DCS-Neural-Network Program for Aircraft Control and Testing

Ames Research Center, Moffett Field, California

A computer program implements a dynamic-cell-structure (DCS) artificial neural network that can perform such tasks as learning selected aerodynamic characteristics of an airplane from wind-tunnel test data and computing real-time stability and control derivatives of the airplane for use in feedback linearized control. A DCS neural network is one of several types of neural networks that can incorporate additional nodes in order to rapidly learn increasingly complex relationships between inputs and outputs. In the DCS neural network implemented by the present program, the insertion of nodes is based on accumulated error. A competitive Hebbian learning rule (a supervised-learning rule in which connection weights are adjusted to minimize differences between actual and desired outputs for training examples) is used. A Kohonen-style learning rule (derived from a relatively simple training algorithm, implements a Delaunay triangulation layout of neurons) is used to adjust node positions during training. Neighborhood topology determines which nodes are used to estimate new values. The network learns, starting with two nodes, and adds new nodes sequentially in locations chosen to maximize reductions in global error. At any given time during learning, the error becomes homogeneously distributed over all nodes.

This program was written by Charles C. Jorgensen of **Ames Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Partnerships Division, Ames Research Center, (650) 604-2954. Refer to ARC-14555-1.

Dielectric Heaters for Testing Spacecraft Nuclear Reactors

Marshall Space Flight Center, Alabama

A document proposes the development of radio-frequency- (RF)-driven dielectric heaters for non-nuclear thermal testing of the cores of nuclear-fission reactors for spacecraft. Like the electrical-resistance heaters used heretofore for such testing, the dielectric heaters would be inserted in the reactors in place of nuclear fuel rods. A typical heater according to the proposal would consist of a rod of lossy dielectric material sized and shaped like a fuel rod and containing an electrically conductive rod along its center line. Exploiting the dielectric loss mechanism that is usually considered a nuisance in other applications, an RF signal, typically at a frequency ≤50 MHz and an amplitude between 2 and 5 kV, would be applied to the central conductor to heat the dielectric material. The main advantage of the proposal is that the wiring needed for the RF dielectric heating would be simpler and easier to fabricate than is the wiring needed for resistance heating. In some applications, it might be possible to eliminate all heater wiring and, instead, beam the RF heating power into the dielectric rods from external antennas.

This work was done by William Herbert Sims of **Marshall Space Flight Center**, *Leo Bitteker of the University of California, and Thomas Godfroy of the University of Michigan. Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31823-1.

Using Doppler Shifts of GPS Signals To Measure Angular Speed

Gyroscopes could be eliminated, reducing costs.

Goddard Space Flight Center, Greenbelt, Maryland

A method has been proposed for extracting information on the rate of rotation of an aircraft, spacecraft, or other body from differential Doppler shifts of Global Positioning System (GPS) signals received by antennas mounted on the body. In principle, the method should be capable of yielding low-noise estimates of rates of rotation. The method could eliminate the need for gyroscopes to measure rates of rotation.

The method is based on the fact that for a given signal of frequency f_t transmitted by a given GPS satellite, the differential Doppler shift is attributable to the difference between those components of the instantaneous translational velocities of the antennas that lie along the line of sight from the antennas to the GPS satellite. On the basis of straightforward geometric considerations (see figure), it can be readily shown that the differential Doppler shift is related to the angular velocity (ω) of the rotating body by

$$f_{r1} - f_{r2} = 2f_t(\omega \times \mathbf{r}) \cdot \mathbf{a}/c,$$

where f_{r1} and f_{r2} are the instantaneous Doppler-shifted frequencies of the replicas of the ft signal received by the two antennas, $\mathbf{r}$ is half of the baseline vector between the two antennas, $\mathbf{a}$ is a unit vector along the line of sight from the antennas to the GPS satellite, and c is the speed of light.

