Simulink: Model based design to simulate real world systems

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The Michigan Tech team is one of the 17 teams competing in the EcoCAR challenge to build an eco-friendly hybrid car which besides being fuel efficient, also keeps the consumers interest in mind. The team is comprised mainly of under-graduate members from different engineering disciplines and a couple of graduate students. This paper will outline the beginning of the use of Matlab-Simulink, the challenges that were present from the very beginning and how each and every member was motivated and were able to contribute to the best of their ability.

The faculty advisor, Dr. John Beard, joined the hybrid vehicle competition team (FutureCar) in 1997 and introduced the team to modeling techniques to accurately predict vehicle performance. "While the first set of models helped the team minimize "trial and error" powertrain sizing, FORTRAN was the code development platform and required enormous time commitments to develop and verify software with pseudo-commercial robustness" says Dr Beard.

At the beginning of FutureTruck, the team shifted to Matlab for engineering software. All of the engineering analysis from fastener sizing to total vehicle performance models were developed in Matlab. The software was validated, used for multiple years, decreased the vehicle design time and improved the team's ability to predict component and vehicle performance. Although this was a vast improvement over FORTRAN, the implementation of SIL by the team was not possible and no Simulink modeling was being performed.

At the first Mathworks Boot Camp and Kick-off Workshop for Challenge X, the MTU team saw the potential for Model Based Design. At the first MTU team meeting in the Fall, Simulink was introduced to the entire team and a plan was developed to teach Simulink fundamentals.

"We came back with lots of enthusiasm, good ideas on model development and assignments for the entire class" explained Dr Beard. "As an experienced educator, I should have known better that to jump right to the ODE's, especially when a student asked "why are there dots over the X's.?" After the initial crash and burn, the team slowly gained skills in model based design." By the last year in Challenge X, the team members had discovered the advantages of using Simulink for other classes and they were now teaching it to the underclassmen."

Dr Beard added "Now that team members were able to save time in other classes, we re-introduced Simulink to the EcoCAR team, but with a much better educational plan. Our goals was to develop the initial model from first principles, starting with the free body diagram of a vehicle and the differential equations governing it. However, prior to attempting building the entire car in Simulink, we started with smaller problems and gained a decent skill level."

Challenge:

One of the big challenges in the first year of EcoCAR competition is the control strategy of the vehicle. "Control, Control, You must learn Control" is an adage that has been made famous by Master Yoda and the Michigan Tech team has made sure that it lives up to the challenge of creating a robust, efficient and reliable control strategy. A part of the control strategy involved the creation of individual components of the hybrid vehicle and integrating them together to finally perform a software-in-the-loop simulation.

The first year of EcoCAR challenge involved the development of the hybrid vehicle model in Simulink. The development of the entire model in turn needed the construction and design of the individual components that make up the hybrid car.

Solution:

"We used the old "crawl, walk, run method" and by the time we developed the actual hybrid math model, the students could envision how we would do this in Simulink" Dr Beard points out. "This let us take a set of equations that normally scare the team and build a Simulink solution quickly and have confidence in the solution. Simulink really accelerated our design process, built confidence in many team members (the business students are still scared) and got us over the HIL hump."

Simulink has many blocksets like Simdriveline, Simscape, Simpowersystems etc. Each of the blocksets are equipped with most of the commonly used blocks that are used on a regular basis. Praveen, the EE graduate student working with all the sub-teams comments "Instead of typing out and solving rigorous differential equations, Simulink provides a basis for programming by already creating the mathematical equations required to describe a particular vehicle subsystem. The team could appreciate the ease of coding offered by Simulink blocks, as the initial approach was to create mathematical functions to define different vehicle components. This approach led the team to understand the physics and math behind the model and made it easier for everyone to grasp the working of each subsystem and a complete view of the entire model."

Understanding the working of the model helped the team to design the control system needed to keep the vehicle running in its most efficient state. The main aim of the controls team is to ensure that the system operates in harmony with each of the subsystems performing the tasks that its supposed to do under the constraints that is being applied. The controls were developed with the aim of running the vehicle to give us the maximum fuel economy but not compromising on the drive quality. The system of utilizing the battery and electric motor effectively to ensure that under different driving conditions, the vehicle operates as per the wishes of the driver and does not create any undesirable responses from the subsystems.

"Control is a very important task for the first year of competition. It has been a great learning experience for the whole team. With the guidance of our advisor, Dr. John Beard, we looked into the underlying equations that govern the drive dynamics of a vehicle. With this knowledge the team was prepared to use the Mathworks toolboxes made available to us." explains Adam Bono, the controls team leader "With the multidiscipline team members we were able to tackle the mechanical and electrical modeling while producing a control for the vehicle. With our architecture in mind the team utilized Stateflow as a means of providing the supervisory control for the driveline components."

The Mathworks team has been really helpful, especially our mentor Kerry Grand, who has conducted webinars for the group and has assisted us immediately every time we ran into a hurdle that we could not immediately leap over.

Results:

Accurate modeling of the car behavior: Using our model that was developed using simulink, after including factors like rolling resistance and air drag, we predicted coast down times for a Chevy Malibu that came really close to the actual value for a practical coast down run.

Engineering experience that lasts a lifetime: Many students from the group have obtained jobs in leading automotive companies based on their engineering knowledge that developed while working with the team. Some students give regular feedback even after working for a few years that gives valuable insight to the current team members.

Saves time and effort: Using model based programming not only develops and aids the knowledge of the whole team but also reduces the amount of time that would otherwise go into modeling a vehicle to such a great detail. Model based simulation and calibration have surely come a long way from the days of FORTRAN.