Concept for an IPG CarMaker-Based Formula Student Simulator for Driver Training

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Introduction

The Institute of Automotive Engineering (FZD) at Technische Universität (TU) Darmstadt in Germany supports the Darmstadt Racing Team (DART Racing) and offers an Automotive Engineering Summer Study Abroad Program to UB Mechanical Engineering students. DART Racing participates in the Formula Student Electric (FSE) competition with a race car which is designed, developed, and manufactured by the team. The DART Racing FSE car is a single-seat, open-wheel formula car which participates in several "static" and "dynamic" events that demonstrate the car's capabilities. There is no on-track practice allowed prior to the competitions, so the only way for a driver to become familiar with the track before competition is to walk around the track. DART Racing has identified a driving simulator as a possible solution to the problem of severely limited track knowledge. If the driver can practice on a simulated track, he or she will become familiar with the layout of the track and perform better during competition. In addition to learning the tracks, a simulator will allow the drivers to better learn the race car, as overall testing and training time is also very limited. Faster laps in the dynamic events will increase the overall score and competitiveness of DART Racing.

Driving simulators were first developed and used in the 1950s and 1960s as a lower-cost alternative to highway driving tests. Simulators remove the need for a driver model and replace it with a real driver in the simulation. Having been significantly developed since then, driving simulators can be used in racing contexts to both train drivers and simulate race car setup changes. Race tracks can be quickly loaded into a simulator in which a driver can "drive" a customizable car around a simulated version of the desired race track, allowing the team to practice the race before it happens.

Objective

DART Racing required a simulator to train race racing drivers, encourage familiarization with vehicle characteristics, and to help teach specific tracks in preparation for competition events. The objective for this Advanced Design Project (ADP) was to develop hardware and software concepts for a Formula Student driving simulator that are based on systematically generated requirements. The feasibility of an IPG CarMaker based solution was investigated. Ultimately, this ADP was tasked with adapting the IPG software to fit a real-time, human-in-the-loop driving simulator application.

Methodology

Completion of the ADP followed a V-Model engineering method. This method is demonstrated visually in (Figure 1), below.
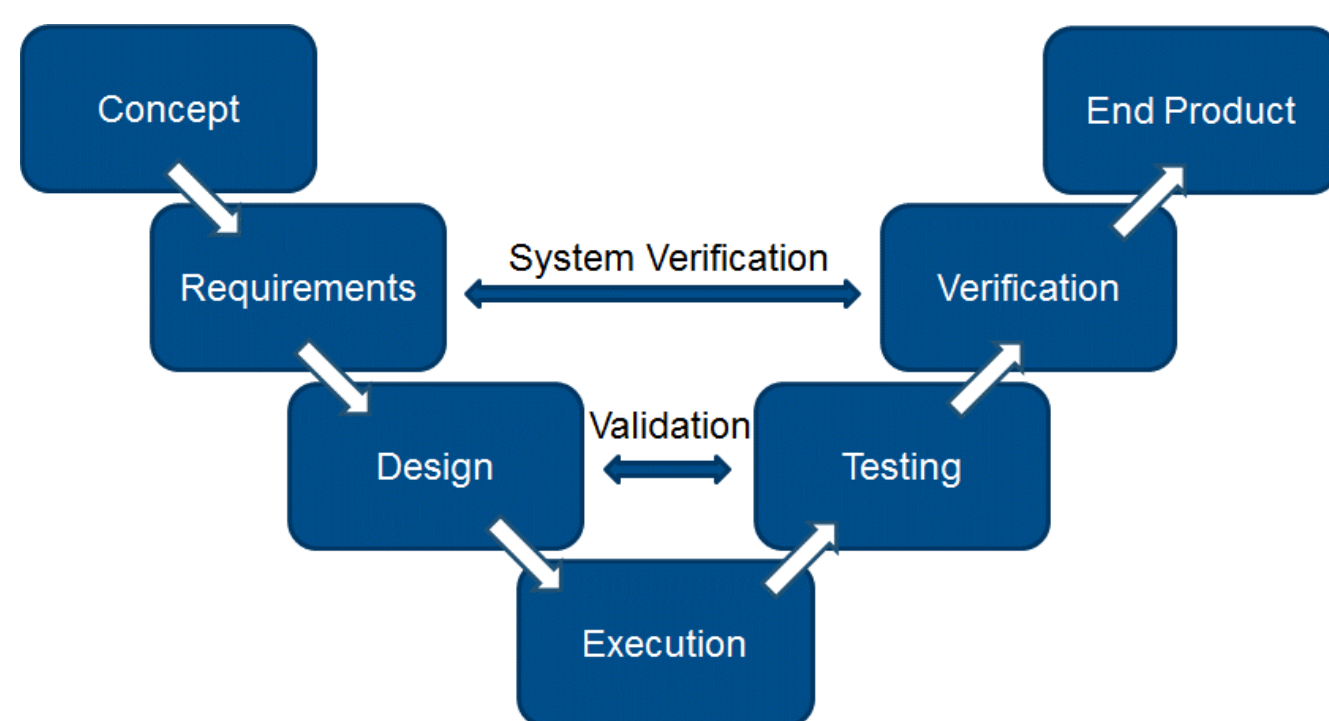

