Applying Grid and urgent computing solutions to forest fire propagation prediction

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A forest fire, as other natural hazards, is a quite significant problem that every year causes significant damages around the world. This kind of hazard provokes significant looses from the ecological, economical, social and human point of view. Therefore, a quick response when an emergency occurs is crucial to minimize its effects. In this context, the accurate prediction of the propagation of forest fire is critical to use the available resources to fight against the fire in the most efficient way.

Several models have been developed by researchers from different fields to represent and predict the fire propagation. These models require input parameters including terrain topography, vegetation conditions and meteorological variables to produce precise and accurate predictions. Some of these parameters are uniform and static, but others have a spatial distribution and a temporal variation, and are difficult to know precisely their values beforehand. So, a two-stage prediction methodology was developed. This methodology calibrates the parameters by applying artificial intelligence evolutionary techniques. In the calibration stage the actual propagation of the fire is observed and then the input parameters are calibrated. The values that best reproduce the actual propagation of the fire are used in the prediction stage. This methodology is represented in figure 1.

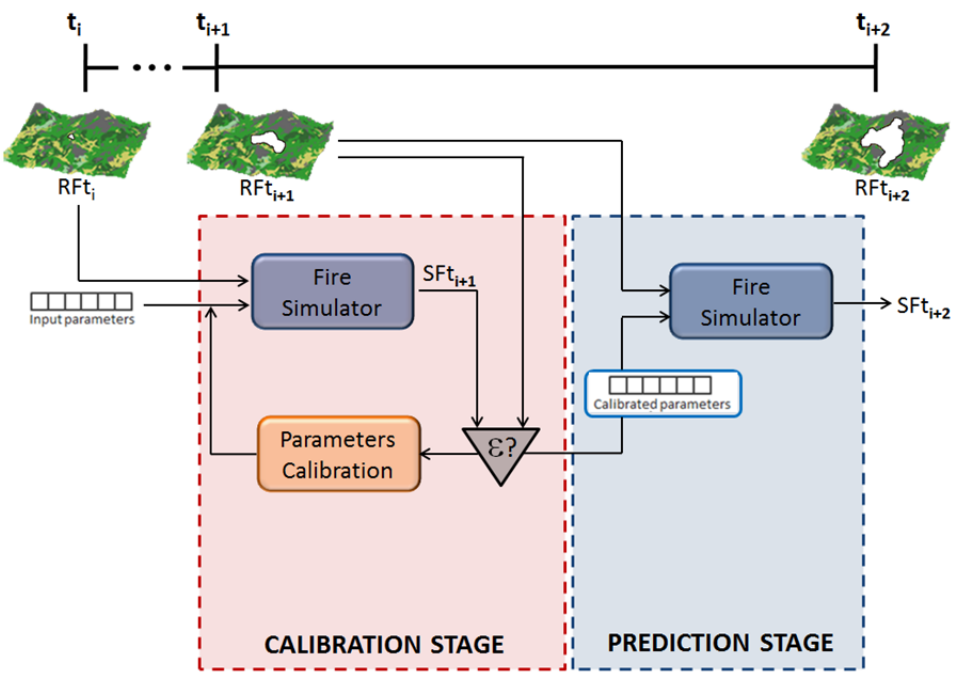

Figure 1.- Two-stage prediction methodology

This methodology is independent from the propagation model and simulation kernel considered. The model itself appears as a black-box and the only point that must be considered are the input parameters required for each simulator. We have used FireSim and FarSite, and we also have some experience with FireStation.

The calibration stage involves the search of the values that best reproduce the actual propagation of the fire. The search space is multidimensional and very huge and, therefore, some evolutionary methods, such as genetic algorithms, tabu search or simulated annealing, have been introduced to accelerate the search. These methods are iterative and require the execution of many simulations per iteration of the algorithm. The method that provides best results is Genetic Algorithms. In this method an initial population with a certain number of individuals (50, 100) is randomly generated. Then, each individual is used to simulate the fire propagation and the individuals are ranked according to their prediction error. Some genetic operation, such as elitism, mutation, crossover, are applied and a new population is generated. This process is repeated for a certain number of iterations. It must be pointed out, that for each individual in each generation it is necessary to execute a simulation of forest fire propagation.

However, when the fire is burning time is critical and it is necessary to determine the future propagation of the fire beforehand. So, we face three main interrelated issues:

- The available time to provide a prediction is a critical point and seriously limits the number of iterations that can be executed on the calibration stage.
- The amount of computing resources determines the amount of simulations that can be simultaneously executed per iteration of the calibration stage.
- The quality of the prediction is directly related to the quality of the calibration, and the quality of the calibration depends on the number of iterations of the evolutionary algorithm and on the number of scenarios used per iteration.

In this context, a first objective of this project is to take advantage of Grid and Urgent Computing infrastructures to accomplish the time and quality constraints of forest fire propagation prediction based on the two-stage methodology.

Currently, the UAB team is working on the coupling of meteorological prediction models, such as WRF, and wind field models, such as Wind Ninja. These models become a key issue since the wind is a key factor on the prediction quality. However, such models are even more time consuming that the fire propagation model itself. Figure 2 shows the coupling of meteorological, wind field and forest fire propagation models.

So, the computing demands of such scheme are even more intensive than the forest fire propagation. Moreover, we are integrating this coupling in the two-stage prediction methodology. This implies the execution of several instances and several iterations applying the whole scheme. Figure 3 shows the integration of the wind field model on the two-stage prediction methodology.

