COMPUTATIONAL MODELLING AND SIMULATIONS - THE FUTURE OF PREDICTING GROWTH AND DEVELOPMENT OF SUSTAINABLE CITIES

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ABSTRACT

The idea of sustainable cities is particularly current in the international public. The authors of this scientific paper pointed out the importance of computational modelling and simulations as a tool for implementing this idea. In this sense, a review of the literature that considers computational modelling and analysing the results of studies dealing with computational modelling in the field of architecture and medicine, as a discipline whose activities are directly related to human well-being, was conducted. Urban and architectural design affects the comfort of life and its consequences for people's health, and therefore the sustainability of the city as a complete system that can be observed using digital technologies. The goal of the paper is to provide insight into the importance of using computational modelling and simulations in modern research in order to predict future problems that will affect the sustainability of the system.

KEYWORDS _ *Computational modelling, Computer models, Architecture and Medicine*

INTRODUCTION

The demands of modern society, aimed at effective and efficient solutions that are financially available, represent one of the drivers of the idea of sustainability. In finding such solutions, computer programs that have the ability to process a huge amount of data in a very short period of time are increasingly being used. For these purposes, computational modelling becomes a tool that represents methodological choice in the experimental phases of scientific research work. Due to the financial availability and speed of obtaining results, computational modelling is increasingly present in many scientific branches, such as urban planning, mechanical engineering, civil engineering, architecture, pharmacy and medicine. A huge potential in the application of computational modelling occurs with the inclusion of artificial intelligence (AI), which is currently in rapid development.

Regardless of the field of research, a well-designed model is crucial for reliable research flow and reliability of results. One of the most important issues is the input and collection of data to make the computational modelling as accurate as possible. For example, in the field of urban design, the challenge is to assess how well a computer program can represent the current design of a city, and then predict how the structures will change over time. There is a physical structure and infrastructure in the city, whose characteristics and interconnections form a complex and complete system, with established rules and principles of functioning at all levels. Specific systems can be observed in other scientific disciplines as well, and each of them requires a consistent input of data to form a computational model.

Analysing many scientific articles, the authors of this text noticed that a significant number of papers treat the contributions of computational modelling and indicate their importance. Based on this, the authors want to underline that computational modelling is an inevitable step in technological development and that its implementation is somehow expected in everyday practice. For this purpose, it is decided to take into account the fields of urban planning, architecture and medicine as disciplines whose activities are directly related to human well-being, and outline the potential of implementing computational modelling and simulations. These disciplines are also crucial for the formation of a sustainable city. The authors look at potentials of computational modelling and simulations in architecture and medicine.

SPECIFICITIES OF COMPUTATIONAL MODELLING IN ARCHITECTURE AND MEDICINE

Setting a definition has always been a challenge for the scientific world. A generalized explanation of a phenomenon or process requires extensive knowledge from several disciplines, but also the ability to simply present that knowledge. When it comes to computational modelling, these challenges are pointed out in the Report prepared by Government Office for Science (2018). The Report indicates that computational models are essential for analysing and explaining complex natural systems varying in size from the very small, such as the workings of a bacterium, to the very large, such as planetary weather and climate systems or the workings of stars and galaxies. It is also emphasized that one of the new capacities of computational modelling is the ability to integrate models at different scales and of different types.

In the aforementioned Report, the advantages of the models are explained: „A model is not a picture of the world, but a kind of tool — a knowledge tool. It helps us to track what would happen to intricate interactions that we cannot imagine in our minds, and for which solvable mathematics is not adequate… It should be clear that establishing a model for one purpose does not justify its use for another and anything else risks confusion and unreliability. If it is being suggested that a model can be used for another purpose, it has to be separately justified for this new purpose."

Nowadays, design, planning, and implementation techniques in almost all disciplines are based on the achievement of human well-being. Considering the increasingly complex systems of creation and

functioning of contemporary social, technical, and medical disciplines, as a consequence of technical and technological development, computational modelling and simulations, as well as sophisticated communication systems are of great importance and help, enabling more and more effective interfaces between complex models, decision-makers and other users. Such complex models are valuable for analysing and explaining enormously complex human systems, behaviour under various changing conditions and assessment of well-being.

In the case of urban planning, architectural design and projecting of building constructions, the possibilities of computational modelling and simulation are considered in the aforementioned Report (Government Office for Science, 2018) as follows: „Buildings and their infrastructure can be modelled, and those models can be used not only to maximize the efficiency and effectiveness of the design and construction processes, but also to analyse and manage buildings and their associated infrastructure throughout their entire working lifespan. In the public sector, policies can be tested before they are implemented, exposing potential unanticipated consequences and preventing their occurrence."

In architecture, computational modelling can be used to simulate the behaviour of materials and buildings in certain given conditions. Computer programs aim to show as faithfully as possible how a building will be implemented and how it will behave over time. Besuievsky et al. (2021) worked on improving the finite element method for simulating the release of heat energy through the building and pointed out: „Describing heat exchanges at building or district scales is an important issue in order to propose guidelines for sustainable urban design. Simulating thermography by FiniteElement Method (FEM) is an attractive approach when accurate solutions are pursued for representing and visualizing long-wave radiation exchanges for digital models (Aguerre et al., 2020)."

