Analysis and Communication of Glacier Simulations using Interactive Visualisation: A Case Study

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I. Problem Statement

The information society considers environmental protection as one of the major tasks for ensuring sustainable development. Environmental protection includes all measures and behavioural patterns of the society that promote the preservation and improvement of the natural environment. A range of people, from experts to laymen, decide on what the threats are to the environment, on the goals of environmental protection and how they can be achieved. Within the context of climate change science has the task of studying the different relationships and factors impacting on the climate system. Subsequently this expert knowledge is transposed by policy-makers into environmental laws and strategies for the society. This process can be marked strongly by the social perception of climate change, its causes, as well as its consequences. Finally, the behaviour of each individual is affected by his own perception of climate change, which is strongly influenced by the society and can differ enormously from the perception of science. Based on this, we would like to outline the following problem areas:

a) Scientific scope: model evaluation

To understand the climate system, scientists employ simplified representations of reality using more or less sophisticated climate models.

- The more the science knows about the climate system, the more complicated and larger the descriptive models become, which can lead to difficulties evaluating the models.
- Physical models with three-dimensional spatial components yield to results which are difficult to analyse with conventional analysing tools.

b) Social scope: perception

- Generally, the climate changes slowly compared to the human lifespan and to the speed of social change. For this reason, humans will typically not have an acute sense of awareness of the changes occurring to the environment.
- Climate models can be used only on a global, not local, scale. Accordingly, newspapers inform the reader solely about the global impacts of environmental change. But the individual is interested in knowing about the changes at a local level because he learns from experiences on this level alone. The knowledge imparted by the experts does not correspond with the knowledge each individual has gained in his past. As a consequence, people are often not aware of the results of their own behaviour.
- Scientific results, especially such derived from models, are often of a high abstract level and thus not well suited for communication.

Therefore we have to use a method which simplifies the analysis and the evaluation of the model output and communicates the model results in a more comprehensible way.

II. Problem Solution

Interactive visualisation makes the exploration of spatial data from different viewpoints and in three dimensions possible. We propose a system which integrates a physical model within an interactive visualisation. This system should improve the scientific perception of the model behaviour and help to interpret the simulated results. Combining the visualisation with a model, we can also study the described process in fast-motion. Moreover, modern visualisation techniques make it possible to view the model

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output in a context closer to reality for a better understanding and communication. The clear and concise communication of scientific results pertaining to climate change increases the social sensitivity to environmental problems.
Instead of considering the whole climate system we confine ourselves to an individual glacier. According to the IPCC climate report 2001, the retreat of glaciers is the only high reliable climate indicator, together with the temperature of the air and of the sea surface. In studying a glacier, one is observing an effect of global climate change on a local scale. The three-dimensional view of the simulated glacier state can help individuals to imagine how our environment could look within several decades. Furthermore, the change of glacier shape is more suitable for a visualisation than air temperature, because one perceives changes in space with our vision sense (and not with our sense of temperature as in case of temperature changes).

a) System Requirements

There are some requirements our visualisation system must fulfil. As stated before the visualisation should allow one to interactively study the glacier from different viewpoints. Moreover, it should be possible to interactively modify some input parameters of the model by a simple user interface. During an interactive session the glaciologist can then perform some changes on the input parameters and see immediately the glacier's response. To achieve operational interactivity, the computing time for the calculation and representation of a new glacier state, including the transformation to computer graphic structures, must be minimized.
The present intention is not to extend the visualisation system to include further simulation models . Thus we can integrate the glacier model into our existing software without having a complex architecture. A strict separation of the objectively-defined model behaviour on the one hand, and subjective evaluation on the other hand, will ease the integration of new model parameters and the communication of the results.

b) System Description

The core of the visualisation system is based on software developed within the open source project 'Virtual Terrain Project'. The terrain rendering algorithms implemented are among the most elegant and quickest we know of, which frees up computing time for glacier modelling. Furthermore, the precision of the terrain visualisation can be interactively adapted to the glacier simulation costs. The more detailed the simulation is required to be, the more one can reduce the complexity of the visualised terrain.
The virtual terrain can then be complemented by the insertion of a glacier object, which is described by a glacier model. The core of the glacier model was developed by Hoelzle (Hoelzle, 1994). This model allows forward-looking through the calculation of a new two-dimensional glacier shape for a given scenario, or backward-looking through the reconstruction of past two-dimensional glacier states (e.g. 'little ice age'). It is a relatively simple, but physically-sound, model with just a few input parameters, making it possible to apply it to glaciers around the globe. As a test case we chose the 'Morteratsch' glacier in the Upper Engadin (Switzerland) because it complies with the few requirements of the glacier model and there exists a good data repository for plausibility checks.
For designing and rendering the three-dimensional shape of the glacier we extend the physical model with a simple approach using Non-Uniform Rational B-Splines (NURBS). This well-known geometric modelling technique has some important advantages for the geometric modelling and interactive visualisation, such as the efficient description of a smooth surface, local control and support of the widespread graphic library OpenGL.
One important note to add is that the forward-look using the glacier model already mentioned is nothing more than a possible scenario, as opposed to accurate prediction. A conceivable behaviour is proposed for the glacier. Additionally, the glacier model says nothing about the appearance of the glacier, and so this aspect cannot be represented in a true-to-life fashion. Consequently we do not try to use the most realistic texture possible, so as to avoid creating the belief in the user that the simulation corresponds to reality.
Since the described application requires a hardware-accelerated rendering system, a fast model simulation and efficient geometric modelling, the approach cannot be adapted directly to other physical models and software systems. It is an experimental case study demonstrating the possibilities and limitations using interactive visualisation for the analysis of simulation results and the communication of climate scenarios to the society.

Bibliography

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