading direction intersects with the sensor's bounded planar geometry, as shown in Fig. 5. TTC sensor can trigger the events under three similar conditions:

- TTC value reaches the threshold specified
- TTC value is less than the threshold and greater than 0
- TTC value is greater than the threshold, or no longer intersecting with the plane

TTC value means the distance between sensor and trigger entity divided by the entity's velocity and the threshold value is used to control trigger time of events.

TTC sensor is useful for creating speed-independent events. It is desirable to provide an event that gives subjects a specific time to react but not to manipulate the driver's speed during the event. The TTC sensor and its TTC threshold value could assure that the event is always initiated giving different subjects the same time to respond to the designed event regardless of how fast they are approaching the event space.

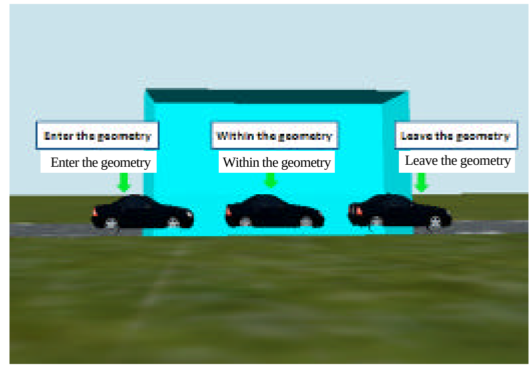

Fig. 4: Illustration of a proximity sensor function

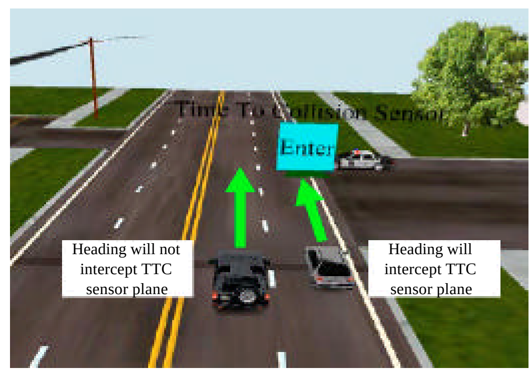

Fig. 5: TTC sensor geometry implicatio

Time sensor: Time sensor has no geometry and its trigger conditions fully depend on time. This sensor could generate continuous or isolated events according to the programmed time information and it has a notion of start time and stop time set by a designer.

The following trigger conditions would lead to a series of time-related events:

- The simulator time reaches the start time
- The simulator time lies between the start time and stop time
- The simulator time reaches the stop time

Maneuver sensor: Maneuver sensor is essentially a proximity sensor with additional functionality. A maneuver sensor is triggered based on the subject's location or a particular time into the simulation. It also includes the parameters of start time and start distance which could be set. The three typical trigger conditions are:

- The simulator time is greater than or equal to the start time or the subject vehicle enters the sensor geometry or the subject vehicle distance is greater than the start distance
- The elapsed time from start time is greater than or equal to a cycle-interval boundary
- The maneuver is completed

EXAMPLE FOR A PRECRASH SCENARIO DESIGN

Before a traffic accident happening, if the driver takes effective actions in critical conditions, these crashes could be avoided. The scenario in which a driver could avoid the potential crash occurrence by changing driving behavior is called precrash scenario (Yan *et al*., 2008). Many researchers have focused on the crash-avoidance technologies such as collision warning avoidance system (Ho *et al*., 2006; Maltz and Shinar, 2004; Lee *et al*., 2002). To provide a better collision avoidance technology, it is essential to investigate driving behavior in the precrash scenarios. In this study, a pedestrian-vehicle precrash scenario at a signalized intersection is selected to illustrate how to use the trigger mechanism to design the scenario and realize the purpose of simulation experiment.

Description of pedestrian-vehicle precrash scenario at a signalized intersectio: When a vehicle approaches an intersection at a certain speed during the green phase, a pedestrian ahead of the vehicle tries to cross the road segment regardless of the red light. In such a scenario, the driver has to adjust his/her driving behaviors to avoid colliding with the pedestrian.

According to the design method and process aforementioned, this scenario design involve three aspects:

Creating basic road scenario: Firstly, an intersection is reated with four 2-lane approaches, one of which is used for testing the precrash scenario. Then, the traffic signal light and other related traffic control devices are positioned in the proper locations. Lastly, some dynamic elements such as pedestrians and vehicles are added to this scenario.

Adding scenario control objects: As shown in Fig. 6, the subject vehicle starts at point A, the pedestrian start moving at point D and perpendicularly crossing the road segment. To better illustrate different sensor functions, this experiment gives two different sensors to trigger the pedestrian's red-light running behavior: proximity sensor and TTC sensor. For proximity sensor, it is positioned at point C with a set of distances to the potential crash point B: 80, 100 and 120 m. For TTC sensor, it is located at the potential crash point B and the threshold values of TTC sensor are set as 5, 4 and 3 s.

