THE ROLE OF MATHEMATICAL TECHNOLOGY IN MODERN AGE

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Abstract— The modern ages sphere has its centre at Mathematics. The mathematical technology has revolutionized every aspect of life. Now a day, it is playing a vital role in the fields of industrial engineering, computational sciences, operation research, management science, economics and many more. In this paper, the use of mathematical models to create virtual or visualized images of objects and systems, forecast system behavior, analyze risk factors, perform intelligent analyses on measurement data, manage and control large information systems, networks, data-bases etc in the fields of industrial engineering, computational sciences, operation research, management science, economics, metal industry, maritime industry, space technology, manufacturing systems etc has been discussed.

Key-words:-Mathematical technology, modeling, simulation.

1 Introduction

Mathematical technology is a term referring to the interdisciplinary area combining applied mathematics, engineering and computer science. Applied mathematics which is an essential part of mathematical technology, is a branch of mathematics that concerns itself with mathematical methods typically used in science, engineering, business, and industry. It describes the professional specialty in which mathematicians work on practical problems and focus on the formulation and study of mathematical models. In the past, practical applications have motivated the development of mathematical theories, which now a day have provided a very strong foundation in the development of modern life. The success of modern numerical methods and software has led to the emergence of computational mathematics, computational science, and computational engineering, which use high-performance computing for the simulation of phenomena and the solution of problems in the sciences and engineering.

Today, life can’t be imagined without computers. The advent of the computer which itself relies on logic, algebra, combinatorics has created new applications: studying and using the new computer technology itself, using computers to study problems arising in other areas of computational science, and studying the mathematics of computation such as theoretical computer science, computer algebra, numerical analysis etc. Statistics is probably the most widespread mathematical science used in the social sciences, but other areas of mathematics are also proving increasingly useful in these disciplines, most notably in Economics. Engineering is another important area which is playing a very important role in modern life.

Mechanical engineering supports the machine age, civil engineering providing foundation to the real estate. Modern life cant be imagined without electronic and electrical engineering. In this article, the use of Mathematical Technology (applied mathematics, engineering and computer science) has been discussed in various fields.

2 Types of mathematical models

The model can describe situations that are impossible to be realized physically or are too extreme for making observations viz. one cant repeat the Big Bang or observe at close distance the explosion of a mine, but one can numerically simulate both situations using modeling. Modeling means an imitation of a real system or process.

The model is assumed to represent the structure and the laws governing the time evolution of the system or phenomenon that it was set out to mimic. Once we are able to produce a satisfactory model, we have a powerful tool to study the behavior and hence to understand the nature of the system. Models may represent different scales, conceptual levels and the model may contain inner structures, partial models or sub models. Macroscopic model tries to catch the big picture, microscopic model zooms at very minutiae details. Take for example the dynamics of weather phenomena where different version of models are needed to describe the formation of rain drops or local air pressure variations, to explain the creation of tornados or to understand the greenhouse effect.

Mathematical models represent many different forms and types. Continuous models deal with quantities like time, distance, force, electric potential that very smoothly over space and time and these models take the form of a set of algebraic or differential equations, integral equations, partial Differential equations. Discrete models deal with quantities that vary in a stepwise manner and take values from a discrete set. Examples of discrete models are recurrence relations, difference equations, Markov chain, digital coding and signals, graphs, integer LP models.

A model which is based on the understanding of the internal mechanisms (physics, chemistry, biology, economics etc) is called a mechanistic model. When a mechanical model and analytic solution is not available we may use simulation.
Deterministic models describe the phenomenon by predicting the actual values of the dependent variables where known input values lead to unique output values. Stochastic models incorporate different random effects into the model structure and they are aimed to describe random behavior and predict the probability distribution of the output values. Optimization models are geared to a specific purpose, to help find the best operating conditions, to find an optimal design for a product, etc. Control models are the devices for control engineering, process control and different mechanisms of guidance viz. the models for steering the operation of power stations and the guidance systems for air traffic.

