Title: Integrated Algorithms for Optimal Energy Use for Mobile Fluid Power Systems

University of Minnesota
Professor Kim Stelson
Jonathan Meyer

As a society we have become dependent on fossil fuels, especially for transportation. Hydraulic hybrid vehicles show promise for greatly reducing fuel consumption. However, the best way to control these vehicles is still unknown. The goal of this project is to find the best way to control a hydraulic hybrid vehicle to minimize fuel consumption while maintaining performance. The focus is on passenger vehicles, the largest segment of the transportation sector. A small improvement in efficiency can lead to a large impact in overall fossil fuel demand. Hydraulic hybrid vehicles are studied, since the high power density of hydraulics means that hydraulic hybrid vehicles will have better performance than electric hybrid vehicles.

An hydro-mechanical architecture with energy regeneration was chosen, an approach that could potentially be better than either parallel or series approaches. Unlike the parallel approach, the hydro-mechanical approach decouples the engine from the wheels allowing efficient engine management. Unlike the series approach, the hydro-mechanical approach allows efficient transmission of power since it combines mechanical and hydraulic power transmission.

This project uses a three-tier approach to solve the control problem. The highest tier is the energy management level, the focus of this study. The energy management strategy (EMS) is responsible for planning which mode the vehicle should operate in given the current vehicle state. This is done offline using dynamic programming with a model that contains limited dynamics to minimize computation. Results show that a 50% improvement in fuel economy can be achieved over a baseline control strategy by optimizing the EMS. A feedback controller is subsequently developed to ensure that the vehicle follows the driver's command. Both the EMS and feedback controller are then implemented in a dynamic simulation of the vehicle to determine how the vehicle will respond. If the EMS and feedback controller are successful in simulation, they are implemented experimentally on the hydraulic hybrid vehicle to validate the simulation results.

One limitation of dynamic programming is that it results in an acausal control law, that is, a control law that requires knowledge of the future. This means that the optimal control can not be implemented. A causal controller approaching the performance of the optimal acausal control must be found. This limitation can be overcome by using stochastic dynamic programming. Although the future can not be known, the statistics of the future can be known. Using these statistics, stochastic dynamic programming develops a control law that can be implemented in real time, without requiring exact knowledge of the drive cycle.