

Traffic-Light-Preemption Vehicle-Transponder Software Module

A prototype wireless data-communication and control system automatically modifies the switching of traffic lights to give priority to emergency vehicles. The system, which was reported in several *NASA Tech Briefs* articles at earlier stages of development, includes a transponder on each emergency vehicle, a monitoring and control unit (an intersection controller) at each intersection equipped with traffic lights, and a central monitoring subsystem. An essential component of the system is a software module executed by a microcontroller in each transponder. This module integrates and broadcasts data on the position, velocity, acceleration, and emergency status of the vehicle. The position, velocity, and acceleration data are derived partly from the Global Positioning System, partly from deductive reckoning, and partly from a diagnostic computer aboard the vehicle. The software module also monitors similar broadcasts from other vehicles and from intersection controllers, informs the driver of which intersections it controls, and generates visible and audible alerts to inform the driver of any other emergency vehicles that are close enough to create a potential hazard. The execution of the software module can be monitored remotely and the module can be upgraded remotely and, hence, automatically.

This program was written by Aaron Bachelder and Conrad Foster of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30445.

Intersection-Controller Software Module

An important part of the emergency-vehicle traffic-light-preemption system summarized in the preceding article is a software module executed by a microcontroller in each intersection controller. This module monitors the broadcasts from all nearby participat-

ing emergency vehicles and intersections. It gathers the broadcast data pertaining to the positions and velocities of the vehicles and the timing of traffic and pedestrian lights and processes the data into predictions of the future positions of the vehicles. Analyzing the predictions by a combination of proximity tests, map-matching techniques, and statistical calculations designed to minimize the adverse effects of uncertainties in vehicle positions and headings, the module decides whether to preempt and issues the appropriate commands to the traffic lights, pedestrian lights, and electronic warning signs at the intersection. The module also broadcasts its state to all nearby vehicles and intersections. The module is designed to mitigate the effects of missing data and of unpredictable delays in the system. It has been intensively tested and refined so that it fails to warn in very few cases and issues very few false warnings.

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Central-Monitor Software Module

One of the software modules of the emergency-vehicle traffic-light-preemption system of the two preceding articles performs numerous functions for the central monitoring subsystem. This module monitors the states of all units (vehicle transponders and intersection controllers): It provides real-time access to the phases of traffic and pedestrian lights, and maps the positions and states of all emergency vehicles. Most of this module is used for installation and configuration of units as they are added to the system. The module logs all activity in the system, thereby providing information that can be analyzed to minimize response times and optimize response strategies. The module can be used from any location within communication range of the system; with

proper configuration, it can also be used via the Internet. It can be integrated into call-response centers, where it can be used for alerting emergency vehicles and managing their responses to specific incidents. A variety of utility subprograms provide access to any or all units for purposes of monitoring, testing, and modification. Included are "sniffer" utility subprograms that monitor incoming and outgoing data for accuracy and timeliness, and that quickly and autonomously shut off malfunctioning vehicle or intersection units.

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Estimating Effects of Multipath Propagation on GPS Signals

Multipath Simulator Taking into Account Reflection and Diffraction (MUSTARD) is a computer program that simulates effects of multipath propagation on received Global Positioning System (GPS) signals. MUSTARD is a very efficient means of estimating multipath-induced position and phase errors as functions of time, given the positions and orientations of GPS satellites, the GPS receiver, and any structures near the receiver as functions of time. MUSTARD traces each signal from a GPS satellite to the receiver, accounting for all possible paths the signal can take, including all paths that include reflection and/or diffraction from surfaces of structures near the receiver and on the satellite. Reflection and diffraction are modeled by use of the geometrical theory of diffraction. The multipath signals are added to the direct signal after accounting for the gain of the receiving antenna. Then, in a simulation of a delay-lock tracking loop in the receiver, the multipath-induced range and phase errors as measured by the receiver are estimated. All of these computations are performed for both right circular polarization and left circular polarization of