UNMANNED TARGET VEHICLE FOR ACTIVE SAFETY EVALUATION IN CUT-IN TEST SCENARIOS

Yeonggeol, Park
Jaejoon, Kwon
Kihong, Park
Jay, Jeong
Kookmin University
South Korea

Paper Number 15-0015

ABSTRACT

In recent years, active safety systems are introduced to the markets and many of them are adopted to improve the possibility to avoid the accidents. These active safety systems include AEBS (Automatic Emergency Braking System,) LKAS (Lane Keeping Assistant System,) BSD (Blind Spot Detection,) and so on. The evaluation methods for those systems also have been developed and determined as international standards. Additionally, target systems for evaluation have been developed too. However, they are usually designed for testing straight rear collision scenarios. To reproduce other scenarios such as cut-in situations, a new concept of the target system is needed. So, in this work, the unmanned target vehicle are designed and developed. The target vehicle is developed as an unmanned vehicle for accurate path following performance. A DGPS with 2cm accuracy and heading angle IMU are installed for the path following function. A soft dummy which resembles a typical SUV is attached on the unmanned target vehicle. To reproduce accident scenarios safely, the target vehicle should be designed to protect the hunter vehicle and the target vehicle itself from the crash shock of the collision situation. The target vehicle in this work is developed with a shock absorber system in the rear part of the target vehicle.

The rear part of the target vehicle is designed to have similar characteristics with a real vehicles in visual shape for vision systems and radio frequency reflection for radar systems. The shape and the material of the part is selected for the hunter vehicle to recognize the target vehicle as a real SUV.

The structural and dynamic analysis are carried out for the target performance. Also, evaluation experiments of the cut-in scenarios are carried out to test the hunter vehicle with the AEBS.

The dynamic performance results of the target vehicle will be presented. The results include the limit of impact speed, maximum speed, maximum lateral speed and accuracy of path following logic. The AEBS performance results of the hunter vehicle will be presented in the test cut-in situation.

In this work, test scenarios to evaluate the hunter vehicles are carried out especially for the 'Rear collision and Cut-in' situations. Frontal collision and accidents in intersection situation are excluded. The hunter vehicles with AEBS are only tested for the evaluation experiments. The test speed is set less than 40km/h.

INTRODUCTION

Currently, the vehicles that adopt the active safety system are launched in the market. There are AEBS, LKAS and BSD as such active safety system and the system of adding points is prepared to be adopted to such system in NCAP. And, the car manufacturing companies are accelerating the development of vehicles that adopt such functions along such trend. It is acknowledged that the test method for verification should be development for the active safety device as well like collision safety test that is carried out in NCAP necessarily. The evaluation methods of active safety performance are developed in Europe actively[1]. Euro NCAP is performing the evaluation of frontal collision prevention device[2].

And, the target vehicle that can represent the scenario is being developed together with the methodology. The target vehicle is the one that simulates accident-causing vehicles such as stop, decelerating and cut-in vehicles to
represent the accident situation in the accident scenario. As the active safety vehicle test is the evaluation of the system for avoiding the collision in accident situation, it always contains the possibility of collision against target vehicle in case the system does not operate completely. So the target vehicle should perform the function that can protect each system against the collision that can occur in the test as well as representation of scenario. The vehicle should attach the shock-absorbing material to absorb the shock, however, the problem of difficulty to let the testing vehicle recognize the target vehicle as real one should be solved.

This study used the analysis of accident data in the advanced projects of Europe and selected the required specifications for the target vehicle using the accident scenario drawn from them. The target vehicles were developed to satisfy such specifications. And, they were developed as the unmanned vehicle was developed considering correct representation of scenario, repeatability of test and safety of test driver. The developed target vehicle verified the reproduction ability of scenario through the performance evaluation of trajectory tracking.

Scenario selection

This study used the analysis results of accident statistical data in the other projects for scenario selection. The project called ASSESS[3] classified the kind of highest frequency and injury value by analyzing the accident data of Europe. It used the scenario classified in the project. ASSESS analyzed it using several database of Europe and selected the generalized analysis method for analysis of several data. The representative accident types were classified for scenario classification in advance and the representative ones were drawn considering the seriousness of accident. The importance was determined by giving the specific weight according to the seriousness of accident along its type for generalizing the frequency and seriousness. The whole generalization was done by giving the weight along the population of each country. The accident of single vehicle, longitudinal collision (including both same and opposite direction), collision at intersection and pedestrian accident were drawn as the accident type and analyzed as the most important type. In here, the collision at intersection and longitudinal collision were finally selected from the accidents of vehicle-to-vehicle again.

It aimed to evaluate the active safety performance of state-of-the-art vehicle and develop the device for that against all accident types ultimately but it aimed to develop the target vehicle that can represent the longitudinal collision (the same direction) in this study. In here, the selected specifications of target vehicle were the speed of 40 km/h to satisfy the low driving speed, trajectory tracking of unmanned driving for correct representation of scenario and deceleration performance of 6 m/s².

Development of target vehicle system

The efforts to develop the target vehicle were spent in the other researches[1],[4],[5]. The target vehicle developed in this thesis was produced by modifying the electric vehicle and installing the unmanned-controlling module. The dynamic performances were increased by lowering total weight of the vehicle through removing all exterior and interior materials of the vehicle. And the actuator and controller such as steering controlling actuator, brake(deceleration) control, acceleration control actuator, speed change actuator, wheel encoder, remote controller, interface module box, control box, interface module box, power supply box were installed for unmanned driving and remote control.

