

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.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

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 constraint 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 sensing sequences of unexpected events.

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## 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

regions, the expectations were that the response to filtering would vary with these flow characteristics. All filtering here is performed in the dissipation range of the Kolmogorov spectrum, at filter sizes from 4 to 16 times the DNS grid spacing. The small-scale (subgrid scale, SGS) dissipation was found by subtracting the filtered-field dissipation from the DNS-field dissipation.

In contrast to the DNS dissipation, the SGS dissipation is not necessarily positive; negative values indicate backscatter. Backscatter was shown to be spatially widespread in all modes of dissipation and in the total dissipation (25 to 60 percent of the domain). The maximum magnitude of the negative subgrid-scale dissipation was as much as 17 percent of the maximum positive subgrid-scale dissipation, indicating that, not only is backscatter spatially widespread in these flows, but it is considerable in magnitude and cannot be ig-

nored for the purposes of LES modeling. The Smagorinsky model, for example, is unsuited for modeling SGS fluxes in the LES because it cannot render backscatter. With increased filter size, there is only a modest decrease in the spatial extent of backscatter. The implication is that even at large LES grid spacing, the issue of backscatter and related SGS-flux modeling decisions are unavoidable.

As a fraction of the total dissipation, the small-scale dissipation is between 10 and 30 percent of the total dissipation for a filter size that is four times the DNS grid spacing, with all OH cases bunched at 10 percent, and the HN cases spanning 24–30 percent. A scale similarity was found in that the domain-average proportion of each small-scale dissipation mode, with respect to the total small-scale dissipation, is very similar to equivalent results at the DNS scale. With increasing filter size, the proportion of

the small-scale dissipation in the dissipation increases substantially, although not quite proportionally. When the filter size increases by four-fold, 52 percent for all OH runs, and 70 percent for HN runs, of the dissipation is contained in the subgrid-scale portion with virtually no dependence on the initial conditions of the DNS.

The indications from the dissipation analysis are that modeling efforts in LES of thermodynamically supercritical flows should be focused primarily on mass-flux effects, with temperature and viscous effects being secondary. The analysis also reveals a physical justification for scale-similarity type models, although the suitability of these will need to be confirmed in *a posteriori* studies.

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## Superpixel-Augmented Endmember Detection for Hyperspectral Images

**Hyperspectral image analysis can be used in remote sensing or industrial applications such as automated detection of manufacturing defects.**

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Superpixels are homogeneous image regions comprised of several contiguous pixels. They are produced by shattering the image into contiguous, homogeneous regions that each cover between 20 and 100 image pixels. The segmentation aims for a many-to-one mapping from superpixels to image features; each image feature could contain several superpixels, but each superpixel occupies no more than one image feature. This conservative segmentation is relatively easy to automate in a robust fashion.

Superpixel processing is related to the more general idea of improving hyperspectral analysis through spatial constraints, which can recognize subtle features at or below the level of noise by exploiting the fact that their spectral signatures are found in neighboring pixels. Recent work has explored spatial constraints for endmember extraction, showing significant advantages over techniques that ignore pixels' relative positions. Methods such as AMEE (automated morphological endmember extraction) express spatial influence using fixed isometric relationships

— a local square window or Euclidean distance in pixel coordinates. In other words, two pixels' covariances are based on their spatial proximity, but are independent of their absolute location in the scene. These isometric spatial constraints are most appropriate when spectral variation is smooth and constant over the image.

Superpixels are simple to implement, efficient to compute, and are empirically effective. They can be used as a preprocessing step with any desired endmember extraction technique. Superpixels also have a solid theoretical basis in the hyperspectral linear mixing model, making them a principled approach for improving endmember extraction. Unlike existing approaches, superpixels can accommodate non-isometric covariance between image pixels (characteristic of discrete image features separated by step discontinuities). These kinds of image features are common in natural scenes.

Analysts can substitute superpixels for image pixels during endmember analysis that leverages the spatial contiguity of

scene features to enhance subtle spectral features. Superpixels define populations of image pixels that are independent samples from each image feature, permitting robust estimation of spectral properties, and reducing measurement noise in proportion to the area of the superpixel. This permits improved endmember extraction, and enables automated search for novel and constituent minerals in very noisy, hyperspatial images.

This innovation begins with a graph-based segmentation based on the work of Felzenszwalb et al., but then expands their approach to the hyperspectral image domain with a Euclidean distance metric. Then, the mean spectrum of each segment is computed, and the resulting data cloud is used as input into sequential maximum angle convex cone (SMACC) endmember extraction.

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