Computational Mechanics

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ABSTRACT
Computational mechanics (CM) is concerned with the use of computational techniques to characterize, predict, and simulate physical phenomena and engineering systems governed by the principles of mechanics. Over the years, CM has made a significant contribution in the design and development of new products and systems. This paper provides a brief, clear introduction to computational mechanics.

Keywords: computational mechanics, computational methods

INTRODUCTION
Nowadays, various computational methods are used in all areas sciences and engineering. They have been introduced for solving problems of mechanics, heat transfer, electromagnetic, and other areas in physics.

Computational mechanics (CM) refers to the application of numerical methods and digital computers to study phenomena governed by the laws of mechanics.

The term "computational mechanics" has been widely used since 1986, after the 1st World Congress of computational mechanics. CM is basically an integral part of computational science and engineering. It is widely regarded as a sub-discipline of applied mechanics or computational science. It has had a profound impact on science and technology over the years. It has transformed much of classical Newtonian theory into practical tools for predicting and understanding complex systems [1].

BASIC COMPONENTS
Computational mechanics is an interdisciplinary research field with three major components [2]:
1. *Mechanics:* This includes computational fluid dynamics, computational thermodynamics, computational electromagnetics, computational solid mechanics, solid and structural mechanics, and fluid mechanics.
2. *Mathematics*: CM usually involves developing mathematical models of physical phenomena using partial differential equations, functional analysis, linear algebra and numerical methods. The most common numerical methods used in CM are the finite element, finite difference, and boundary element methods in order of their popularity. The finite element method (FEM) is robust, effective, and flexible; it has been thoroughly developed into some commercial and non-commercial software packages such as COMSOL and ABAQUSto handle linear and non-linear mechanics problems.
3. *Computer Science*: Computer programming, algorithms, and parallel computing play a major role in CM. The most widely used programming languages are FORTRAN and C++ . MATLAB and Mathematica are also widely used in scientific community. Object-oriented programming is becoming common in CM. It proposes that large complex problems can be broken down into simple, easy to manage problems with the relatively few concepts of objects, classes, encapsulation, inheritance and messages. It has been used to capture some of the abstractions that would have been very hard using a procedural language such as FORTRAN or C [3,4].

APPLICATIONS
CM tools have successfully been used to simulate complex problems that would be difficult if not impossible to handle using analytical methods. Examples of practical applications include [1,5]:
➢ **Vehicle Crash Worthiness***:* This involves computer-generated simulation of the crash worthiness of automobiles. This has replaced hundreds of full-scale tests and saved automobile manufacturers several millions of dollars.
➢ **Predictive Surgery***:* CM models are generated for analysis by surgical teams to assist in determining the best procedure for the patient under treatment. The results predicted by these models are used before the actual surgery takes place.
➢ **Manufacturing***:* Modern manufacturing systems are known to be complex. CM provides an opportunity to apply insights to manage complexity in manufacturing systems [6].
➢ **Military Applications**: CM models are used in the analysis and design of weapons and armor.

Other applications include petroleum reservoir modeling, biomechanics, glass manufacturing, semiconductor modeling, environmental modelling, computational wave propagation, bioinformatics, and bioengineering, stretchable/compressible electronics, and information fusion.

CHALLENGES
While it is generally acknowledged that parallel supercomputing offers considerable promise for solving large problems of practical interest, it is essential that some challenges faced by CM are addressed so that it is competitive.

The issue of reliability of computer-generated predictions is a great concern to CM specialists. The size of the simultaneous linear equations to be solved in using CM has been growing larger and larger. Another major challenge in computational mechanics research is bridging the different

scales without sacrificing resolution. Modeling events in which the remarkably varying scales are significant in a single system is important.

The computational mechanics suffers a lack of modifiability and interactivity. This undermines its potential to help engineers in solving problems faster and cheaper. This problem can be tackled by full integration of computer design in CM [7].

CM suffers from a general deficiency of modelling, namely introduction of errors. In principle, there are two major sources of error in computer simulations of physical phenomena events: approximation error, due to the inherent inaccuracies incurred in the discretization of mathematical models, and modeling error, due to the natural imperfections in models of physical phenomena [8, 9].

CONCLUSION

The success of computational mechanics will be determined by its effectiveness in solving real-world problems of interest to society. Future research in CM will be broader than ever before. By incorporating new models of physical and biological systems, CM has a great potential for future growth and applicability. It willl have a profound impact on many facets of our life, including advances in biology, medicine, energy conservation, and national security.

There are two main organizations that are committed to promoting CM. *International Association for Computational Mechanics* (IACM) is an international organization (based in Spain) that provides a common forum for discussion, education and research information on CM. *United States Association for Computational Mechanics* is an organization that promotes activities on computational mechanics in the United States and is an affiliate of IACM.

More information about CM can be found in the following journals:
➢ Computational Mechanics
➢ European Journal of Computational Mechanics
➢ Journal of Applied and Computational Mechanics
➢ Journal of Computational Applied Mechanics
➢ Applied and Computational Mechanics
➢ International Journal for Computational Methods in Engineering

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