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URGENCY VERSUS ACCURACY: DYNAMIC DATA DRIVEN APPLICATION SYSTEM FOR NATURAL HAZARD MANAGEMENT

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Abstract. This work faces the problem of quality and prediction time assessment in a Dynamic Data Driven Application System (DDDAS) for predicting natural hazard evolution. Natural hazard management is undoubtedly a relevant area where systems modeling and numerical analysis take a great prominence.

Modeling such systems is a very hard problem to tackle. Besides, the results obtained by simulators usually don't provide accurate information, mostly due to the underlying uncertainty in the input parameters that define the actual environmental conditions at the very beginning of the simulation.

For this reason, we have developed a two-stage prediction strategy, which, first of all, carries out a parameter adjustment process by comparing the results provided by the simulator and the real observed hazard evolution. It has been demonstrated that this method improves notably the quality of the predictions. Furthermore, we have designed data injection techniques that allow us to take advantage from real-time acquired information, so that our strategy fits the DDDAS paradigm.

Nevertheless, because of the urgent nature of the systems we deal with, it is also necessary to assess the time incurred in applying the above mentioned strategy, in order for it to be useful and applicable in a real emergency situation. In this sense, we have developed a new methodology for prediction time assessment under this kind of prediction environments, based on Artificial Intelligence techniques.

In this research work, we have chosen forest fires as a representative study case, although the exposed methods can be extrapolated to any kind of natural hazard.

Key words. DDDAS, Data Uncertainty, Natural Hazard Management, Prediction Quality, Prediction Time Assessment

1. Introduction

A natural hazard is an unexpected or uncontrollable natural event of unusual intensity that threatens people's lives or their activities. Unfortunately, the losses caused by natural hazards are increasing dramatically, mostly due to the rapid increase in human population. Therefore, in order to mitigate the tragic consequences of such disasters, it is interesting to be able to make urgent decisions while the natural catastrophe is taking place. For this purpose, many interdisciplinary research has been carried out to provide models/simulators to the community for evaluating in advance the natural hazard evolution. However, model-related issues aside, many simulators lack precision on their results because of the inherent uncertainty of the data needed to define the state of the system environment. This uncertainty is due, basically, to the difficult in gathering precise data at the right places where the disaster is taking place. So, in many cases, the simulators have to work with interpolated, outdated, or even absolutely unknown data values.

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In this kind of environmental systems, the use of knowledge extraction techniques from the data collected from different sources (e.g. meteorological stations) would be suitable, in order to improve the accuracy of the predictions, as well as to speed up the simulations. However, as it is widely discussed in [3], when designing such data mining processes, it is critical to take into account the fact that the results we will obtain are affected by the underlying uncertainty in the data.

To overcome the just mentioned input uncertainty problem, we have developed a two-stage prediction strategy, which, first of all, carries out a parameter adjustment process by comparing the results provided by the simulator and the real observed disaster evolution. Then, the underlying simulator is executed taking into account the adjusted parameters obtained in the previous phase, in order to predict the evolution of the particular hazard for a later time instant. A successful application of this method mainly depends on the effectiveness of the adjustment technique that has been carried out. In this sense, our research group has developed several solutions for input parameters optimization, all of them characterized by an intensive data management: use of statistical approach based on exhaustive exploration of previous fires databases [8], application of evolutionary computation [14], calibration based on domain-specific knowledge [32], and even solutions coming from the merge of some of the above mentioned [29]. Since all these approaches perform the calibration stage in a data driven fashion, they all match the Dynamic Data Driven Application Systems paradigm [12, 13, 15].

In particular, we have developed this prediction scheme using forest fire as a study case and it has been demonstrated that the above mentioned adjustment techniques contribute to improve the quality of the fire spread prediction.

Another key point to be considered when dealing with an ongoing disaster is the time incurred in providing evolution prediction results. While a natural catastrophe is taking place, it is necessary to make urgent decisions to effectively fight against it. Many times there exist several constraints that make arise the question of how and where to execute our prediction system, depending on the available resources we have. Consequently, we come up with the *urgency-accuracy* binomial.

There exist diverse factors that may affect both precision of the results and time invested to get them. The power of computational resources is an aspect that has important influence, so are the intrinsic features of both the simulator and the adjustment technique chosen to face the environmental hazard.

For this reason, we introduce a new methodology to characterize each element of the proposed DDDAS prediction process, with the aim of being able to design a tool for prediction time assessment during an emergency management. This work is part of a more ambitious project, which consists of determining in advance, how a certain combination of natural hazard simulator, computational resources, adjustment strategy, and frequency of data acquisition will perform, in terms of execution time and prediction quality.

This paper is organized as follows. In the next section, an overview of the two-stages DDDAS for forest fire spread prediction is given. In Section 3, we expose in detail our developed solutions for quality enhancement and prediction time assessment, as well as how this framework could be generalized to any natural hazard. In Section 4, the experimental study is reported and, finally, the main conclusions are included in Section 5.