tion is contained in a TSP (see page 1). MSC-24492-1

Geometric Reasoning for Automated Planning

An important aspect of mission planning for NASA's operation of the International Space Station is the allocation and management of space for supplies and equipment. The Stowage, Configuration Analysis, and Operations Planning teams collaborate to perform the bulk of that planning. A Geometric Reasoning Engine is developed in a way that can be shared by the teams to optimize item placement in the context of crew planning.

The ISS crew spends (at the time of this writing) a third or more of their time moving supplies and equipment around. Better logistical support and optimized packing could make a significant impact on operational efficiency of the ISS. Currently, computational geometry and motion planning do not focus specifically on the optimized orientation and placement of 3D objects based on multiple distance and containment preferences and constraints.

The software performs reasoning about the manipulation of 3D solid models in order to maximize an objective function based on distance. It optimizes for 3D orientation and placement. Spatial placement optimization is a general problem and can be applied to object packing or asset relocation.

This work was done by Bradley J. Clement and Russell L. Knight 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 Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47436.

Water Detection Based on Color Variation

This software has been designed to detect water bodies that are out in the open on cross-country terrain at close range (out to 30 meters), using imagery acquired from a stereo pair of color cameras mounted on a terrestrial, unmanned ground vehicle (UGV). This detector exploits the fact that the color variation across water bodies is generally larger and more uniform than that of other naturally occurring types of terrain, such as soil and vegetation. Non-traversable water bodies, such as large puddles, ponds, and lakes, are detected based on color variation, image intensity variance, image intensity gradient, size, and shape.

At ranges beyond 20 meters, water bodies out in the open can be indirectly detected by detecting reflections of the sky below the horizon in color imagery. But at closer range, the color coming out of a water body dominates sky reflections, and the water cue from sky reflections is of marginal use. Since there may be times during UGV autonomous navigation when a water body does not come into a perception system's field of view until it is at close range, the ability to detect water bodies at close range is critical. Factors that influence the perceived color of a water body at close range are the amount and type of sediment in the water, the water's depth, and the angle of incidence to the water body. Developing a single model of the mixture ratio of light reflected off the water surface (to the camera) to light coming out of the water body (to the camera) for all water bodies would be fairly difficult. Instead, this software detects close water bodies based on local terrain features and the natural, uniform change in color that occurs across the surface from the leading edge to the trailing edge.

From a water body's leading edge to the trailing edge, brightness and saturation levels tend to increase, with saturation content changing at a faster rate than the brightness content. For all the pixels on a water body, a plot of brightness/saturation vs. incidence angle is fairly linear with high slope. Fortuitously, this slope tends to be higher for water than other naturally occurring terrain. This phenomenology was exploited here to develop software that detects water bodies at close range. First, candidate water regions are identified in image space by locating regions having low texture. Next, the color changes are evaluated across each candidate water region to locate those consistent with water. Finally, an ellipse fit is performed on remaining candidate water regions and size and aspect ratio filtering is applied to prune regions that geometrically are not likely to be water.

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

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-47088, volume and number of this NASA Tech Briefs *issue, and the page number.*