Information Sciences

Multi-Modal Image Registration and Matching for Localization of a Balloon on Titan

NASA's Jet Propulsion Laboratory, Pasadena, California

A solution was developed that matches visible/IR imagery aboard a balloon in Saturn's moon Titan's atmosphere to SAR (synthetic aperture radar) and visible/IR data acquired from orbit. A balloon in Titan's atmosphere must be able to localize itself autonomously both globally and with respect to local terrain. The orbital data is used to provide the balloon imagery with global context.

Due to the highly dissimilar appearance of imagery from the different types of sensors under consideration (radar, IR, visible), traditional image matching techniques based on pixel similarity do not work. Technology pioneered by the medical imaging community has been adapted to match across sensor modalities. These techniques are driven by information content rather than appearance. While imagery of Titan's surface taken from a visible imager may appear very different from SAR imagery, there is statistical/information theoretic similarity.

The work is novel in applying mutual information (MI) to orbital vs. aerial data. There are unique challenges in this setting. Image offsets are much higher than in medical imaging, there is local distortion due to 3D terrain relief, and the fields of regard from orbit and from the air are quite different.

Because of the large differences in image scale between an orbiter at hundreds of kilometers above the surface and a balloon at a few kilometers altitude, it is necessary to match mosaics from the balloon to single-frame orbital images. In addition to localizing the balloon, this implies the ability to generate high-resolution global maps of the surface that are correctly geo-referenced.

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Entanglement in Quantum-Classical Hybrid

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It is noted that the phenomenon of entanglement is not a prerogative of quantum systems, but also occurs in other, non-classical systems such as quantum-classical hybrids, and covers the concept of entanglement as a special type of global constraint imposed upon a broad class of dynamical systems. Application of hybrid systems for physics of life, as well as for quantum-inspired computing, has been outlined.

In representing the Schrödinger equation in the Madelung form, there is feedback from the Liouville equation to the Hamilton-Jacobi equation in the form of the quantum potential. Preserving the same topology, the innovators replaced the quantum potential with other types of feedback, and investigated the property of these hybrid systems. A function of probability density has been introduced. Non-locality associated with a global geometrical constraint that leads to an entanglement effect was demonstrated.

Despite such a quantumlike characteristic, the hybrid can be of classical scale and all the measurements can be performed classically. This new emergence of entanglement sheds light on the concept of non-locality in physics.

This work was done by Michail Zak of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL. Refer to NPO-46213.

Algorithm for Autonomous Landing

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Because of their small size, high maneuverability, and easy deployment, micro aerial vehicles (MAVs) are used for a wide variety of both civilian and military missions. One of their current drawbacks is the vast array of sensors (such as GPS, altimeter, radar, and the like) required to make a landing. Due to the MAV's small payload size, this is a major concern.

Replacing the imaging sensors with a single monocular camera is sufficient to land a MAV. By applying optical flow algorithms to images obtained from the camera, time-to-collision can be measured. This is a measurement of position and velocity (but not of absolute distance), and can avoid obstacles as well as facilitate

a landing on a flat surface given a set of initial conditions.

The key to this approach is to calculate time-to-collision based on some image on the ground. By holding the angular velocity constant, horizontal speed decreases linearly with the height, resulting in a smooth landing. Mathematical proofs show that even

with actuator saturation or modeling/measurement uncertainties, MAVs can land safely. Landings of this nature may have a higher velocity than is desirable, but this can be compensated for by a cushioning or dampening system, or by using a system of legs to grab onto a surface.

Such a monocular camera system can increase vehicle payload size (or correspondingly reduce vehicle size), increase speed of descent, and guarantee a safe landing by directly correlating speed to height from the ground.

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Quantum-Classical Hybrid for Information Processing
This innovation allows the coordination and synchronization of robots at remote distances.

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Based upon quantum-inspired entanglement in quantum-classical hybrids, a simple algorithm for instantaneous transmissions of non-intentional messages (chosen at random) to remote distances is proposed. The idea is to implement instantaneous transmission of conditional information on remote distances via a quantum-classical hybrid that preserves superposition of random solutions, while allowing one to measure its state variables using classical methods. Such a hybrid system reinforces the advantages, and minimizes the limitations, of both quantum and classical characteristics.

Consider n observers, and assume that each of them gets a copy of the system and runs it separately. Although they run identical systems, the outcomes of even synchronized runs may be different because the solutions of these systems are random. However, the global constrain must be satisfied. Therefore, if the observer #1 (the sender) made a measurement of the acceleration v_1 at $t = T$, then the receiver, by measuring the corresponding acceleration v_1 at $t = T$, may get a wrong value because the accelerations are random, and only their ratios are de-

terministic. Obviously, the transmission of this knowledge is instantaneous as soon as the measurements have been performed. In addition to that, the distance between the observers is irrelevant because the x-coordinate does not enter the governing equations. However, the Shannon information transmitted is zero. None of the senders can control the outcomes of their measurements because they are random. The senders cannot transmit intentional messages. Nevertheless, based on the transmitted knowledge, they can coordinate their actions based on conditional information. If the observer #1 knows his own measurements, the measurements of the others can be fully determined.

It is important to emphasize that the origin of entanglement of all the observers is the joint probability density that couples their actions. There is no centralized source, or a sender of the signal, because each receiver can become a sender as well. An observer receives a signal by performing certain measurements synchronized with the measurements of the others. This means that the signal is uniformly and simultaneously distributed over the observers in

a decentralized way. The signals transmit no intentional information that would favor one agent over another. All the sequence of signals received by different observers are not only statistically equivalent, but are also point-by-point identical. It is important to assume that each agent knows that the other agent simultaneously receives the identical signals. The sequences of the signals are true random, so that no agent could predict the next step with the probability different from those described by the density.

Under these quite general assumptions, the entangled observers-agents can perform non-trivial tasks that include transmission of conditional information from one agent to another, simple paradigm of cooperation, etc. The problem of behavior of intelligent agents correlated by identical random messages in a decentralized way has its own significance: it simulates evolutionary behavior of biological and social systems correlated only via simultaneous sensoring sequences of unexpected events.

This work was done by Michail Zak of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46367

Small-Scale Dissipation in Binary-Species Transitional Mixing Layers
This method enables cost-effective modeling for supercritical conditions prevailing in gas-turbine and liquid-rocket engines.

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Motivated by large eddy simulation (LES) modeling of supercritical turbulent flows, transitional states of databases obtained from direct numerical simulations (DNS) of binary-species supercritical temporal mixing layers were examined to understand the subgrid-scale dissipation, and its variation with filter size. Examination of the DSN-scale do-

main-averaged dissipation confirms previous findings that, out of the three modes of viscous, temperature and species-mass dissipation, the species-mass dissipation is the main contributor to the total dissipation. The results revealed that the percentage of species-mass by total dissipation is nearly invariant across species systems and initial conditions.

This dominance of the species-mass dissipation is due to high-density-gradient magnitude (HDGM) regions populating the flow under the supercritical conditions of the simulations; such regions have also been observed in fully turbulent supercritical flows. The domain average being the result of both the local values and the extent of the HDGM