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A causal modelling framework for the simulation and explanation of the behaviour of structures

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Abstract

An approach to the modelling of systems in civil engineering is presented. It allows the integration of quantitative relations in a qualitative causal framework which uses objects and Petri nets to represent the device and process ontologies. This approach supports the modelling and simulation of the behaviour of a physical system and causal explanations of it. The explanations are customisable depending on the needs of different users. The approach is shown by modelling the seismic behaviour of a masonry building, simulating it and generating causal explanations tailored for the needs of different users. An example application is presented through IGOR, a decision support system for seismic assessment of buildings and planning of precautionary operations.

Key words: qualitative models, causal models, qualitative/quantitative knowledge integration, explanation, seismic engineering.

INTRODUCTION

Much of the knowledge employed by engineers is of a qualitative nature. Every day they deal with quantitative entities such as equations and numbers, but qualitative reasoning is crucial for comprehending problems. planning for solving them, identifying suitable quantitative relations and interpreting the results of quantitative computations [1].

There has been great effort, in the past, in formalising quantitative reasoning, so that there are programs supporting engineers in the quantitative aspects of their activity, but other work has still to be done in the formal representation of qualitative aspects of engineering problem solving [2]. The aim of the research in this field is the formalisation of those qualitative aspects so that computer systems can be developed to support qualitative reasoning. [1] Moreover, existing approaches bridge the methodologies in the field of artificial intelligence and in the field of simulation. They introduce methodologies and formalisms for developing multiple, cooperative models derived from qualitative physics [3].

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In the field of seismic engineering, several researchers have taken advantage of qualitative techniques to model the seismic behaviour of buildings. For example Miyasato et al. [4], Ishizuka et al. [5] and Pagnoni et al. [6] modelled the knowledge in form of a tree of factors to evaluate the seismic vulnerability, while Zhang and Yao [7] used conceptual networks and frames to map data into damage states and Bozzo and Fenvesg introduced a qualitative reasoning methodology to support the preliminary design of earthquake resistant buildings,

In particular, qualitative causal analysis is very important in an engineer's problem solving. The need for the prediction and causal explanation of the expected behaviour of a system and, in engineering in particular, of an artifact is common in many domains. For example. a simulation activated by critical inputs can allow the detection of the weakest components of the modelled system in order to plan precautionary operations on them for preventing possible failures and damage.

THE PROBLEM

The paper describes an approach to the integration of quantitative relations in a qualitative Causal framework. This supports the modelling and simulation of the behaviour of a physical system and causal explanations of it. The explanations are customisable depending on the needs of different users.

An example of the application of this approach is IGOR (Fig. 1), a decision support system that helps technicians seismically assess buildings and plan pre- cautionary operations on them. The approach and the work done were initially related to the problem of…

[…]

CONCLUSIONS

The modelling framework has been used to implement several models. The main result is the availability of tools which allow easy implementation of models at various levels of abstraction, which may exploit both quantitative and qualitative knowledge.

The IGOR system, which applied those tools to the seismic risk evaluation of buildings, provides a powerful support to engineers which was not available before. They may define a suitable strategy for assessing the seismic risk of an urban nucleus and IGOR will support them to store the data collected, simulate the behaviour using various models, explain the behaviour and simulate possible strengthening actions.

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