Editing Javascript commands: Corresponding o he two types of sensors, TTC sensor (point B) and proximity sensor (point C), the Javascript commands are further edited to fulfill the following events. If selecting the proximity sensor to trigger the pedestrian's walking movement, the pedestrian will cross the road segment at the designed speed (4.5 km h^{-1}) regardless of the red light when the subject vehicle enters the sensor's geometry. If selecting the TTC sensor, pedestrian would walk along the same path when TTC between subject vehicle and pedestrain reaches the designed threshold value.

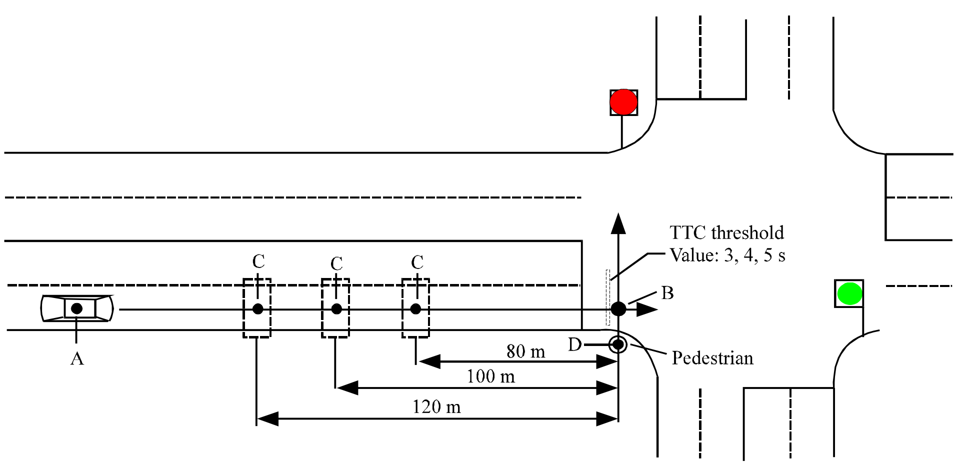

Fig. 6: Pedestrian-vehicle precrash scenario

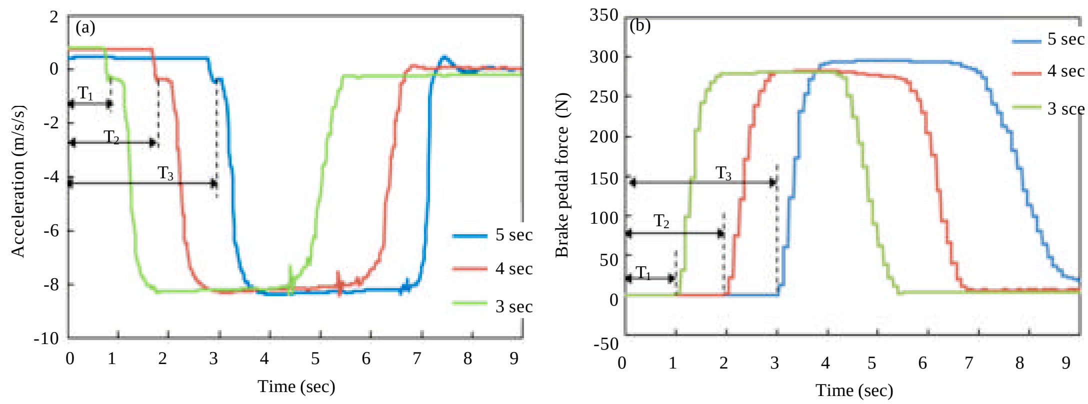

Fig. 7: Data collected using TTC sensor; (a) Accelasation vs. time and (b) Brake pedal fore vs. time