It must be noted that the equation above can be solved to obtain only partial information about ω. However, if there are three or more antennas and if signals can be received from two or more GPS satellites, then one can form simultaneous independent equations for different pairs of antennas and different unit vectors that can be solved to obtain all of the components of ω.
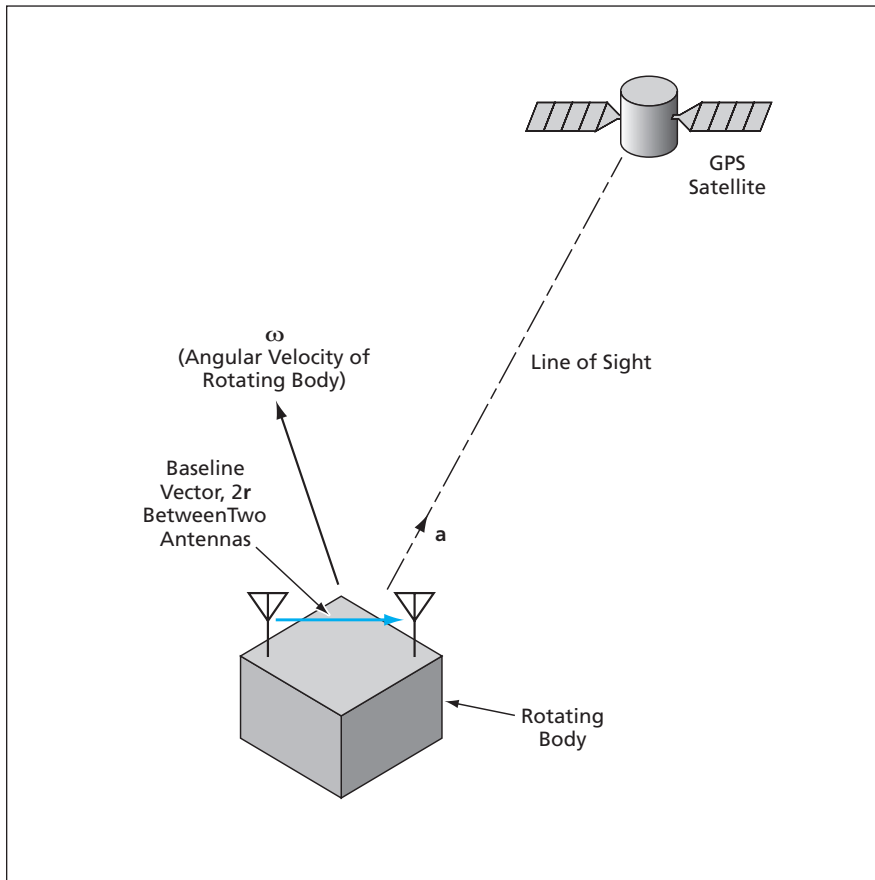
Two Antennas on a Rotating Body would have different components of velocity along the line of sight to a GPS satellite, giving rise to different Doppler shifts of the two received GPS signals.

It is assumed that the received f_{r1} and f_{r2} signals would be subjected to the usual GPS processing, including phase-shifting and cross-correlation with the applicable GPS pseudorandom-noise code for acquisition and tracking. To obtain the differential Doppler frequency $f_{r1} - f_{r2}$ for a given antenna pair and a given GPS satellite, the f_{r1} and f_{r2} signals would be fed to a multiplier. By virtue of the trigonometric identity for the product of sines of different arguments, the low-frequency multiplier output would be a sinusoidal waveform of frequency $f_{r1} - f_{r2}$. For high accuracy, the multiplier output could be fed to a subsystem containing a zero-crossing detector coupled with a counter driven by a quartz-crystal clock circuit. Such a subsystem could accumulate counts over times long enough to enable estimation of periods of rotation to within microseconds.

Monitoring Temperatures of Tires Using Luminescent Materials

Hot spots are detected and monitored as indications of local damage.

John H. Glenn Research Center, Cleveland, Ohio

A method of noncontact, optical monitoring of the surface temperature of a tire has been devised to enable the use of local temperature rise as an indication of potential or impending failures. The method involves the use of temperature-sensitive paint (or filler): Temperature-sensitive luminescent dye molecules or other luminescent particles are incorporated into a thin, flexible material coating the tire surface of interest. (Alternatively, in principle, the luminescent material could be incorporated directly into the tire rubber, though this approach has not yet been tested.) The coated surface is illuminated with shorter-wavelength light to excite longer-wavelength luminescence, which is observed by use of a charge-coupled-device camera or a photodetector (see Figure 1).

If temporally constant illumination is used, then the temperature can be deduced from the known temperature dependence of the intensity response of the luminescence. If pulsed illumination is used, then the temperature can be deduced from the known temperature dependence of the time or frequency response of the luminescence. If sinusoidally varying illumination is used, then the temperature can be deduced from the known temperature dependence of the phase response of the luminescence.

Unlike a prior method of monitoring the temperature at a fixed spot on a tire by use of a thermocouple, this method is not restricted to one spot and can, therefore, yield information on the spatial distribution of temperature: in particular, it enables the discovery of newly forming hot spots where damage may be starting. Also unlike in the thermocouple method, the measurements in this method are not vulnerable to breakage of wires in repeated flexing of the tire. Moreover, unlike in another method in which infrared radiation is monitored as an indication of surface temperature, the luminescence measurements in this method are not significantly affected by changes in infrared emissivity.

This method has been demonstrated in application to the outside surface of