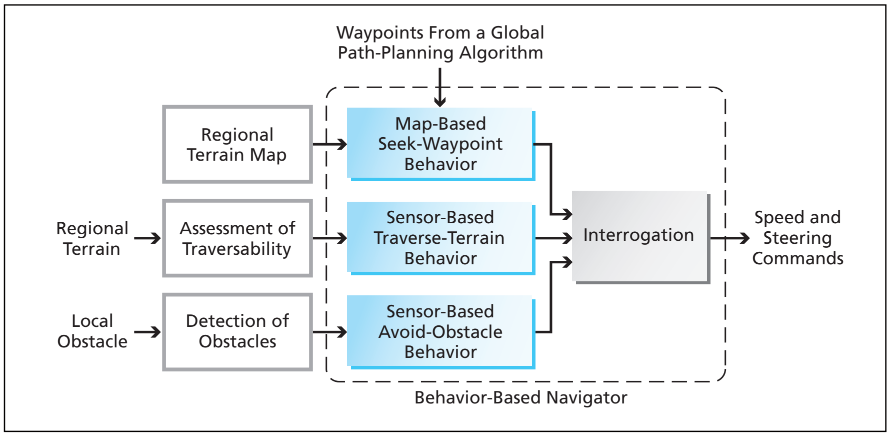
Information Sciences

Integrating Terrain Maps Into a Reactive Navigation Strategy

Traversability of terrain is taken into account as an integral part of navigation.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of processing information for autonomous navigation of a robotic vehicle across rough terrain involves the integration of terrain maps into a reactive navigation strategy. Somewhat more precisely, the method involves the incorporation, into navigation logic, of data equivalent to regional traversability maps. The terrain characteristic is mapped using a fuzzy-logic representation of the difficulty of traversing the terrain. The method is robust in that it integrates a global path-planning strategy with sensor-based regional and local navigation strategies to ensure a high probability of success in reaching a destination and avoiding obstacles along the way. The sensor-based strategies use cameras aboard the vehicle to observe the regional terrain, defined as the area of the terrain that covers the immediate vicinity near the vehicle to a specified distance a few meters away. The method at an earlier stage of development was described in "Navigating a Mobile Robot Across Terrain Using Fuzzy Logic" (NPO-21199), *NASA Tech Briefs*, Vol. 27, No. 2 (February 2003), page 5a. A recent update on the terrain classification stage of the method was reported in "Quantifying Traversability of Terrain for a Mobile Robot" (NPO-30744), *NASA Tech Briefs*, Vol. 29, No. 7 (July 2005), page 56. To recapitulate: The basic building blocks of the method are three behaviors that focus on successively smaller spatial scales and are integrated (in the sense of blended) through gains or weighting factors to generate speed and steering commands. The weighting factors are generated by fuzzy logic rules that take account of the current status of the vehicle.



The **Navigation-System Architecture** implements three behaviors that focus on successively smaller spatial scales. These behaviors are integrated to enable safe traversal of rough terrain from a starting point to a destination.

At the present state of development, the three behaviors are denoted as a map-based seek-waypoint behavior, a sensor-based traverse-terrain behavior, and a sensor-based avoid-obstacle behavior (see figure). Navigation is initiated by a global path-planning algorithm, which generates a sequence of waypoints that define an optimal path that passes through safe (that is, sufficiently traversable) regions of the terrain from a starting point to a destination. The waypoints are fed to the map-based seek-waypoint behavior, which, as its name suggests, seeks to direct the vehicle safely from the starting location to a waypoint. The sensor-based traverse-terrain behavior determines the safest regional segment to traverse on the basis of information from regional terrain images acquired by the cameras. The sensor-based avoid-obstacle behavior involves the use of local-obstacle information from the images to develop steering and speed commands to maneuver the vehicle around the obstacles.

This work was done by Ayanna Howard, Barry Werger, and Homayoun Seraji of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-30794

Reducing Centroid Error Through Model-Based Noise Reduction

Corrections are made for bias and noise.

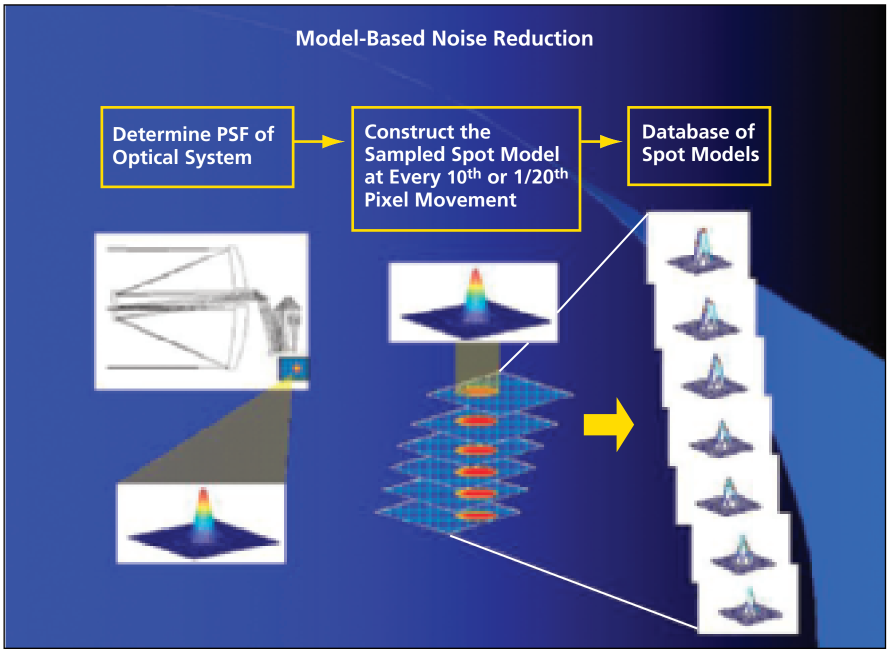
NASA's Jet Propulsion Laboratory, Pasadena, California

