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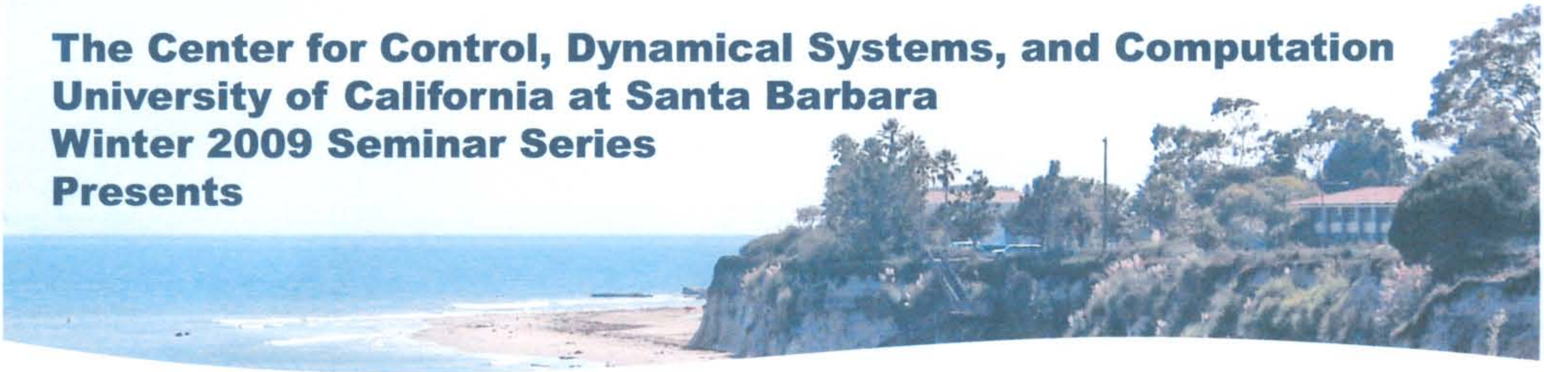
Presents



Optimal Control of Heavy-Haul Freight Trains to Save Fuel

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Abstract:

Fuel burned by North American Class 1 railroads in diesel-electric freight service in 2007 exceeded 4.1 Billion gallons, resulting at 2007 fuel prices, in 13% of overall operations expense1. Trends in fuel prices, ignoring the present hiatus due to the economy, are only upward. As more freight shifts to rail directly and via inter-modal truck/train haulage to leverage incredible efficiency of rail transit compared to other modes, total fuel usage will accelerate. This presentation describes a software control system applicable to diesel-electric locomotive hauled freight that can achieve double-digit fuel savings. Energy savings derive from managing train momentum, with anticipation of its effects, to reduce the net energy outlay by the train as it completes a trip. GE's system has two major components: the first is a planning system that derives an optimal way to drive the train (throttle together with a corresponding speed trajectory versus distance) subject to speed restrictions along the route and locomotive operating constraints; the second component is a dynamic control system that executes the plan closed-loop, correcting for modeling errors from various sources and assuring safe train handling. We'll show how this reduces to a familiar two-point boundary value problem in optimal control. Solving this optimal control problem requires a simplified model of the physics of motion and a highly efficient optimization algorithm. Key features of the algorithm are ability to optimize for minimum fuel subject to a desired arrival time (pacing) or to minimize travel time, and in both cases to assure safe train handling. A closed-loop dynamic control regulator system takes the optimal solution and corrects for various disturbances and model errors. Location along the track route is derived from GPS blended with on-board measurements in a Kalman filter. The resulting software was rapid prototyped 100% in a Matlab xPC platform, installed in locomotives on various railroads in live revenue service. This enabled quick proof of projected benefits and was a major factor in the decision to commercialize the system, which GE calls, "Trip Optimizer". The talk will present field test results using the system prototype in revenue service on several North American railroads, where savings exceeding 10% were successfully demonstrated on trains hauling between 3000 and 19000 tons. Finally, some lessons learned about taking complicated controls ideas from concepts to commercial products are summarized.

About the Speaker:

Paul earned his B.S. from Syracuse University, his M.S. from New York University, and his Ph.D. from M.I.T., all in Electrical Engineering. From 1966-1970, he was a member of technical staff in the Power Systems division of Bell Laboratories, in Whippany NJ. At Bell an assignment to develop a fuel-optimal control strategy for the Apollo lunar lander spawned a life-passion for controls. He was a post doc in MIT's Laboratory for Information and Decision Systems from 1974-1978, where his research focused on freeway traffic control and model-based highway incident detection. Paul transitioned to the Mechanical Engineering faculty at MIT in 1978 as Detroit Diesel Allison Assistant Professor, where his research and teaching concentrated on control systems for vehicular propulsion systems (gas and diesel engines), wind-power generation and manufacturing process control. Since 1985, has been associated with the Automation and Controls Laboratory at GE Global Research, where he was recently promoted to Principal Engineer, Controls.