3 Applications of mathematical technology
The development of technology has modified in many ways according to the expectations of society and practices of applied research. Today industry is typically high tech production. Sophisticated methods are involved at all levels. Computationally intensive methods are also used in ordinary production chains, from timber industry and brick factories to bakeries and laundry machines. The increased supply of computing power has made it possible to R&D and is an essential development factor. The increasing demand and sphere of applications and the evolving computational possibilities have created what may be called mathematical technology or industrial mathematics which is used to describe the active contact zone between technology, computing and mathematics. The major areas where mathematical technology plays its role in the development of modern society are:

3.1 Traffic and transportation
Roads, railway networks and air traffic are the means of transportation in modern age and contain many challenges for modeling. In railway industry, one is interested on the mechanical models about the rail-wheel contact, explaining the phenomena of wear, slippage, braking functions etc. The train itself is a dynamical system with a lot of vibrations and other phenomena. Regarding the road network, analysis of traffic flow, scheduling, congestion effects, planning of timetables, derivation of operational characteristics etc. need sophisticated models. In air traffic, guidance systems and the flight control of an aircraft represent computational mathematical control theory. Hence in transport system mathematical modeling plays a very important role for controlling the road, rail and the air traffic.

3.2 Maritime industry
The maritime and offshore industries use advanced mathematical methods in the design of ships and mechanical analysis of offshore structures for studying the dynamical behavior of floating structures under wave force effects and wind conditions. Individual technical tasks like the optimal design of an anchor cable or the laying of communication cables at sea bottom lead to interesting mathematical problems. One particular challenge is the modeling of the sea and the wave conditions itself for the sake of simulation purposes.

3.3 Space technology
Modeling of the mechanical properties of the man-made structures in the spatial orbit leads to advanced mathematical problems. An example could be the stability study of an extremely large light antenna structures in the weak gravity field. Each individual space mission represents a massive task for dynamical modeling and optimal control.

3.4 Earthquake engineering
The frequent occurrence of earthquakes in some or the other part of earth, which results in destruction of buildings and loss of human life, has posed a serious challenge to mathematicians and earth scientists. The seismologists have been making efforts to find the causes and effects of the earthquakes since a very long time. The problems related to the reflection, refraction and scattering of seismic waves due to the presence of various types of irregularities in the surface of earth are also of great importance at the present time as they directly affect the human life. The studies related to the propagation of these types of waves through the interiors of earth surface also helps in understanding the internal structure of earth, which in turn can also be used for exploration of valuable materials like oil, minerals etc which are providing a very strong foundation to modern life. The mathematical modeling helps in finding the solutions of problems related to earthquake engineering.

3.5 Economics and management
The daily functioning of our modern society is based on numerous large-scale systems such as transportation, communication, energy distribution and community service systems. The planning, monitoring and management of these systems offers a lot of opportunities for mathematical approach. System models, methods of operations analysis, simulation etc. can be used to gain understanding on the behavior of these mechanisms. Corporate management uses methods in which mathematical knowledge is embedded in different levels. Econometric models are used especially at the banking sector to describe the macro level changes and mechanisms in the national economy. Risk analysis, game theory, decision analysis etc are used to back up strategic decisions, to design a balanced financial strategy, to optimize a stock portfolio. The mathematics of the financial derivatives (options, securities) has been a sector of rapid mathematical development in recent years.

3.6 Product design and geometry
The modern toolbox of analytic and numerical method has made mathematics a real power tool for design engineers,
production engineers, architects etc. One can bypass costly trial and error prototyping phases by resorting to symbolic analysis and numerical models. Mathematics is a natural tool to handle geometrical shapes, like the surfaces of car bodies and in the visualization techniques in CAD and virtual prototyping. In fact entertainment industry is one of the great clients for mathematical software nowadays. Visualization and animation is the basis of computer games and the vivid special effects in movies etc. These tricks are made possible by mathematical models.

**3.7 Performance analysis, manufacturing systems and reliability**
The major source of economic added value in using mathematical methods comes from the possibility of simulate devices, mechanisms, systems including complex large scale systems prior to their physical existence. The whole new system - like an elevator system in a high rise building, a microelectronic circuit containing millions of elements, or a high tech manufacturing system can be designed and tested for its performance and reliability using mathematical modeling.

