ISSN 2350-109X
www.indianscholar.co.in

Indian Scholar

An International Multidisciplinary Research e-Journal

COMPUTATIONAL MODELLING AND SIMULATION IN HEALTHCARE: A SUMMARY

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Abstract

Computational systems, modelling and simulations (CM&S) have been part of human history for about 50 years in the field of medicine. This study aimed to evaluate, analyse and synthesise its contributions in healthcare. The author compiledseveral field-specific publications, provided personal input and diluted complicated terminology, making it conceivable for the reader. The method implemented used the internet and certain online databases for the reading and citing. The results obtained were simple and most positive, depicting the irreplaceability of CM&S in healthcare. The author concludesCM&S has been and will continue to be vital the betterment of the medical field.

Keywords: Computational modeling and simulation (CM&S), Simulations in healthcare, Epidemiology, Modelling and Simulation During Pandemic, Literature Review

INTRODUCTION

As the fast-paced era of machinery progresses, making breakthroughs in and using technology becomes easier. This applies to the healthcare industry as well. A popular component in the history of medicine has been the art of modelling, which has developed leaps and bounds by contribution of computers. Computational modelling and simulation (CM&S) makes use of technology to demonstrate ideas, reveal gaps in knowledge sustained theoretically, or simply observe constructed scenarios. It uses mathematical and scientific explanations of naturally occurring phenomena to make them observable digitally.Some of the major types of simulations used in healthcare are: discrete event simulation (DES), system dynamics (SD) and agent-based simulation (ABS). Abiding with this paper's objective, the author will not be going into further details.

This paper talks about the history of computerised systems and how CM&S has given rise to the marginal development of the healthcare industry.As the paper unfolds, it moves from the past of CM&S and towards its significant work in the most recent pandemic, covering certain contributions and other examples.

A majority of the latest publications under this topic talk mainly about CM&S applied to very particular areas of medicine, e.g. making slit-lamp shields, exploring vaccine efficacy, studying transcranial simulation, etc. Some publications go into extreme detail, combining other published works, which may prove them unuseful to the novice reader with their complex terminology.

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METHODOLOGY

To gain a general understanding of the topic of computational systems, modelling and simulation, the author read various magazine articles and watched lectures available online.

However, due to the overwhelming volume of data presentwith questionable credibility, the author decided to view public access research papers from various trusted websites. The process of selection was fairly straightforward: The author first went to a database, e.g. PubMed Central, and used the search option. Keywords used included: 'Simulation and modelling', 'computational modelling and simulation', 'modelling and simulation in healthcare'. The following filters were applied to ensure maximum relevancy and availability: 'published from 2012 to 2022' and 'public access'. The second step of the process entailed reading the abstract to familiarise with the papers and pick ones appropriate for this research. For the final step, the author went for a full-text reading to scan for relevant material and quotations.

The information capturing for this paper meant identifying the notable inventions in each work and their uses. The dates of these inventions – or lack thereof, in which case another extensive search was required – were compiled and organised chronologically. This list of inventions is by no means exhaustive, and is only a compilation of ones that were taken note of by the author.

RESULT

Pertaining to the collected data, the author determined that despite not having the most illustrious presence, CM&S played a significant role in the progress of medicine and medical equipment. Not only did it help in training medical staff in harmlessly, it also gave healthcare equipment manufacturers the opportunity to create and design tools to ensure utmost efficiency and effectiveness.The commonest forms of CM&S, i.e. DES, SD and ABS, have contributed to health-risk assessment, planning of healthcare services, public health policy evaluations and in several cases, training; thus, playing drastic role in minimizing casualties caused by untrained staff. Simulations have allowed medical practitioners to refine surgical techniques with minimal experimentation on actual humans, while obtaining equally pertinent results. It has made a significant contribution in our recovery from the COVID-19 pandemic.

DISCUSSION

The earliest computational model that promoted medical advancement is the First Generation of Stylised Phantoms created at Oak Ridge National Laboratory in the 1960s. Its application was to calculate the internal doses from nuclear medicine procedures, making it easier to figure out how much radioactive material was deposited in workers and patients alike.

As specific as the use was, it was the foundation for the better and ultimately more useful phantoms. These were called the Second Generation Voxel (Volumetric Pixel) Phantoms, produced in c.1980, which made use of voxels to recreate the 3D human body digitally.

While the phantoms progressed on their own, David Gaba et al. manufactured the Comprehensive Anesthesia Simulation Environment (CASE) at Stanford University in 1988. This simulation allowed medical students to practice anesthetising patients with realistic human responses. This was a huge win, for a great number of deaths of the era were caused due to mistakes performed by practitioners with insufficient practice or experience.

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The early 2000s introduced the third generation of phantoms, called Boundary Representation Phantoms (BREP). These were an immense improvement from the voxel phantoms, as they allowed formation of versatile bodies with a wide range of postures, organ shapes and organ volumes. Popular examples include the Polygonal Mesh-Based Phantoms still prevalent today, mainly assisting radiation dosimetry.

In relation to CASE: in 2007, medical schools developed internet-based systems that would allow their students to gain and improve the skills required for history-taking and clinical examination.

At University of Michigan, Alberto Figueroa et al, performed the first ever surgical procedure to entail computerised blood flow simulation, in 2015. This is considered a substantial step in the use of modelling and simulation for surgery.

With the SARS-CoV-2 virus outbreak in 2020, CM&S played a vital role in combating the pandemic. Popularly, computational models of the virus structure were created to spread awareness and eventually to develop vaccines. Other examples include the use ofsimulated systems to test vaccine roll-out strategies and using simulation to increase equipment effectiveness for medical practitioner safety.

Aside from what was aforementioned, the 21st century also saw an increase in the use of CM&S in the manufacturing of medical tools and equipment. For example, companies used product modelling to observe proposed pieces and assess them for post-market failures. This plays a role in decreasing the burden on patients and volunteers byminimising the need for the product to be tested on living humans, and in several cases, animals. It ensures that products are tested at least computationally before being launched for public use, e.g. stents, IVC filters, stent-grafts, etc.

CONCLUSION

There were some limitations to this study: the lack of access to resources making it difficult to review a greater number of samples; and coming across paywalls and other barriers, interrupting research. This issue prompted the author to implement filters and directly ignore some resources. The filters applied may have led to certain important results going unnoticed. However, while this limits the generalisability of the results, it improves the relevancy ofselected articles.

In the present study, the author examines multiple studies pertaining to various parts of healthcare. Significant difficulties of other publications included the surplus amount of detail and/or complexity. To overcome this, the author evaluated several documents, finding patterns and materials relevant to the untrained reader.

To conclude, this research finds that although not the most popular, CM&S has been a crucial contributor in the development of the healthcare industry. It has created potential for substantial progress of medical research and made room for practitioners to exceed human limitations in surgical procedures and other treatments.

For better understanding of the implications of these results, future studies should address the aforementioned limitaitons, and attempt to gather more resources, then examine them fully.

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