Tarek Zohdi

MODELING AND SIMULATION TOOLS FOR INDUSTRIAL AND SOCIETAL RESEARCH APPLICATIONS: DIGITAL TWINS AND GENOME-BASED MACHINE-LEARNING

(Записано з виступу на конференції)

UC Berkeley, Will C. Hall Family Endowed Chair in Engineering Dept. of Mechanical

Abstract

A variety of seemingly disparate physical processes can be treated with similar modeling and simulation tools. In this talk, I discuss the modeling and rapid digital-twin simulation of technologies related to next-generation food production: Part 1: modeling of robotic machine-learning for advanced manufacturing; Part 2: modeling of laser and optical processing of materials; Part 3: modeling of multiphysical solid processing and continuum behavior; Part 4: modeling of ignition, fire propagation and ember flow; Part 5: modeling of multiple unmanned aerial vehicles for complex tasks; Part 6: modeling of industrial safety: pandemics, transmission, decontamination, as well as aspects of genomic/evolutionary computing for system optimization, utilizing multiphysics paradigms. The tools range from discrete element methods, computational optics, voxel-based computation to agent-based modeling-all connected together via machine-learning algorithms.

Ключові слова: digital dual modeling, physical processes, robotic machine learning, laser and optical processing of materials, unmanned aerial vehicles, industrial security.

Modeling and simulation tools play a crucial role in industrial and societal research applications by providing valuable insights and predictions in a cost-effective and efficient manner. Two important technologies that have gained significant attention in recent years are digital twins and genome-based machine learning. Let's explore each of these technologies and their applications in more detail.

Digital Twins: Digital twins are virtual replicas or representations of physical systems, processes, or assets. They are created by combining real-time data from sensors, Internet of Things (IoT) devices, and other sources with computational models. Digital twins enable researchers to simulate, analyze, and optimize the performance of complex systems, predict their behavior, and make informed decisions.

Industrial Applications:

-Manufacturing: Digital twins can be used to optimize production processes, monitor equipment health, and predict maintenance requirements, thereby improving efficiency and reducing downtime;

-Energy: Digital twins can model and simulate energy systems, such as power plants or smart grids, to optimize energy generation, distribution, and consumption, leading to more sustainable and reliable energy solutions;

-Transportation: Digital twins can simulate traffic flow, optimize logistics and supply chain operations, and enhance vehicle performance and safety;

-Healthcare: Digital twins can model human physiology, diseases, and drug responses, enabling personalized medicine and treatment optimization.

Societal Applications:

-Smart Cities: Digital twins can simulate and optimize urban infrastructure, including transportation networks, energy grids, and waste management systems, to create more sustainable and livable cities:

-Disaster Management: Digital twins can help simulate and predict the behavior of natural disasters, such as fires, floods, or earthquakes, to support emergency response planning and decision-making;

-Environmental Monitoring: Digital twins can simulate and analyze environmental systems, such as ecosystems or climate patterns, to understand their dynamics, predict impacts, and guide conservation efforts.

Genome-Based Machine Learning: Genome-based machine learning refers to the application of machine learning techniques to analyze genomic data. It involves the integration of genetic information with computational models and algorithms to gain insights into biological systems, diseases, and drug responses.

Industrial Applications:

-Pharmaceutical Research: Genome-based machine learning can help identify potential drug targets, predict drug efficacy, and optimize drug discovery and development processes;

-Agriculture: By analyzing genomic data of plants and animals, genome-based machine learning can improve crop yields, enhance livestock breeding programs, and develop disease-resistant varieties;

-Biotechnology: Genome-based machine learning can be used in areas such as bioengineering, synthetic biology, and industrial biotechnology to optimize enzyme design, metabolic engineering, and biofuels production.

Societal Applications:

-Healthcare and Precision Medicine: Genome-based machine learning can aid in the diagnosis and treatment of diseases by analyzing an individual's genetic information to personalize healthcare interventions;

-Genetic Counseling: Machine learning algorithms can assist genetic counselors in interpreting complex genomic data and providing personalized risk assessments for genetic disorders;
-Forensic Science: Genome-based machine learning can aid in DNA profiling, identification of individuals, and solving criminal cases.

There is a computer model in a complex system. Typically, we develop computer models, but the computer models have many complex interacting parts, a large number of adjustable parameters, low rates, laser strength, and things of that sort, so typical simulation would go into each of these components.