Figure 1: V-Model Engineering Method

In the concept phase, investigation of historical precedents in the field of automotive simulators and their relevance to this project was conducted. This included important information pertaining to human interaction with the simulator, especially with regards to simulator sickness and means of mitigating performance issues. This phase also involved the development of requirements and customer needs. The relevant constituents were identified, and through question-and-answer sessions, email correspondence, and other information gathering sessions, the needs were defined.

Development of the system involved experimentation within the IPG CarMaker interface, as well as within the MATLAB Simulink environment. Initial testing led to the knowledge needed to work around the built-in system, and ultimately to develop the desired simulator for this design project. With the necessary knowledge from the Simulink experimentation, the development of the simulator simply required accurate implementation of the driving system.

Investigation and Review

The investigation phase of this project revealed critical information against which this project needed to be evaluated. These primarily stemmed from research into simulator sickness, a form of motion sickness. Symptoms are a result of differences between expected visual and physical clues, and those seen on the projected surfaces. These differences are usually caused by a discrepancy between visual perception, tactile perception, and a stationary frame of reference. Different people have varying levels of tolerance to motion and simulator sickness making it difficult to predict how much sickness a simulator might cause each individual. The quantifiable triggers for simulator sickness are primarily as follows:

- A frame rate of higher than 25 fps as a minimum
- A field of vision between 50 and 180, with 120 being optimum
- Video latency of fewer than 30 ms

Development

The development of the coding component was the most difficult task faced during this design project. Before the actual MATLAB Simulink system could be developed, the IPG CarMaker components needed to be reverse-engineered, so as to allow for modification of certain components. This component proved difficult, and nearly ended the ADP prematurely. However, upon careful examination, and much persistence, a breakthrough occurred in the IPG CarMaker Simulink interface. This can be seen in (Figure 2) below.
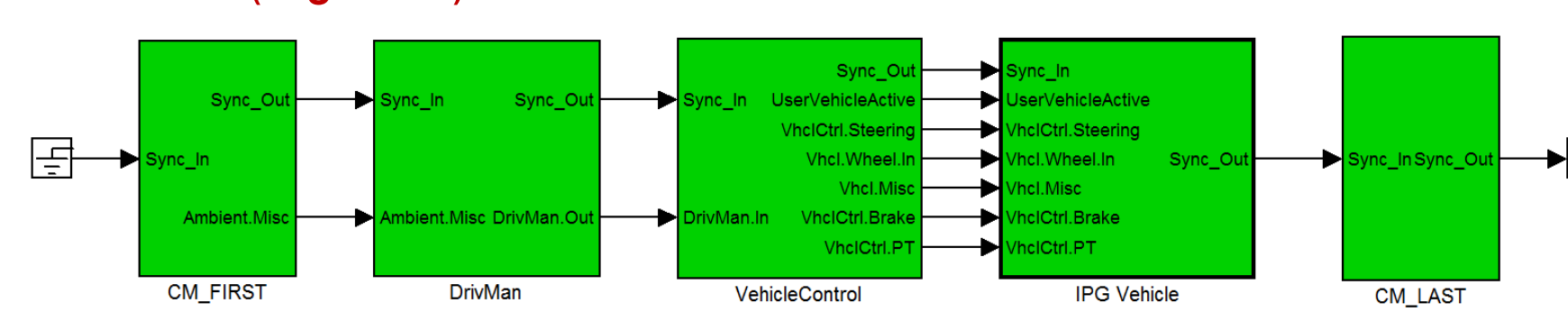

Figure 2: IPG CarMaker Default Simulink Blocks

It was found that, by modifying the control block, "VehicleControl," the computer-controlled car behavior could be overrode and replaced. To prove this, initial testing was performed using constant gain blocks on critical components, such as acceleration and brakes. Upon favorable results, development continued with joystick blocks, rather than gains.

