Technology Focus: Sensors

Cryogenic Flow Sensor

Marshall Space Flight Center, Alabama

An acousto-optic cryogenic flow sensor (CFS) determines mass flow of cryogens for spacecraft propellant management. The CFS operates unobtrusively in a high-pressure, high-flow-rate cryogenic environment to provide measurements for fluid quality as well as mass flow rate. Experimental hardware uses an optical "plane-of-light" (POL) to detect the onset of two-phase flow, and the presence of particles in the flow of water.

Acousto-optic devices are used in laser equipment for electronic control of the intensity and position of the laser beam. Acousto-optic interaction occurs in all optical media when an acoustic wave and a laser beam are present. When an acoustic wave is launched into the optical medium, it generates a refractive index wave that behaves like a sinusoidal grating. An incident laser beam passing through this grating will diffract the laser beam into several orders. Its angular position is linearly proportional to the acoustic frequency, so that the higher the frequency, the larger the diffracted angle.

If the acoustic wave is traveling in a moving fluid, the fluid velocity will affect the frequency of the traveling wave, relative to a stationary sensor. This frequency shift changes the angle of diffraction, hence, fluid velocity can be determined from the diffraction angle. The CFS acoustic Bragg grating data test indicates that it is capable of accurately determining flow from 0 to 10 meters per second. The same sensor can be used in flow velocities exceeding 100 m/s. The POL module has successfully determined the onset of two-phase flow, and can distinguish vapor bubbles from debris.

This work was done by John Justak of Advanced Technologies Group, Inc. for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32730-1.

Multi-Sensor Mud Detection

This technology is also applicable to terrain hazard assessment in terrestrial or planetary situations.

NASA's Jet Propulsion Laboratory, Pasadena, California

Robust mud detection is a critical perception requirement for Unmanned Ground Vehicle (UGV) autonomous off-road navigation. A military UGV stuck in a mud body during a mission may have to be sacrificed or rescued, both of which are unattractive options. There are several characteristics of mud that may be detectable with appropriate UGV-mounted sensors. For example, mud only occurs on the ground surface, is cooler than surrounding dry soil during the daytime under nominal weather conditions, is generally darker than surrounding dry soil in visible imagery, and is highly polarized. However, none of these cues are definitive on their own. Dry soil also occurs on the ground surface, shadows, snow, ice, and water can also be cooler than surrounding dry soil, shadows are also darker than surrounding dry soil in visible imagery, and cars, water, and some vegetation are also highly polarized. Shadows, snow, ice, water, cars, and vegetation can all be disambiguated from mud by using a suite of sensors that span multiple bands in the electromagnetic spectrum. Because there are military operations when it is imperative for UGV's to operate without emitting strong, detectable electromagnetic signals, passive sensors are desirable.

A General Dynamics Robotic Systems (GDRS) experimental unmanned vehicle (XUV) navigates through a muddy grass field during a data collection for the **Daytime Mud Detection System**.

JPL has developed a daytime mud detection capability using multiple passive imaging sensors. Cues for mud from multiple passive imaging sensors are fused into a single mud detection image using a rule base, and the resultant mud detection is localized in a terrain map using range data generated from a stereo pair of color cameras. Thus far at the time of this reporting, JPL has:

1. Performed daytime data collections, on wet and dry soil, with several candidate passive imaging sensors, including multi-spectral (blue, green, red, and near-infrared bands), short-wave infrared, mid-wave infrared, long-wave infrared, polarization, and a stereo pair of color cameras.
2. Characterized the advantages and disadvantages of each passive imaging sensor to provide cues for mud.
3. Implemented a first-generation mud detector that uses a stereo pair of color