Front shape similarity measure for data-driven wildfire spread modeling

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Résumé

Real-time forecast of wildfire spread is still a key challenge for fire emergency response. Current operational wildfire spread simulators simulate large-scale fire hazard as a propagating front based on Level-Set or Lagrangian formulations. They use simplified models to calculate the rate of spread (ROS) as a semi-empirical function of biomass fuel properties, topography and near-surface meteorology. As recent progress made in remote sensing technology provides new ways to monitor wildfires, a promising approach to improve wildfire spread forecasting capability is to integrate fire modeling and fire sensing technologies using data assimilation. We have thus developed the FIREFLY prototype using an Ensemble Kalman Filter [1].
FIREFLY initially treated the observed fire front as a discretized contour with a finite set of markers. The distance between these simulated and observed fronts was computed by pairing each observed marker with its closest neighbor along the simulated front. This selection procedure is questionable since the resulting observation operator is not the same for all members of the ensemble. It also becomes unsuitable when moving to real-world wildfire events with a complex front topology due to heterogeneous environment and fire behavior.

To overcome this issue, we propose a new method to represent the distance between observed and simulated fronts. This method – deriving from object detection in image processing theory and already adapted in the context of electrophysiology data assimilation [2] – formulates a shape similarity measure based on the Chan-Vese contour fitting functional [3]. We thus propose to define a local innovation based on this shape similarity measure in FIREFLY. The resulting innovation formulation is adapted to both Level-Set and Lagrangian fire spread models for state and parameter estimation. In our case, we choose to base our state estimation on direct nudging correction, whereas the input parameters of the

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ROS model are estimated with a Kalman-based correction. To ensure a meaningful feedback on the controlled parameters is achieved, the sensitivity of the innovation to changes in the parameters is studied using metamodel methods. The estimation results on the 2012 RxCADRE controlled fire [4] and on the Rim fire hazard [5] show that the proposed shape similarity measure is able to accurately track fire fronts and identify fire spread conditions.

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