Once the simulator performed satisfactorily, peripheral elements were developed. These included an automatic course generator, which converted GPS coordinates to track coordinates for use in IPG CarMaker, and a visual model for the vehicle.
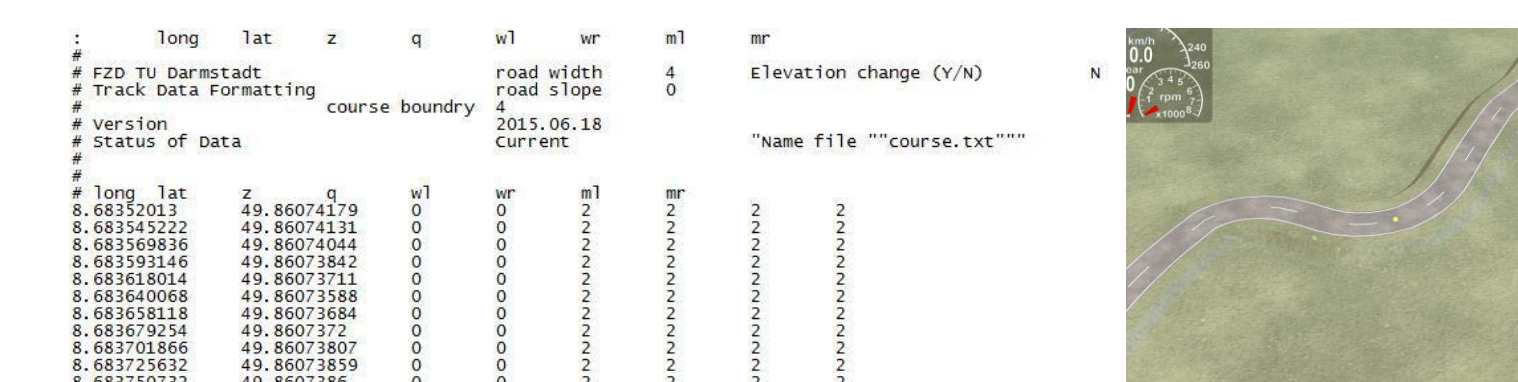

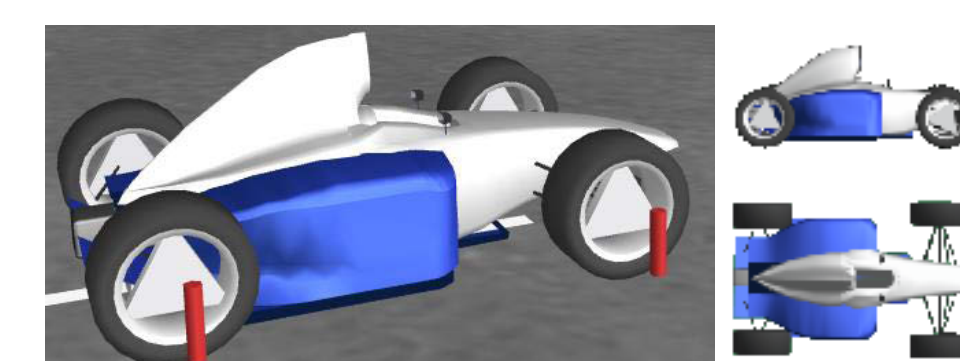Figure 3: GPS Coordinates, and In-Simulator Track, Post-Processing

Figure 4: Sample Vehicle Visual Model for use in the Simulator

Final Product

The final product is a fully functional racing simulator, including the capability to tune the vehicle, develop test tracks from data acquired on a race-day track walk, and the ability to implement new visual models from common CAD model formats.

