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BART and Sandia: Fellow travelers in transit technology

Sandia algorithms can help smooth subway rides with new train control techniques

By Nancy Garcia

The Bay Area Rapid Tansit System, BART, will be unique among subway systems to employ a radio-ranging technique, originally developed by Hughes to help locate tanks of friendly forces on the battlefield, when it begins to bring a new train control system on-line in the fall.

Called the Advanced Automatic Train Control system, or AATC, it will use radio communication between wayside control computers and trains to provide train location, smooth and precise speed control, and efficient power usage. BART is partnering with Harmon Industries to develop and implement the advanced system, as well as with Raytheon, which took on the radio-ranging work from Hughes.

BART currently uses the most common automatic train control method, in which circuitry in the train tracks is used to locate and communicate with trains. With the existing control system, BART can only command trains to travel at eight speeds between zero and 80 mph, and a train can be located only to an accuracy of several hundred feet.

In the future, the new AATC system will allow more precise speed control, at 1 mph increments, with new commands issued as often as half a second apart, says systems analyst Susanna Gordon (8112), who has collaborated with BART for more than five years, along with other Sandians. She recently became the program manager of an ongoing cooperative research and development agreement with the transit agency. Richard Wheeler (8112) preceded Susanna as program manager prior to taking a Washington, D.C., assignment.

Controlling trains' voltage variations

In the partnership, Susanna worked with software designer Timothy Sa (8114) to model the traction power system that powers the trains. They integrated the model with an existing simulation of the train control system developed in BART's in-house R&D department. This simulation testbed allowed analysis of advanced train control techniques and their impact on energy efficiency and power availability. Train voltage, for example, fluctuates due to train activity in a fashion that is not simple to predict. Working with Don Sheaffer (8416) to develop advanced-logic neural networks, Susanna provided an approach that reliably estimates voltage available based on train activity and controls trains so as to avoid low voltages.

This was an issue, she says, because BART wanted to prevent low voltages in the transbay tunnel. BART originally worked with Sandia to investigate the feasibility of adding an energy storage device in the four-mile-long tube that traverses the San Francisco Bay. Susanna was funded through DOE's Energy Storage Program to analyze the source and extent of the power problem and see if an energy storage device was a solution. She showed that the issue was caused by uncommon train behaviors that demanded too much power in the tube, and wouldn't be fixed by providing the proposed extra energy supply.

More trains, closer together

The primary impetus to change train control methods is that BART's extended rail lines have led to more trains needing to merge onto the San Francisco line from all of the East Bay lines. The objective is to run trains closer together at this crossroads to accommodate the additional traffic from the extensions. The AATC system currently under development will allow for this additional traffic. It will simultaneously provide the capability to address other control-related issues such as low voltages.

The radio-control system has been demonstrated on BART's test track in Hayward and will soon be tested on a portion of the revenue track. In the future, after the AATC is fully operational, the control algorithms developed by Susanna and co-workers can be added to boost the reliability and efficiency of the system.

One such algorithm would smooth transit when trains are stacked up in a row approaching a station. Her algorithm would clear the backup without requiring each train to stop repeatedly and then re-accelerate. Instead, each would steadily approach the station in sequence. Another technique to smooth travel would permit closely spaced trains to follow at an optimal distance so as to avoid braking and re-accelerating, providing a more comfortable trip for passengers. Finally, to prevent low voltages, power use would be managed through managing acceleration, utilizing the neural network estimation of train voltages.

Although the heuristic logic employed by these algorithms was sufficient to provide significant improvements to the basic capability of the AATC system, true optimization of control may be possible in the future. Pamela Williams (8950) is working with Susanna to develop control strategies that employ optimization techniques to provide smooth service. Pamela has developed one new technique that has already demonstrated a substantial improvement in the smoothness of the ride that can be achieved by the control algorithms.

Jim Ringland (8112) has also been involved in the AATC development effort, helping to review and comment on safety aspects of the system during its development. Jim is a statistician who has also participated in safety studies as widely varying as weapon dismantlement at Pantex and the operation of hydrogen-powered vehicles.

Other Sandia/BART collaborations

Other activities in the BART CRADA collaboration include work by Jason Bowie (2251), who conducted a short study to investigate potential advanced technologies to address other BART issues, such as detection of broken rails. BART is interested in reliably detecting cracks or breaks in the tracks with a real-time detection system. The transit agency is currently working to develop an acoustic system akin to systems used to sense breaks in pipes over short distances. Wei-Yang Lu (8725) is providing his expertise in this area to BART, working with them as they conduct research on this system.

The transit background Susanna gained in this collaboration became applicable to her other work on sensing and warning architectures for protection of infrastructures, such as subways and airports, against chemical and biological terrorist attacks — a specialty in which she has recently co-authored two papers.