The convex optimization based upon machine learning is to try to ascertain what are the correct parameters to make the simulation deliver desired responses, how the desired responses could be aspirational in the sense that it could be something we want the model to do, or it could be, that we want the model to match a certain requirement. When the computer chips became faster desktop computing became faster, and the ability to read information from camera feed. You became viable then to start adjusting these parameters and including them in the simulation of the machine in the real-time. In my institute, we look at many different problems using these kinds of technologies for example training robots to do complex printing. In this case it's electro, hydrodynamic printing, where we have electric fields that guide particles into certain patterns a real time flow control of multi-phase materials that might be fluidized, but are strongly electromagnetic heterogeneous.

The issues with phase transformations are the control of lasers as indicated before in the real time control in terms of stress analysis, using modern types of element techniques not the classical ones, but one's based upon voxel-based computing where we take three dimensional pictures of an object and convert that directly into a Vauxhall so that we can use that as a computing entity. It is quite fast to go from camera. In all of these kinds of calculations, really what we're looking at as we're developing a non-convex optimization technique to control them we need a technique which has been around for a while and is based upon genetic algorithms and embedding that into a machine learning algorithm and convert them into a genetic string or a piece of computation of DNA. Within tests we start to alter the DNA with the type of gene editing now the idea is that we used for many different applications. One in particular for California is the fighting of fires with drones and using drones to release fire retardant onto fire area. The simulation is a simulation of a drone that is basically dropping fire retardant over a large-scale fire that has a huge amount of buoyancy governed by the equations.

The main point here is that there are hundreds of parameters, and you need to let the machine figure it out, so how are the machine figure, by direct brute, force training, we compute the robot position at a given time with all of the system parameters. Appropriately it is very fast and the entire simulation here can be run several hundred thousand times in an hour. This is where the machine learning is used. The idea is that we take the system parameters for the robot. We create a population of small robots. We run the robots and their performance is ranked with a computer, maybe by taking the genes of the good robots and combining them appropriately we can put the baby robots in the competition: the parents against new robots and we repeat the process over and over again. It starts to hunt everywhere in the search domain. We run the simulation again a little bit better, and improve the performance each loop.

It's important to note that both digital twins and genome-based machine learning require robust data collection, integration, and analytics frameworks, as well as ethical considerations regarding privacy, data security, and responsible use of the technology.

Tarek Zohdi, *Professor of Mechanical Engineering, W. C. Hall Family Endowed Chair in Engineering, Chair of the Designated Emphasis Program in Computational and Data Science and Engineering and Associate Dean for Research in the College of Engineering at UC Berkeley, as well as Faculty Scientist at Lawrence Berkeley National Labs, member of the National Academy of Sciences and the National Research Council of the US National Commission on Theoretical and Applied Mechanics, national coordinator of AmeriMech USA, Email: zohdi@berkeley.edu*

Інструменти моделювання та імітації для промислових та суспільних досліджень: цифрові двійники та машинне навчання на основі генома

Анотація

Різноманітність різнорідних фізичних процесів можна розглядати за допомогою схожих інструментів моделювання та імітації. У цій доповіді я розповім про моделювання та швидке моделювання цифрових технологій, пов'язаних із виробництвом продуктів харчування наступного покоління: Частина 1: моделювання роботизованого машинного навчання для передового виробництва; Частина 2: моделювання лазерної та оптичної обробки матеріалів; Частина 3: моделювання мультифізичної обробки твердого тіла та поведінки континууму; Частина 4: моделювання займання, розповсюдження вогню та потоку; Частина 5: моделювання багаторазових безпілотних літальних апаратів для комплексних завдань; Частина 6: моделювання промислової безпеки: пандемії, передача, знезараження, а також аспекти геномних/еволюційних обчислень для оптимізації системи з використанням мультифізичних парадигм. Інструменти варіюються від

методів дискретних елементів, обчислювальної оптики, обчислень на основі вокселів до моделювання на основі агентів – усі вони об'єднані разом за допомогою алгоритмів машинного навчання.

Keywords: цифрове подвійне моделювання, фізичні процеси, роботизоване машинне навчання, лазерна та оптична обробка матеріалів, безпілотні літальні апарати, промислова безпека..

Тарек І. Зохді, *професор кафедри інженерії, заступник декана з дослідження в Інженерному коледжі Каліфорнійського університету в Берклі, науковий співробітник університету Лоуренса Берклі, член Американської академії механіки, член Національної Академії наук та Національної дослідницької ради Національної комісії США за відділенням теоретичної та прикладної механіки, національний координатор AmeriMech США, Email: zohdi@berkeley.edu*