Amidst continuing risk posed by environmental challenges, the use of environmental computing for modelling presents many opportunities as **Professor Dr Dieter Kranzlmüller** writes

Modelling for risk

Many of the everyday activities that we take for granted rely on processes that are impossible to fully capture mathematically or algorithmically. Logistics processes that ensure that goods are available in the shops, algorithms determining optimal traffic planning, or expert systems monitoring credit card transactions and protecting everyone against fraud are examples of such complex systems. Considerable effort has been invested in building suitable models, software infrastructure, and standards that can be used to explain and understand the behaviour of these systems, both in normal and crisis situations.

In light of the considerable socioeconomic importance, such activities are understandably supported. For example, according to the World Trade Organization the value of cross-border merchandise exports was estimated at $16.7 trillion (€15.5tr) in 2011. Yet here, even a very minor increase in operational efficiency can result in benefits that are measured in millions.

Model challenge

However, when it comes to modelling underlying environmental risks that may threaten the smooth operation of the abovementioned processes, and even more, society as a whole, the approach is less consistent. Traditional modelling techniques address some aspects of the risk scenarios; such as meteorology, seismology or civil engineering. However, at the moment there are almost no modelling tools that could provide an overall risk assessment for a typical environmental risk scenario: understanding flooding or the impact of a major earthquake requires painstaking, manual combination of different models, their execution environments and data representations.

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For example, to understand the full impact of an extreme weather event (storm with extreme rainfall), it is necessary to combine the meteorological model with models that describe the flow of water (on and through the surface), and the dynamic model of the terrain (taking into account changes due to landslides or sediment transfer). In another example, the impact of a major seismic event is influenced by the interaction between soil conditions, possible landslides, tsunamis (triggered either directly by the quake or by the landslides) and more.

Furthermore, each of these component models may consist of several sub-models, each of which are typically developed independently from each other, often with different assumptions related to data formats and execution environments. Hence, while these component models themselves represent the best scientific knowledge of the phenomena they describe, combining them together can introduce unanticipated consequences that may be difficult to identify. The multi-model system may end up working correctly with certain parameter values, but different components may introduce errors at certain values that may either reinforce or cancel each other. These features of multi-model systems make a broad operational deployment difficult; the experts that have an in-depth understanding of the models (including details of their implementation), and the phenomena they represent need to be involved in the production of the predictions and analyses of the events.

Preparing for impact

Solving the tension between considerable socioeconomic impact, and technical and procedural challenges involved in the development of reliable environmental multi-model systems is a major challenge. The technical, procedural and policy actions aimed at addressing this challenge form the core of environmental computing. The interplay between these three areas is crucial due to the high socioeconomic impact. For example, the annual direct losses related to environmental disasters are typically measured in thousands of lost lives and tens of billions of euro; indirect losses are likely even more serious a burden on the societies exposed to these events.

Consequently, it is not surprising that average investments in societal resilience against natural disasters represent good value. For example, it is estimated that one UK pound invested in flood defences saves eight pounds in damages during the operational lifetime. However, individual infrastructure projects aimed at reducing disaster risk often require massive investments – typically hundreds of millions of euros. The resulting savings may be difficult to identify and are typically realised during the next tens or even hundreds of years. Due to these reasons it is clear that the investments in societal resilience need to be carefully prioritised, using the best available science.

The field of environmental computing will contribute to this prioritisation. While in the short to medium term the development of the model components will not be standardised (at least not to the degree of e.g. telecom software development), methods that allow taking the initial model implementations, and adapting and maturing them, will form the technological and procedural foundation of the common body of knowledge. These recipes, supported by reusable software libraries, will make it easier to execute models in (super)computer environments. This will also encourage model developers to document software and data models in a way that will eventually form *de facto* standards. Mapping the advances in the software and service development so that they link with top-level policy statements (such as the Sendai Declaration and Sendai Framework for Disaster Risk Reduction reached during the Third World Conference on Disaster Risk Reduction) will complete the picture, making the common body of knowledge relevant and usable on the policy level as well.

Projects come to the fore

Today, a number of key components needed to realise the vision of environmental computing have already been obtained. Projects such as Distributed Research Infrastructure for Hydro-Meteorology (DRIHM) have demonstrated the potential of multi-model systems that can integrate a wide range of data sources as an input. By running this multi-model system in a European supercomputing environment, it was possible to capture the development of a recent Genoa flash flood that was practically impossible to model using the standard tools.

Environmental computing is aiding risk modelling

Similarly the Multiscale Applications on European e-Infrastructures (MAPPER) project built a platform to provide support for urgent computing that allowed launching multi-model simulations with a very short lead-time, utilising heterogeneous resources. Additionally, first steps towards standardisation and procedural development have also been taken in collaboration with UNISDR, the UN organisation responsible for Disaster Risk Reduction (Sendai Framework for Action). A recently launched strategic joint venture aims to engage with the necessary stakeholders to collect, codify and standardise best practices related to environmental computing.

The topic will also be an important part of the programme of the upcoming IEEE eScience Conference (31 August – 4 September 2015) that has dedicated a focus day and several workshops on the topic of environmental computing. A dedicated environmental computing website will collect relevant case studies and event announcements, as well as hosting an open forum for discussion on the topic. We see these as crucial initial steps in formalising environmental computing as a field of study and realising its full potential.

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