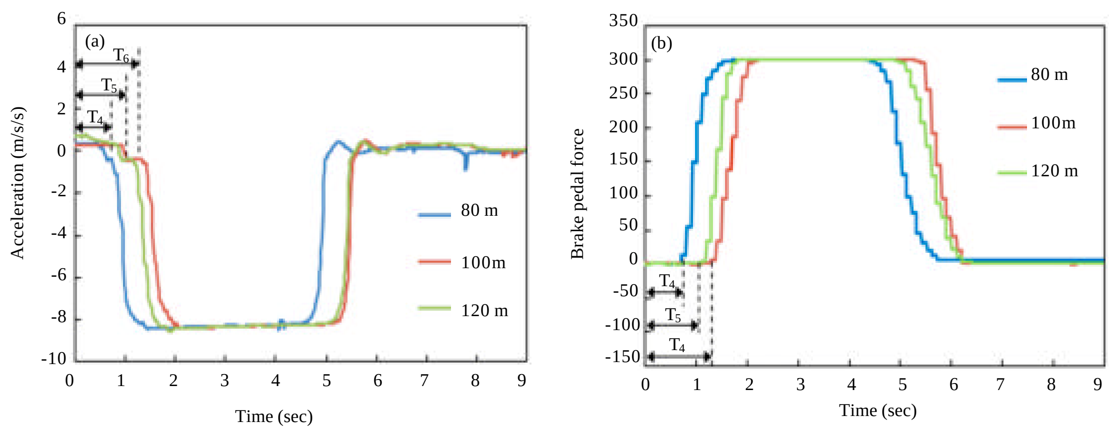

Fig. 8: Data collected using proximity sensor; (a) Accelasation vs. time and (b) Brake pedal fore vs. time

Data collection and analysis: In this example, two critical variables are selected to characterize the driver maneuver: Acceleration rate and brake pedal force. Reaction time is further analyzed to measure driving performance. The reaction time is defined as the duration from the time point that driver notices the pedestrian will cross the road to the time point that the driver starts braking. It is assumed that the moment that the pedestrian encroaches into the edge of the roadway is the time point that driver notices the pedestrian.

Using the TTC sensor, the test sample data are shown in Fig. 7, where the axis of Time represents the time series of simulation starting at the moment when the pedestrian encroaches into the edge of the roadway. The curves for Acceleration and Brake pedal force indicate the driver's response maneuver to the pedestrian under different threshold values of TTC respectively and T_1, T_2 and T_3 represent driver's reaction time accordingly. Obviously, $T_1<T_2<T_3$. It depicts that the driver's reaction time decreases as the TTC value reduces. It can be explained that the less TTC, the more emergent situation that needs the driver quickly make decision and take actions to avoid the potential crash.

Using the proximity sensor, the test sample data are shown in Fig. 8. The curves for Acceleration and Brake pedal force indicate the driver's response maneuver to the pedestrian under different distances to the potential crash point B and T_4, T_5 and T_6 represents driver's reaction time in different conditions. Obviously, $T_4<T_5<T_6$. It depicts that the driver's reaction time is shorter as the driver is approaching to the potential crash point B more closely. The proximity sensor illustrates the similar precrash simulation mechanism to the TTC sensor. However, T_4, T_5 and T_6 is less than T_1, T_2 and T_3, respectively which indicates the driver's precrash response time could be complexly associated with the vehicle approaching time, distance and speed when the potential conflict exists.

CONCLUSION

This study shows the method of the driving scenario design in the BJTU driving simulator based on the trigger sensor mechanism. The method is easily manipulated and helpful to support high-fidelity driving simulation experiments. A typical precrash scenario for simulating pedestrian-vehicle conflict process was presented to illustrate applications of both proximity sensor and TTC sensor. The simulation sample data using the two types of sensors give the same conclusion that the driver's reaction time will decrease when the appearance of the pedestrian is closer to the subject-vehicle whatever on time or distance. The simulation experiment data could effectively reflect driver's behaviors in the precrash scenario. In the future, the driving simulator will be used as a platform to test more complex scenarios for investigating whether or how a new technology or engineering countermeasure can enhance driving behavior and reduce crash risk.

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REFERENCES

Beede, K.E. and S.J. Kass, 2006. Engrossed in conversation: The impact of cell phones on simulated driving performance. Accid. Anal. Prev., 38: 415-421.

Ho, C., N. Reed and C. Spence, 2006. Assessing the effectiveness of intuitive vibrotactile warning signals in preventing front-to-rear-end collisions in a driving simulator. Accid. Anal. Prev., 38: 988-996.

Knodler, Jr., M.A., D.A. Noyce, K.C. Kacir and C.L. Brehmer, 2005. Evaluation of traffic signal displays for protected-permissive left-turn control using driving simulator technology. J. Transp. Eng., 131: 270-278.

Konstantopoulos, P., P. Chapman and D. Crundall, 2010. Driver's visual attention as a function of driving experience and visibility: Using a driving simulator to explore driver's eye movements in day, night and rain driving. Accid. Anal. Prev., 42: 827-834.

Lee, J.D., D.V. McGehee, T.L. Brown and M.L. Reyes, 2002. Collision warning timing, driver distraction and driver response to imminent rear-end collisions in a high-fidelity driving simulator. Hum. Factors, 44: 314-334.

Maltz, M. and D. Shinar, 2004. Imperfect in-vehicle collision avoidance warning systems can aid drivers. Hum. Factors, 46: 357-366.

Yan, X., R. Harb and E. Radwan, 2008. Analyses of factors of crash avoidance maneuvers using the general estimates system. Traffic Inj. Prev., 9: 173-180.