AC 2010-1979: UNIVERSITY STUDENTS COACHED BY DSPACE MODEL AUTOMOTIVE CONCEPTS USING HARDWARE-IN-THE-LOOP

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Abstract

The development of prototype vehicles using conventional automotive test procedures on an actual vehicle is both expensive and time-consuming. Engineers are increasingly using modeling and simulation tools to aid in the overall Road-to-Lab-to-Math (RLM) development process which strives to bring engineering design and assessment out of the physical world and into the virtual environment. One such tool widely used by automotive powertrain engineers is hardware-in-the-loop (HIL) testing. HIL uses some of the vehicle's actual computer control units and inserts them in a control loop with a computer-based simulation platform which simulates response of actual vehicle components, such as the engine, transmission, and battery. dSPACE is the premier developer of automotive development tools, including HIL technologies, and is a sponsor of EcoCAR. Their engineers are coaching the Mississippi State University team so that the students can take full advantage of these advanced capabilities, including HIL hardware and software donated by dSPACE. The showcase laboratory is an invaluable tool to student engineers involved in the vehicle development process for EcoCAR, and is an asset to the automotive instructional program at Mississippi State University. The breadth and depth of students' understanding of this development tool has already been greatly enhanced.

Introduction

EcoCAR: The NeXt Challenge is a three-year, student-led engineering design competition which challenges 17 universities from across North America to develop solutions to common technological issues facing today's automotive industry. This will be done by redesigning a stock 2009 Saturn VUE as a hybrid, thereby improving the vehicle's fuel efficiency and emissions, while maintaining or enhancing its level of utility and consumer acceptability.

Teams are provided a wide range of components and tools from an array of competition sponsors. The competition is headline sponsored by General Motors (GM), which is providing the platform vehicle, and the United States Department of Energy (DOE). There are also numerous other competition sponsors, including dSPACE Inc., which is a leading developer of automotive controls development tools. Their tools allow engineers to test and validate automotive control components and strategies in the lab, before prototype vehicles have to be developed. This speeds up the development process, and allows for a better finished product through more thorough design. It also saves a substantial amount of cost by allowing components and architectures to be simulated through a virtual environment, as opposed to developing prototype platforms or test stands.

A specific part of the controls development technology offered by dSPACE is hardware-in-the-loop (HIL) simulation. This is a model-based simulation method, which allows testing and validation of actual vehicle hardware, such as electronic control units (ECUs). The ECUs are connected to an HIL simulator via a production-style wiring harness, and vehicle plant models are loaded onto the simulator. dSPACE's software tools can then be used to provide inputs to

the control strategy, such as accelerator or brake pedals. The control strategy is simulated through the HIL chassis as though the ECU was driving a real vehicle.

HIL Test Bench Development

dSPACE has generously provided several EcoCAR teams with multiple advanced simulation toolsets with which to develop their vehicles. Mississippi State University (MSU) has received a mid-size HIL simulator chassis, along with dSPACE's MicroAutoBox ECU. These two components are very powerful and represent the best controls development technology available today. In addition to this hardware, dSPACE has also provided its full suite of software development tools, including ControlDesk and Real-time Interface, AutomationDesk, MotionDesk, TargetLink, and SystemDesk. Together, these tools allow controls system testing and validation which would otherwise be impossible.

MSU's hardware-in-the-loop test bench composed of dSPACE donated components

To take full advantage of these tools, Mississippi State University has set up an HIL test bench in the electronics lab of its Center for Advanced Vehicular Systems. This test bench allows students to learn and apply the tools while developing their EcoCAR vehicle. It uses the HIL simulator chassis, along with a MicroAutoBox and student-developed wiring harnesses. The system is controlled by a Sun PC with a high-end graphics card and two 24.1 in displays. The test bench is set up on an 8-foot work top, which allows room for testing external loads and developing the wiring harnesses. It is located in an electronics lab with access to tools for building the wiring harnesses. This test bench has already proven to be invaluable to the team in developing their EcoCAR vehicle.

Training

To aid in teaching EcoCAR students how to use its products, dSPACE has twice hosted workshops at their North American headquarters in Wixom, MI. The most comprehensive training took place at the EcoCAR Winter Workshop during January of 2009. The teams were presented with their HIL chassis and MicroAutoBoxes and subsequently received three days of hands-on training on their specific machines. The learning experience was aided by the fact that the training was done by the same dSPACE engineers who were assigned to be team mentors. The students learned about all of the dSPACE software, including ControlDesk and MotionDesk, and were given a demonstration model to practice on.

Students have also been trained through a Model Based Systems Design class offered at Mississippi State University. In this class, the students were trained using tools offered by The

MathWorks, such as Matlab and Simulink. These programs are the basis for the dSPACE software suite. In this class, students were given projects which required them to develop component models and integrate them into an HIL simulation. For example, one group modeled an electric traction motor by setting up and instrumenting the motor on a dynamometer. This model was then used as part of a larger cooling system model which allowed for testing of controls designed to regulate vehicle component temperatures.

MSU EcoCAR Applications

dSPACE Sr. Applications Engineer Jim Hollowell, a mentor to the MSU EcoCAR team, said simulation technology is especially beneficial to EcoCAR teams because they do not have the time or resources to test their control strategy on individual components before putting them in the vehicle.

> "dSPACE tools are helping the team to develop their controls, testing, and failsafe strategies. Developing these strategies on dSPACE tools saves time and allows critical development to be done long before the vehicle and components are available and installed on the vehicle. When the vehicle and hardware become available, much of the critical development work is already completed. Trying to develop all of these strategies on the real vehicle, perhaps with much 'trial and error', would be difficult and costly, and most likely would have to be done in a very compressed time schedule.
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> "Generally most 'real' vehicle development cycles are less than two years," Hollowell continued. "Often real prototype cars are only available during the second year, so time saving is critical and big cost savings are a benefit of dSPACE tools."

The MSU EcoCAR team has been using their test bench to develop a vehicle model for their hybrid VUE. This will allow the team to try different control strategies and measure the results over different standardized drive cycles, as well as custom drive cycles and even real-time inputs. dSPACE also offers fault simulation capability, which allows students to test and analyze fault detection of their controller.

Preparation for Industry

Perhaps the greatest benefit to students from this partnership has been the ability to gain experience in tools which will carry directly over into industry. Not many students get the opportunity to learn vehicle development tools which are used throughout the automotive industry during their education. Having experience with hands-on tools such as this will make EcoCAR students especially attractive to employers. MSU has placed a number of graduates in modeling and simulation jobs in the automotive industry since the inception of this program. Previously, the university had very little representation in that field. Response from those graduates has been that they feel they are better prepared for industry than most of their fellow graduates. The team has also had success recruiting engineers to enroll in graduate school for the purpose of furthering their knowledge of advanced simulation methods such as HIL. These graduate students are required to take a leadership role, guiding and training undergraduates through the framework of the EcoCAR competition.

Conclusion

The opportunities afforded to MSU's EcoCAR team through dSPACE's generous donation of hardware, software and support are immeasurably beneficial to the team. HIL represents the leading edge of automotive controls prototyping technology. The practical experience in real-world industry tools gained through the use of their products is invaluable to the team's engineering students. Use of these tools has also inspired further growth of advanced simulation programs, such as a class in model based systems design. MSU's HIL simulation test bench is being used to develop and test a control strategy for their plug-in hybrid Saturn VUE. Thanks to help from competition sponsors like dSPACE, MSU EcoCAR team students are being trained in automotive technologies that are used throughout the industry.