A method of processing the digitized output of a charge-coupled device (CCD) image detector has been devised to enable reduction of the error in computed centroid of the image of a point source of light. The method involves model-based estimation of, and correction for, the contributions of bias and noise to the image data. The method could be used to advantage in any of a variety of applications in which there are requirements for measuring precise locations of, and/or precisely aiming optical instruments toward, point light sources.

The principal sources of centroid error are bias and noise in the outputs from the pixels of the CCD. Noise consists mainly of fixed components (readout noise and noise from dark current) and variable components (pixel defects and shot noise from background light).

Bias is caused mainly by stray light and nonuniform distribution of light in a background image.

In the present method, prior to normal operations of the CCD, one measures the point-spread function (PSF) of the telescope or other optical system used to project images on the CCD. The PSF is used to construct a database of spot models representing the nominal CCD pixel outputs for a point light source projected onto the CCD at various positions incremented by small fractions of a pixel (see figure).



Spot Models are constructed from the measured PSF. The spot models are thereafter used in processing digitized CCD outputs to correct for bias and noise to refine centroid estimates.

During normal operation of the CCD, the centroid of the image of a point source of light is initially computed from the digitized CCD pixel outputs in the conventional way. However, this initial computation of the centroid is used to retrieve the corresponding spot model that was constructed earlier. Then the boundary between noise and signal is determined by comparing the spot model with the CCD pixel outputs. Pixel positions of same pixel value of the spot model and the image data in the background area are defined as the boundary. All pixels of the image data beyond this boundary are set to zero. This effectively removes the noise and bias in the subsequent centroid estimation from the corrected image data.

This work was done by Shinhak Lee of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

NPO-30585

Adaptive Modeling Language and Its Derivatives

Modeling language enables automation of the entire product development cycle.

TechnoSoft, Inc., Cincinnati, Ohio

Adaptive Modeling Language (AML), developed by TechnoSoft, Inc., is the underlying language of an object-oriented, multidisciplinary, knowledge-based engineering framework. TechnoSoft is a leading provider of object-oriented modeling and simulation technology used for commercial and defense applications. AML offers an advanced modeling paradigm with an open architecture, enabling the automation of the entire product development cycle, integrating product configuration, design, analysis, visualization, production planning, inspection, and cost estimation.

The AML framework is truly adaptive. Its successful history includes a wide variety of defense and commercial applications including aerospace, automotive, and capital equipment.

TechnoSoft has worked with the Vehicle Analysis Branch (VAB) at NASA LaRC on the development of the Collaborative Hypersonic Airbreathing Vehicle Environment (CoHAVE) built using AML. The collaborative enterprise environment of CoHAVE and its criteria-management environment are applicable to the design of NASA, military, and private commercial vehicles.

CoHAVE is applicable to the Reusable Space Transportation System's product area for evaluating the architectures of the Space Transportation Architecture Studies and Second Generation RLV Studies. Elements of this architecture include enhanced Shuttle, Reusable Two Stage to Orbit, and Venture Star (an SSTO design). Complementary to these delivery vehicles are Orbital Transfer Vehicles, Crew Transfer and Crew-Cargo Transfer Vehicles, and the Reusable First Stage Booster for Space Shuttle Upgrades. CoHAVE is platform independent and enables multiple users to collaborate across geographically-distributed, heterogeneous workstations. CoHAVE provides a comprehensive environment that facilitates the performance of concurrent engineering of hypersonic airbreathing vehicles at a level not currently available.

Recently, CoHAVE has been extended to incorporate models for other applications such as re-entry vehicles. Since the environment now includes vehicles other than traditional hypersonic airbreathing vehicles, the name has morphed into the Advanced Vehicle Integration and Synthesis Environment (AdVISE).

This work was done by Adel Chemaly of **TechnoSoft, Inc.** *under a NASA Small Business Innovation Research (SBIR) contract monitored by* **Langley Research Center**. *For further information, contact:*

Mr. Adel Chemaly
TechnoSoft, Inc.
11180 Reed Hartman Hwy.
Cincinnati, OH 45242
Phone No.: (513) 985-9877
E-mail: adel.chemaly@technosoft.com
Web site: www.technosoft.com.

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