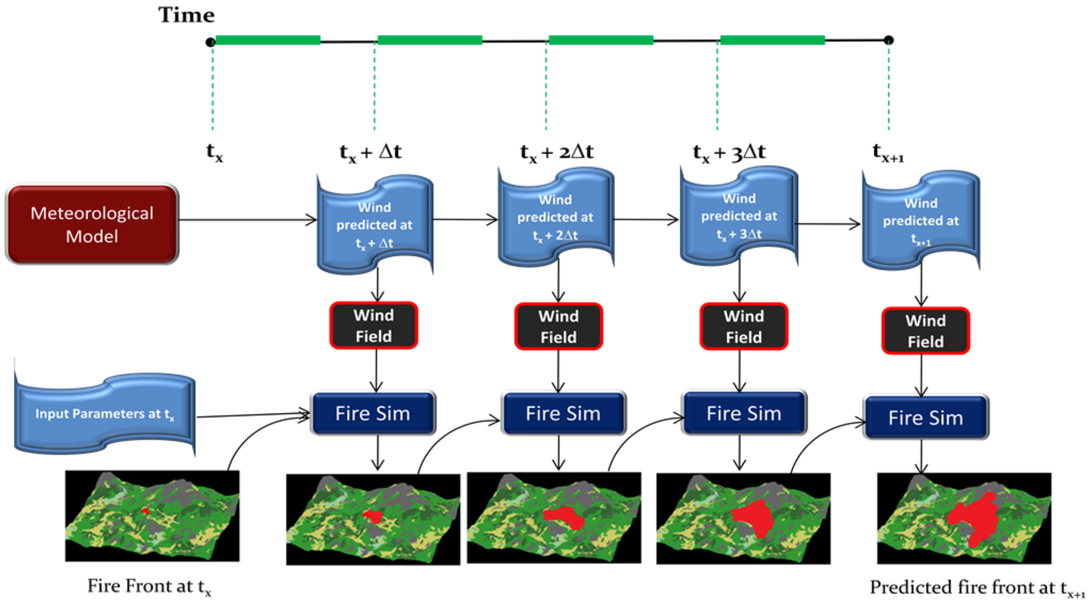

Figure 2.- Meteorological, wind field and forest fire propagation models coupling

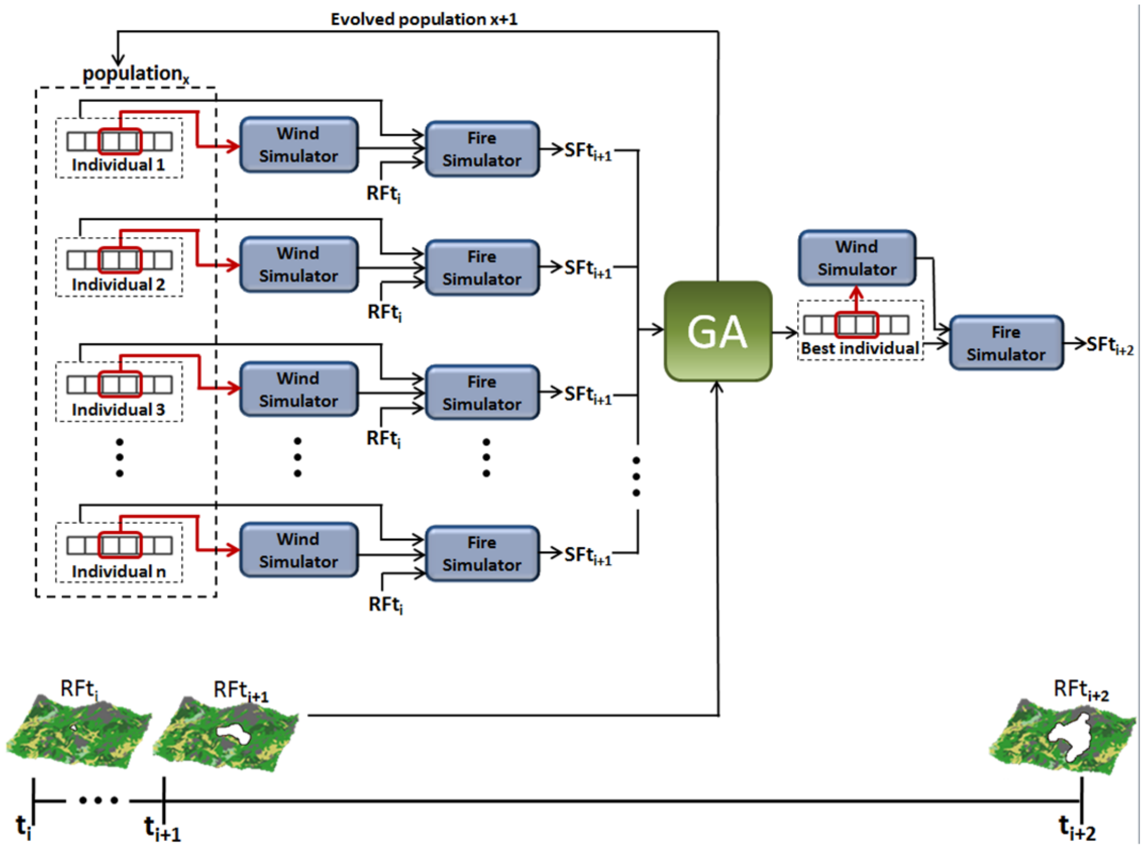

Figure 3.- Integration of the wind field model on the two-stage prediction methodology