



Adaptive System Modeling for Spacecraft Simulation

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This invention introduces a methodology and associated software tools for automatically learning spacecraft system models without any assumptions regarding system behavior. Data stream mining techniques were used to learn models for critical portions of the International Space Station (ISS) Electrical Power System (EPS). Evaluation on historical ISS telemetry data shows that adaptive system modeling reduces simulation error anywhere from 50 to 90 percent over existing approaches.

The purpose of the methodology is to outline how someone can create ac-

curate system models from sensor (telemetry) data. The purpose of the software is to support the methodology. The software provides analysis tools to design the adaptive models. The software also provides the algorithms to initially build system models and continuously update them from the latest streaming sensor data. The main strengths are as follows:

- Creates accurate spacecraft system models without in-depth system knowledge or any assumptions about system behavior.

- Automatically updates/calibrates system models using the latest streaming sensor data.
- Creates device specific models that capture the exact behavior of devices of the same type.
- Adapts to evolving systems.
- Can reduce computational complexity (faster simulations).

This work was done by Justin Thomas of Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24419-1

Lidar-Based Navigation Algorithm for Safe Lunar Landing

This algorithm could be used as a sensor approach for navigation of autonomous air vehicles for military surveillance.

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The purpose of Hazard Relative Navigation (HRN) is to provide measurements to the Navigation Filter so that it can limit errors on the position estimate after hazards have been detected. The hazards are detected by processing a hazard digital elevation map (HDEM). The HRN process takes lidar images as the spacecraft descends to the surface and matches these to the HDEM to compute relative position measurements. Since the HDEM has the hazards embedded in it, the position measurements are relative to the hazards, hence the name Hazard Relative Navigation.

HRN processing starts with an initial elevation map from the Hazard Detection and Avoidance (HDA) phase. This map is generated by mosaicking the lidar over the Hazard Map Area (HMA). A feature selector is applied to the map to find a reference surface point that is surrounded by significant terrain relief and is therefore easier to identify in subsequent lidar images. This reference point does not have to be the landing site, and it probably won't be because the landing site should be free of terrain relief.

Next, the gimbal points the lidar sensor at the reference point and a lidar image is taken. The lidar image is converted to 3D points and these points are transformed into the local level coordinate frame using the current knowledge of the spacecraft position and attitude. These points are re-gridded into an elevation map. This elevation map is spatially correlated with the HDEM to determine the position change of the reference point in the local level frame between where it was predicted to be given the current state and its observed position when the HDEM was constructed.

The reference point is not actually moving in the local level frame, so this change in position is actually a measurement of current navigation state error growth from the time the HDEM was created. Since attitude errors are expected to be very small, the change in position of the reference point is most likely due to errors in the position of the spacecraft. This process is repeated with multiple new lidar images as the spacecraft descends.

During descent, the correlation performance degrades due to the shrinking field of view, increasing resolution and

changing in view angle. The ground sample distance (GSD) of the basemap should be no more than twice the GSD of the current lidar map. To prevent the correlation from failing, resulting in a loss of knowledge of the position error on the reference point, a new base map is generated for correlation. This new base map is created by mosaicking the lidar around the landing site. A new, higher-resolution elevation map is created from the lidar mosaic. The feature selector is applied to the new base map to generate a new reference point. Lidar images are then taken of this new reference point and correlated with the new base map.

The process of generating a new base map, then correlating lidar images to it, is repeated until the beginning of vertical descent (30 m). Each time the base map changes, it is correlated with the previous base map to tie its position to the original HDEM. This correlation introduces a fixed error to the estimate of the change in position of the original reference point. Fortunately, this fixed error is a function of the resolution of the corresponding base map, so the fixed error contribution is decreasing.