To explain each actuator simply, steering controlling actuator used MDPS module as the mechanical part that controls the steering of vehicle. The acceleration controlling actuator controls the accelerator pedal using the accelerator pedal of the vehicle with mechanical part and wire. Brake (deceleration) control actuator controls the brake pedal using the mechanical part to brake pedal. Remote controller can control power status of system, power of each actuator and operation mode of system at driver’s seat. The rear side of vehicle had power supply box that supplies the power of operating system and control box that controls each actuator by processing the power and processing signal between actuator and controller (See Figure 1). The wheel and encoder were installed to measure the movement and moving speed of vehicle in this system. Wheel encoder (DMI) has the principle that forwards the value to the encoder as the bearing rotates when the wheel of vehicle rotates with the connection of encoder to bearing. Bearing was designed to increase the durability of abrasion against vehicle wheel by urethane-covering and measure the correct positional value with tighter adherence between the rotating part of wheel and encoder. 2 DMI’s were installed at the rear wheel.
And remote control server (See Figure 2) was installed to control the target vehicle so that the tests of various collision evaluation scenarios could be conducted in the unmanned way.

**Development of soft crash**

Soft crash was developed to protect the developed target vehicle from the collision. Soft crash should absorb and disperse the collision energy generated from the collision enough and guarantee the safety of testing and target vehicles by minimizing the impulsive force. Soft crash was developed to be installed at the height that the actual vehicle collides at the position of the bumper. As the position of vehicle frontal bumper ranges from 220mm to 720mm generally, soft crash was installed at the position that is suitable for that. Shock absorber and sponge were used to absorb the shock generated from the collision. 4 shock absorbers were used and two of them were installed to disperse the shock by mounting at the height of 220mm and 700mm. They were developed to relieve the first shock and prevent the damage of the bumper against the collision of metals as the sponge was attached to the rear side of shock absorber in case of vehicle collision.

![Figure 1. Layout of target vehicle.](image1)

![Figure 2. Control server and program of target system.](image2)

**Performance evaluation of target vehicle**

The specific track was composed for autonomic driving control algorithm performance evaluation for the developed target vehicle and one time of decelerating section and double lane change section were applied. And, in case of target speed, it was set as 45km/h for whole areas except the decelerating section. Its results were shown in Fig. 4 and Fig. 5.

Looking into autonomic driving control algorithm performance evaluation, it was known that the specific steering angle was input properly to track the designated route in real vehicle evaluation and the designated route was tracked as the result. But, it was recognized that the vehicle slightly got out of the coordinate of the designated way-point. It was judged that it came from GPS error generated from the influence of various surrounding environments including weather considering the characteristics of real vehicle that tracks the reference path based on the position of the vehicle that was input GPS actually.
Real vehicle test of active vehicle

Real vehicle test was carried out using the developed target vehicle. The AEBS-adopted vehicle was selected as test vehicle for the test and the test was composed by mounting soft crash to the target vehicle (See Figure 4). The scenario used in the test was carried out at the difference of relative velocity of 10km/h in the condition of 0, 20, 30, 40km/h based on the speed of target vehicle in cut-in situation and it was programmed to implement cut-in and generate the steering at the time when TTC (Time To Collision) of both hunter vehicle and target vehicle became 4 seconds in case of cut-in scenario (See Figure 5). Looking into the test result of 40km/h, it was known that the speed of target vehicle kept 40km/h and the trigger was generated at the point when TTC of testing vehicle became 4 seconds in the test procedure. It could be checked out that TTC increased in a moment due to braking of testing vehicle at the testing time of 35 seconds. And, looking into the change of steering angle, it was checked out that steering began at the same time of generation of trigger and cut-in completed after 3.5 seconds (See Figure 6).

Figure 4. Active safety car test environment.

Figure 5. Cut-in scenario for the test
DISCUSSION

Looking into the results of real vehicle test, it could be recognized that AEBS of testing vehicle operated approximately 5 seconds after target vehicle began to cut in, however, it was known that it performed the given scenario correctly. And, it was recognized that cruise driving of target vehicle could be performed well at the speed of 35~40km. The objective of target vehicle was to perform the testing situations correctly and repeatedly, however, it was regarded that such things could be satisfied well. And, it did cut in at TTC 4 seconds and finished cut-in in 3.5 seconds in respect of scenario, however, it was too much slow cut-in. TTC that began to cut in was needed to be performed in the reduced time to produce the more realistic accident situation and it was considered that the faster cut-in could be available by increasing the steering angle. It was considered that the additional performance improvement of vehicle and more precise speed control were required for that.

CONCLUSIONS

The scenario to be applied to this study was selected to evaluate the active safety performance of active safety vehicle by investigating the projects of Europe that analyzed real accident data. The target vehicle was developed to represent the accident situations of such scenario and the developed vehicle performed the test that conducted the designated scenario to verify the unmanned driving performance. As the results of test, it was checked out that it followed the route correctly in unmanned driving. It was checked out that it performed the scenario correctly by conducting the test that used the real vehicle. And, it was also checked out that the actual accident situation whose cut-in time had to be shortened could represented by increasing lateral acceleration through the additional performance improvement. It is planned that system stabilization of system developed in this study and the research of the target vehicle that is capable of collision at high speed will be carried out continuously, the integration test of active safety vehicle will be possible hereafter if the system and methodology for the test are developed, and it is expected that it would suggest the more clear standards for consumers to choose the vehicles.
ACKNOWLEDGEMENTS

This research was supported by the Ministry of Land, Infrastructure and Transport. It was also supported by the Korea Agency for Infrastructure Technology Advancement(Project No.: 13PTSI-C054118-05)

REFERENCES