Glimpses and Challenges of Computer Modelling in Civil Engineering

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Abstract

The study of natural phenomena or major environmental problems usually requires the analysis of interdisciplinary data acquired from increasingly powerful sensors to achieve sustainability. This almost always results in complex interactions of hard mathematical modeling and the adoption of holistic system views. In many cases, the initial conditions are not known, the domain is not well defined and the constitutive parameters are heterogeneous generating large uncertainties. For this reason, knowledge-based models evolved from huge amounts of data have generated enormous interest to understand and solve such phenomena that do not always find suitable mathematical laws for their representation. So, the purpose of this communication is to briefly discuss the technical and challenges on data processing and engineering and give a glimpse on the scientific development and future direction of this domain.

Introduction

The systems modeling goal is to find and formulate laws that govern phenomena in a mathematical and precise way. However, it is recognized that such perfect descriptions are not always possible. Lockwood [1], Hansson [2] & Fagerström [3]. Incomplete and imprecise knowledge, qualitative observations and great heterogeneity of many interacting agents usually cause uncertainties when modeling complex phenomena of the ever changing nature or in the business world. It is recognized that knowledge is kept by experts or stored in data Gaul & Schader [4]. For organizations, the most important is to understand the great dynamism of the natural systems or the competitive environment in which they are inserted to make decisions about the sustainability and the responsiveness of their decisions. Therefore, information, knowledge and data are preemptive.

Sensors and Data

Talking about smart phones, tablets, notebooks, and connected objects, one need to understand that these "things" are full of sensors. A forecast shows it could exceed one trillion as early as the early 2020s according to estimates from various companies and industries attentive in these flows. The data is observed, stored and released dynamically, which requires that science be online. Thus, to be able to make accurate models and update themselves in dynamic competitive environments, it is increasingly necessary to develop methodologies to generate current and adaptive forecasts for decision making. On the other hand, the cost reduction of electronic sensors applied in environmental monitoring allowed data to be collected and used to build models in real time Rolph et al. [5]; Pereira et al. [6]; Sánchez-Rosario et al. [7].

These models use a continuous flow of data and there is no control over the order of arrival of each element to be processed. Flow data has unlimited size, once processed, an element is usually discarded. It is not recovered unless it is stored in memory, which is usually small for the size of the data received. Queries about these flows need to be processed in real time (for a real world event or because it is expensive to store the data). These methodologies should be able to extract knowledge in huge amounts of structured and unstructured data from in situ monitoring, regulations and web, and add it to existing knowledge. In the models generation, one can rely on statistical methods, machine learning and computational methods inspired in nature as presented by Fairbairn et al. [8] in a civil engineering application. These models have great robustness because they are noise tolerant and can be coupled to other models providing hybrid solutions.

Scientific and Data Intensive Computing

It should be reappraised the use of high performance computers and database technology which has caused significant changes in the development of design techniques and programming of algorithms for engineering problem solving. In

the case of scientific computation of large systems, the different ways in which numerical methods are designed or adapted stimulated research in technical and applied aspects. New, scalable computing architectures (Big Data, NOSql databases) have boosted database technology, allowing simulation of real problems with great consistency and accuracy. Big Data refers to data that is too big to fit on a single server, too unstructured to fit into a row-and-column database, or too continuously flowing to fit into a static data warehouse.

The adopted methodology implies the integrated use of several technologies and can be briefly described by the following activities:

a. Acquisition of the database containing the relevant parameters. For models development and subsequent simulation, the availability of reliable data is indispensable.

b. Expert selection and data analysis and data selection for model construction, test and validation;

c. Selection of the data knowledge representation technique and acquisition of specialized knowledge, if necessary;

d. Construction, Testing and validation of the model;

e. Generalization for different configurations;

f. Analysis of results and conclusions.

The main characteristics of traditional Scientific Computing model and Intensive and Distributed Data Computation model are resumed in Table I.

Table 1: Traditional Scientific Computing model and Intensive and Distributed Data Computation mode.

Scientific Computing	Data Intensive Computing
Mathematical laws governing the phenomenon	No mathematical law
Differential equations	Knowledge extracted from large masses of data and expert
Simplifications: homogeneity of properties, boundary conditions, geometry	Statistics, Machine Learning, Database, Nature inspired Methods
Solution of large systems of algebraic equations, eigenvalues,	Big Data, Data Stream, Unstructured data...
Scalability: parallel computing(MPI Message Passing Interface), decomposition, iterative algorithms	Scalability: MapReduce, Hadoop, data storage, NoSQL databases

Both represent computing strategies, but the best and most efficient one depends on the situation. Large-scale data processing in the distributed system is very challenging in many concepts of the system performance for reliability. Typically, the MPI (Message Passing Interface) supports a more flexible communication method than MapReduce (asynchronous versus synchronous). While MPI Gropp et al. [9] moves the data during communication, MapReduce Lämmel [10] uses the concept of

"data locality", making the transmission between CPU and disk possible once, this task, cannot be performed in MPI because it requires that data "be processed" should fit in memory (Core Processing).

Research Challenges and Development

The use of large volumes of data will become a fundamental competition and growth for individual companies. From the point of view of competitiveness and value-capture potential, all companies need to fit large volumes of data. In most industries, competitors and new entrants will use strategies to innovate, compete and capture value, based on information of depth and in real time. Parallel processing, clustering, virtualization, large environments, high connectivity and cloud computing, as well as other of flexible resources, are enabling organizations to take advantage of the Big Data and big data analytics.

The opportunities of the future will be greater and more difficult to be solved, to the point of challenging our capacity for imagination. Quantum computers will introduce a new era in computing. Quantum systems will help us to find new ways to model financial data and isolate key global risk factors to make better investments. And they may make facets of artificial intelligence such as machine learning much more powerful. The response and decision making will be very demanding with our ability to respond. We are approaching a moment of life or death. Firms that act, will thrive, those that will not, will disappear. The future lies in innovation. In the convergence of Bio-Cogno-Info-Nano Ebecken [11]. In the mining of scientific trends for innovation.

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