Information Technology

⊃ Certification-Based Process Analysis

Technique analyzes a process and identifies potential areas of improvement.

NASA's Jet Propulsion Laboratory, Pasadena, California

Space mission architects are often challenged with knowing which investment in technology infusion will have the highest return. Certification-based analysis (CBA) gives architects and technologists a means to communicate the risks and advantages of infusing technologies at various points in a process. Various alternatives can be compared, and requirements based on supporting streamlining or automation can be derived and levied on candidate technologies.

CBA is a technique for analyzing a process and identifying potential areas of improvement. The process and analysis products are used to communicate between technologists and architects. Process means any of the standard representations of a production flow; in this case, any individual steps leading to products, which feed into other steps, until the final product is produced at the end. This sort of process is common

for space mission operations, where a set of goals is reduced eventually to a fully vetted command sequence to be sent to the spacecraft. Fully vetting a product is synonymous with certification. For some types of products, this is referred to as verification and validation, and for others it is referred to as checking. Fundamentally, certification is the step in the process where one insures that a product works as intended, and contains no flaws.

Candidate technologies are evaluated against a potential area of improvement using criteria such as risk, adaptation cost, adaptation time, reduction in cost, reduction in duration, reduction in risk, and maintainability. Where risk and maintainability are acceptable, and gains in either cost or duration outweigh adaptation costs, then the technology is deemed a suitable candidate. For many technologies, especially artifi-

cial intelligence technologies, certification of a technology implies the certification of the process (or process step) that the technology is used for, as compared to certifying the product (using a separate process, which, for space applications, is often manual). Certifying the process, and not the product, is the key tenet of CBA.

This work gives specific direction to architects on what operations can be allowed that are not usually allowed in modifying/designing architecture with respect to technology transfer. This work applies to any production process in general, but specifically it is being applied to spacecraft operations design, planning product production, and stowage product production.

This work was done by Russell L. Knight of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47692

⊃ Surface Navigation Using Optimized Waypoints and Particle Swarm Optimization

This technique could be used in search and rescue, tracking, military scouting, navigation, and as a field resource support tool.

Lyndon B. Johnson Space Center, Houston, Texas

The design priority for manned space exploration missions is almost always placed on human safety. Proposed manned surface exploration tasks (lunar, asteroid sample returns, Mars) have the possibility of astronauts traveling several kilometers away from a home base. Deviations from pre-planned paths are expected while exploring. In a time-critical emergency situation, there is a need to develop an optimal home base return path. The return path may or may not be similar to the outbound path, and what defines optimal may change with, and even within, each mission.

A novel path planning algorithm and prototype program was developed using

biologically inspired particle swarm optimization (PSO) that generates an optimal path of traversal while avoiding obstacles. Applications include emergency path planning on lunar, Martian, and/or asteroid surfaces, generating multiple scenarios for outbound missions, Earth-based search and rescue, as well as human manual traversal and/or path integration into robotic control systems. The strategy allows for a changing environment, and can be re-tasked at will and run in real-time situations.

Given a random extraterrestrial planetary or small body surface position, the goal was to find the fastest (or shortest) path to an arbitrary position such as a safe zone or geographic objective, sub-

ject to possibly varying constraints. The problem requires a workable solution 100% of the time, though it does not require the absolute theoretical optimum. Obstacles should be avoided, but if they cannot be, then the algorithm needs to be smart enough to recognize this and deal with it. With some modifications, it works with non-stationary error topologies as well.

A novel path planning algorithm has been developed, in coordination with PSO, that generates a piece-wise linear path from a set of optimal waypoints. The path is guaranteed to be continuous, though the problem space itself may be discontinuous. The path avoids obstacles while minimizing total path distance.

The steps include setting up a region of interest, a start position, and a stop position, as well as initially random traversal waypoints. The optimization routine moves the way points around for each candidate solution and attempts to evolve the best path with regards to the reference cost function. The program calculates a path connecting all the waypoints from start to finish, and feeds this path to a cost function. The cost function determines various metrics such as length of path, collision with obstacles, work required to traverse the path, smoothness, weight on exploration of new territory vs. tracking the original outbound path, etc. The calculation of the optimal path is iterative; several rounds of feeding candidate solutions and using their associated costs to calculate new candidate solutions are required. The practical result of the pairing of this cost function strategy with PSO is that an optimal path is evolved much faster than random search, and completely forgiving of discontinuities.

The path planning prototype can be re-tasked on the fly and uses a unique "way point" optimization strategy. Unlike other optimization strategies, this one will work in a discontinuous environment with no modification necessary and is guaranteed to provide a continuous path from start to finish.

This work was done by Brian Birge of L-3 Communications for Johnson Space Center. Further information is contained in a TSP (see page 1). **MSC-24864-1**

⊇ Smart-Divert Powered Descent Guidance to Avoid the Backshell Landing Dispersion Ellipse
The software and methods are valid for planetary or lunar powered descent.

NASA's Jet Propulsion Laboratory, Pasadena, California

A smart-divert capability has been added into the Powered Descent Guidance (PDG) software originally developed for Mars pinpoint and precision landing. The smart-divert algorithm accounts for the landing dispersions of the entry backshell, which separates from the lander vehicle at the end of the parachute descent phase and prior to powered descent. The smart-divert PDG algorithm utilizes the onboard fuel and vehicle thrust vectoring to mitigate landing error in an intelligent way: ensuring that the lander touches down with minimum-fuel usage at the minimum distance from the desired landing location that also avoids impact by the descending backshell.

The smart-divert PDG software implements a computationally efficient, convex formulation of the powered-descent guidance problem to provide pinpoint or precision-landing guidance solutions that are fuel-optimal and satisfy physical thrust bound and pointing constraints, as well as position and speed constraints. The initial smart-divert implementation enforced a lateral-divert corridor parallel to the ground velocity vector; this was based on guidance requirements for MSL (Mars Science Laboratory) landings. This initial method was overly conservative since the divert corridor was infinite in the down-range direction despite the backshell landing inside a calculable dispersion ellipse. Basing the divert constraint instead on a local tangent to the backshell dispersion ellipse in the direction of the desired landing site provides a far less conservative constraint. The resulting enhanced smart-divert PDG algorithm avoids impact with the descending backshell and has reduced conservatism.

This work was done by John M. Carson and Behcet Acikmese of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

The software used in this innovation is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-47884.

⊇ Estimating Foreign-Object-Debris Density From Photogrammetry Data

John F. Kennedy Space Center, Florida

Within the first few seconds after launch of STS-124, debris traveling vertically near the vehicle was captured on two 16-mm film cameras surrounding the launch pad. One particular piece of debris caught the attention of engineers investigating the release of the flame trench fire bricks. The question to be answered was if the debris was a fire brick, and if it represented the first bricks that were ejected from the flame trench wall, or was the object one of the pieces of debris normally ejected from the vehicle during launch. If it was typical launch debris, such as SRB throat plug foam, why was it traveling vertically and parallel to the vehicle during launch, instead of following its normal trajectory, flying horizontally toward the north perimeter fence?

By utilizing the Runge-Kutta integration method for velocity and the Verlet integration method for position, a method that suppresses trajectory computational instabilities due to noisy position data was obtained. This combination of integration methods provides a means to extract the best estimate of drag force and drag coefficient under the non-ideal conditions of limited position data. This integration strategy leads immediately to the best possible estimate of object density, within the constraints of unknown particle shape. These types of calculations do not exist in readily available off-the-shelf simulation software, especially where photogrammetry data is needed as an input.