ABSTRACT

Smart structures are complex systems situated in even more complex and large scale urban environments. This chapter opens the field of agent based modelling and simulation (ABMS) to civil engineers. ABMS offers a wide range of tools for implementing simulation models of systems with high degrees of interconnectivity and a large number of component subsystems. The ease of use for specialized engineers and the capabilities of integration with existent technologies and infrastructures, make agent based models a very attractive way to incorporate the social system in the design process of buildings. Moreover, ABMS allows for the testing and validation of structure wide control and automation systems. This chapter presents past and current efforts of using agent based modelling for smart structures, as well as the main challenges brought by this new interdisciplinary research domain.

INTRODUCTION

Agent based modelling and simulation (ABMS) is a field that deals primarily with the computational techniques applied in studies of complex and large scale systems. ABMS is a powerful tool for simulating complex and dynamic behaviours of systems with important consideration regarding the interactions between entities in systems of systems.

The most common uses of ABMS are in social simulation and optimisation problems, such as traffic flow. Other applications refer to manufacturing and supply chains, economics with orientation towards financial markets, city infrastructure especially transportation and electric grids, biology and medicine for animals and behaviour of cells simulation.

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The purpose of a structure is to shelter life, protect its inhabitants. But more than that, buildings host an array of activities vital to both the 21st century society and the growth of civilization. From the daily regular operations of the social structures accommodated within buildings, to the critical, time sensitive responses of control systems in order to protect human life, the current modelling directions should strive to include bio-social components when talking about structural performance. Moreover, the complexity of structural systems increases when taking into account the design of control systems, from environmentally friendly and energy saving automation systems, to robust control of seismic vibration, to efficient and dedicated safety protocols, and so on.

Additionally, special attention must be given to the unexpected disturbances of daily life, such as earthquakes, fires and other events. Specialized equipment (actuators, transducers, and controllers) has developed significantly, adding to the complexity of models necessary to design, control, monitor, and evaluate smart structures.

In order to integrate the requirements of civil engineering with the methodology of systems engineering, it is necessary that the models (and subsequent simulation environments) include the interactions between infrastructure and humans, control systems and social behaviour, structural performance and purpose of functionalities.

Thus, applying ABMS techniques in the design process of smart structures is the next step in the complementary vision of buildings that offer both protection and comfort, with focus on hosting daily life activities, in the larger context of a smart world.

In this chapter, a view of agent oriented programming is discussed, when applied to structural systems under the perspectives previously described, as the go-to tool when developing agent based models. The advantages of using ABMS depend on the problem that needs to be solved and a very important influence is given by the tools that the users choose. Some of these languages, environments, and frameworks are offering more accessible methods for the implementation of the standard concepts that describe the ABMS.

Moreover, the specificity of these computational modelling techniques make way for the subsequent development of simulation models, which are powerful tools in understanding complex systems, that offer integration of non-biological and biological systems within simulations, and that ultimately allow engineers to test and analyse what-if types of scenarios, safely observing and recording unexpected effects of various events that can take place within a building.

Thus, opening ABMS to the field of civil engineering can prove useful in long term, especially within the technological progress whirlwind of the current decade. The main objectives of this chapter are to introduce civil engineers to agent based computational techniques, to offer solutions for integrating the control systems component in the performance analysis of structures, and last, but not least, to open a new research area in agent based simulation models applied to structural engineering.

AGENTS AND MULTI-AGENT SYSTEMS

The Agent Based Modelling and Simulation Concept

*When everything happens at once, wide and fast moving problems simply route around any central authority.* (Kelly, 1995)
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