Computer programs are also being developed for urban planning. Ideas for this were started in the 60s of the last century, which can be seen in the Special Report 97 - URBAN DEVELOPMENT MODELS (1967), which presents the proceedings of the conference held in June 1967. As noted in the Report the conference on urban development was held against a background of rapid but uncoordinated growth in the field of land use and urban development modelling. The expansion of 'modelling' in the physical, social, and management sciences has had a long and respectable history, but its more recent explosion is largely a consequence of the advent of the computer. At that conference, it was pointed out that there are a significant number of ingredients that affect the success of the formation of computer models, and they relate to programming, calculations and computer resources. The following was also highlighted: „Programming time and effort have been influenced by a number of factors other than the experience and sophistication of the programmer. By far the largest factor is probably the difficulties of calibration; models which, for one reason or another, do not need to be calibrated require substantially smaller amounts of programming. A special case arises in the event that model development requires the invention and application of new mathematical methods. By far the most substantial obstacle to the operationalizing of models has been the delay and frustration involved in assembling, organizing, and utilizing the necessary and relevant data."

It is interesting that there is a serious discussion in the world about the importance of using computational modelling. It can be seen that the experts are of divided opinion. According to one group, modelling is indispensable in the scientific and educational system with a tendency to spread towards everyday life, while others believe that it is necessary to work with less artificial intelligence, especially in the initial stages of the formation of experts. Giving a critical review of digitization in architectural education, the author Dr Levent Kara (2015) states: „the conventional tools of hand drawing, physical modelling, and hand making should be embraced in the foundational levels, and the digital tools should be introduced after developing a certain set of skills of one-to-one physical making where a sense of tectonic resolution, scale, and spatial experience is cultivated as a basis of architectural thinking with digital tools."

Computational modelling and simulation (CM&S) involve the use of numerical tools to create virtual models of complex systems to better understand processes and predict effects of different

interventions (Lesage at al., 2023). Lesage et al. (2023) noted that CM&S can be used in medicine to mimic biological processes with the goal of understanding pathophysiology, improving diagnosis, treatment, or the prevention of diseases. In this paper authors gave a definition for computational modelling and simulation in medicine, with the idea of showing through a survey the importance of using computer technology in order to make diagnosis and therapy as individualized as possible. As can be seen, a personalized approach to diagnosis and therapy is the main requirement of today's medicine.

A review of the literature shows that digital technologies make a great contribution to the development of both diagnostic and therapeutic procedures. Many clinicians today are faced with the problem of a personal therapy protocol. Pronounced standardization leads to the fact that even though the therapy is set correctly, it does not give adequate results.

This problem is addressed by a group of authors (McKenna et al.,2011), pointing out that in addition to cellular and genetic mechanisms, there are numerous measures that contribute to the response to treatment, and the idea of these authors is that by using computational modelling, problems related to the effectiveness of therapy can be overcome.

Guided by the main medical principle 'First do no harm', clinicians and scientists in their work face increasing challenges every day in the development of digital technologies, computational modelling and bioengineering, all with the aim of achieving quick, efficient and of course affordable solutions.

When it comes to techniques for diagnosing patients and using computers for this purpose, Amisha et al. indicate the following procedures: „Computers learn the art of diagnosing a patient via two broad techniques - flowcharts and database approach… The flowchart-based approach involves translating the process of history-taking, i.e. a physician asking a series of questions and then arriving at a probable diagnosis by combining the symptom complex presented… On the contrary, the database approach utilizes the principle of deep learning or pattern recognition that involves teaching a computer via repetitive algorithms in recognizing what certain groups of symptoms or certain clinical/radiological images look like."

Ethan Waisberg et al. (2023) in their paper explained the importance of AI in medicine on example of ChatGPT: „This generative model has already been capable to do a variety of useful medical tasks, from writing discharge summaries to generating images from patient descriptions of neuro-ophthalmic conditions to helping with triaging of ophthalmic conditions. ChatGPT was shown to be able to respond to patient questions from a social media forum with higher levels of empathy and quality than the responses provided by physicians. ChatGPT can also able to generate basic code, which can be useful for clinician-scientists to begin working with artificial intelligence (AI) for the first time."

CONCLUSIONS

Models, including computer models, are tools that help experts translate their experiences into predictions of future events, making it easier to make decisions about what to do to achieve the best results in a complex and changing world. The convenience provided by computational modelling is reflected in getting answers to the question 'What if? ' through a virtual simulation and thus getting relevant answers about the outcome of the experiment before things are tried in reality. The largest number of computer simulations provide answers to one problem, for example, how much heat is lost through the facade, how the behaviour of the product depends on the properties of the material from which it is made, or what is the effectiveness of the drug on a specific cell line that is targeted therapy. The development of computational modelling needs to be focused on the possibility of solving complex problems of layered structures in which different disciplines are involved. This can be seen as the very beginning of future simulations that will provide answers to complex questions, such as: how the settlement will develop, what will be the structure of the population of that settlement

in the future and what will be the average age, education, state of health, what infrastructure will be needed for those residents, what kind of health facilities will be needed, what service activities, what jobs will be current, etc. Such computational modelling and simulations give the possibility of better insight into the future and solving obstacles that could not be assumed to appear. This type of use of new technologies is a tool that contributes to the survival of the idea of sustainable cities and other systems.

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