**3.8 Chemical reactions and processes**
Chemical processes are being modeled on various scales. In the study of molecular level phenomena, mathematical models are used to describe the spatial structures and dynamical properties of individual molecules to understand the chemical bonding mechanisms etc. The chemical reactions are modeled using probabilistic and combinatorial methods where the reaction kinetics takes the form of differential equations as in the case of biochemical response in the design of a laboratory test. Chemical factories use large models to monitor the full-scale production process. The increasingly important area of environmental monitoring is also benefited from models that describe and explain biochemical processes.

**3.9 Materials behavior**
Materials science is one of the really active fields where the mathematics based methods have proved their necessity and power. The aim is to understand the micro level molecular and subatomic effects, subtle engineering of special compounds etc. The behavior of non-typical materials or new materials like semiconductors, polymer crystals, composite materials, piezoelectric materials, optically active compounds, optical fibers etc. create a multitude of research questions, some of which can be approached with mathematical models. The models can further be used to design and control the manufacturing processes.

**3.10 Metal industry**
The whole production chain of metals starting from mining industry, enrichment processes, furnace, casting, hot rolling, sheet forming, profiling etc. contains a lot of challenge to mathematical models. Quite modern and sophisticated methods such as optimal control theory, free boundary problems, optimization methods and advanced probabilistic methods etc. are employed for such type of assignments. There are delicate questions like modeling of the material deformation during manufacturing processes, the phase change phenomena in the heat treatment of steel and the study on the fatigue mechanisms, which are easily handled by mathematical modeling.

**3.11 Food and brewing industry**
Mathematics is not only a numerical subject but it also plays a very important role in day to day life. The mathematical technology has to do with butter packages, lollipop ice-cream, beer cans and freezing of meat balls. The food and brewing industry means biochemical processes, mechanical handling of special sorts of fluids and raw materials. These less typical constituents lead into non-trivial mathematical questions. The control of microbial processes is quite crucial and adds to the complexity. Some of the questions deal with simple aesthetics like the problem of proper filling of lollipop moulds in an automatic production chain and so on.

**3.12 Flow phenomena**
The ability to model sophisticated phenomena including non-linear effects, the possibility to solve the equations with advanced numerical methods combined with the latest visualization tools have created a luxury environment for mathematical engineering. The computational simulation can be used to support the design of systems from tooth paste tubes, regional heating networks and aircraft fuselage design to ink-bubble printers making the fascinating flow phenomena visually observable. One of the important fields of application is diffusion phenomena, like the spreading of pollutants in air, soil, rivers etc.

**3.13 Semiconductor industry**
The tiny devices are so small that it takes a microscope to see the details. The modeling of the single transistor has generated a lot of research. The industry wants accurate device models describing the performance characteristics of a chip prior to its production. To find the optimal architecture for an integrated circuit demands heavy calculations. The procedure of electron beam lithography that is used during the manufacturing of the integrated circuit leads to interesting problems for mathematical modeling.

**3.14 Systems design and control**
The design engineers and systems engineers have always been active users of mathematics in their profession. The possibility to set up realistic large-scale system models and the development of modern control theory has made the computational platform a powerful tool with new dimensions.
3.15 Measurement technology, signal and image analysis
The computer and the advanced technologies for measurement, monitoring devices, camera, microphones etc. produce a flood of digital information. The processing, transfer and analysis of multivariate digital process data has created a need for a considerable amount of mathematical theory and new techniques. The area of signal processing is one of the hot areas for applied mathematics.

3.16 Experiments and data analysis
The ample output of processed data means a demand of mathematics. Intelligent methods are needed for the utilization of experimental data. The process control and monitoring systems, the sampling procedures etc have to be designed carefully. The quality inspection at different parts of the production chain and the testing procedures for the finished products all involve the questions for intelligent techniques for the handling of data. There has been a speedy development of methods for data-analysis and the novel techniques for processing data.

4 Conclusions
Mathematical technology is playing a very crucial role in the development of modern society. The sphere of life cant be completed without use of modern mathematical technology. Starting from the very basic things like butter-bread, lollipops, ice-creams etc to the highly technical industrial machinery, space technology, computer technology etc, everything finds its base in mathematical modeling. Computational technology has made sophisticated mathematical methods viable for practical applications. There is a window of opportunity for mutually beneficial two-way knowledge transfer between academia and industry. The modern and dynamic view of mathematics should be reflected in educational practices so that the modern society can reach the acme of success, we have not imagined even today.

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6 References