Figure 5: In-Simulator Screenshot during FPS Testing

Testing of the product revealed satisfactory performance in terms of frame rate and customizability. It also revealed that, more research is needed to implement force-feedback. However, one glaring problem was discovered, namely unsatisfactory latency. Visual latency was tested by setting up the simulator with both an overhead projector and a computer monitor, and performing a normal test drive. During the drive, a high-speed camera recorded a shot including the steering wheel, the monitor, and the projection screen. As maneuvers were initiated and ended, the time between the actual input, the monitor output, and the projector out was filmed, and later analyzed frame-by-frame. From this test, the following plot was generated.
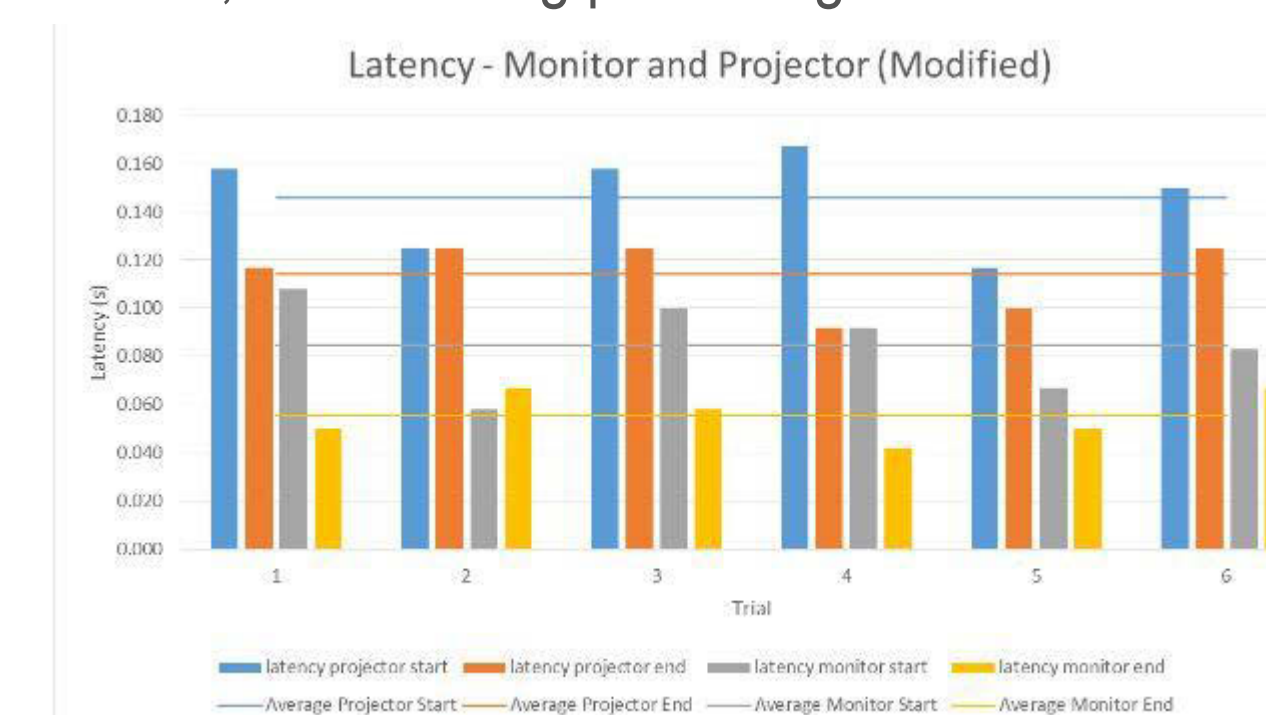

Figure 6: Results of Latency Test

While none of the test drivers reported adverse health impacts, it is important that this result is minimized through future development. This can be done by upgrading the hardware used.

Conclusion

The development team achieved a working simulator by combining the driving simulation capabilities of IPG CarMaker with driver input hardware via MATLAB Simulink. This means that the simulation can be easily adjusted while remaining highly realistic. Customer needs and functional requirements that were generated from research and interviews guided this design. The capabilities of IPG CarMaker were examined to verify that a Formula Student Electric car could be simulated, then Simulink models were adapted to facilitate real-time driver input into IPG CarMaker. The IPG CarMaker model and Simulink interface will require refining to model the DART car at a high level of accuracy, but in its current state, the driving simulator can be used for driver training. With further software development, the simulator could be used as a design simulator to help DART Racing design their cars. DART has expressed positive feedback about this IPG CarMaker-based simulator and believes that it will increase their competitiveness in Formula Student competitions.

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Acknowledgement