ID BTech Program on Computational Engineering

Introduction

Usage of high-end computational techniques for design of new products or processes, troubleshooting and management of its overall life-cycle is ubiquitous in modern industry. Though traditional engineering BTech curriculums introduce important computational techniques related to the specific branch of engineering, however, they do not cover the wide array of computational methods used in industry. Therefore, the graduates from the traditional engineering streams have limited exposure to these methods. Industry has to spend valuable time and resources to train these graduates on various computational methods that are used in their respective fields. To address this vital gap area of engineering education, a new interdisciplinary BTech program is introduced in Computational Engineering that aims to produce graduate engineers who will have expertise in using modern computational methods for a wide variety of industrial applications.

Philosophy

Before dwelling into the philosophy of Computational Engineering, it will be worthwhile to explore a bit more on the need of this course. As part of the Saturday Manufacturing Lecture at the CoE in Advanced Manufacturing of IIT Kharagpur, Prof Shuvra Das has presented an excellent treatise on Education 4.0 which is in-line with the requirement of Industry 4.0[1]. The evolution of modern education in conjunction with the evolution of modern industry is summarized in Fig 1.

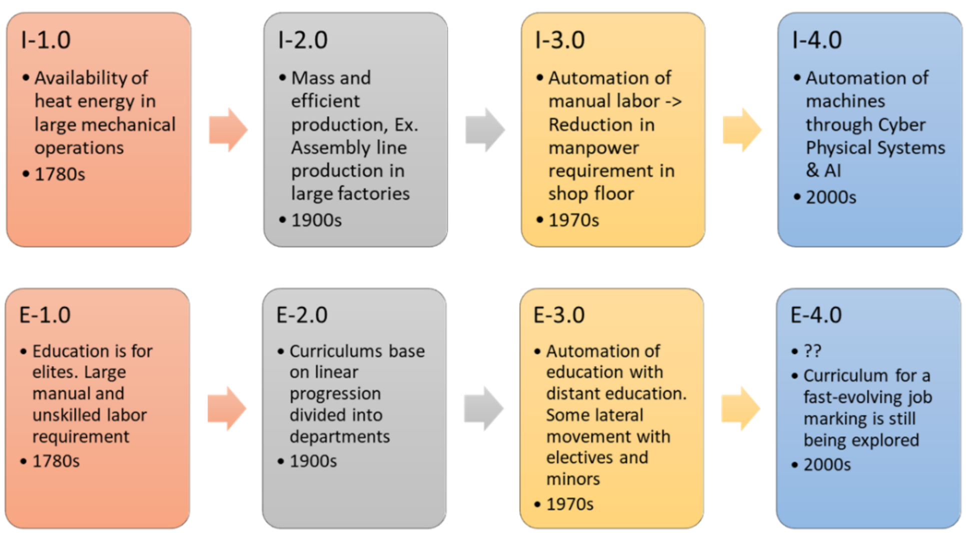

Fig 1. Evolution of Industrial Revolution (top) and the corresponding evolution of Education (bottom)

As can be seen from this schematic, the duration between each successive generation of industrial revolution has been decreasing rapidly. The timeline shown in the above figure are for the western economies. Though these transitions are also happening in India, the durations between successive generation are even shorter. Considering

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[1] 8th week (01-May-21) of Saturday Manufacturing Talks by Prof Shuvra Das - YouTube

the rapidly changing industry requirement, evolution of the education curricula is occurring at a slower pace. Modern education needs to be more interdisciplinary in nature and prepare graduates who can rapidly conform to ever changing job market. This has also been emphasized in the National Education Policy, 2020. Education 4.0 is still evolving. However, all modern curricula should be cognizant to the requirement of the rapidly evolving job market.

An important aspect of Industry 4.0 is a strongly networked Cyber Physical System and automation of workplace with a high dependency on Artificial Intelligence. For core engineering disciplines, that translates to heavy dependence on computational tools to design and analyze products and processes to create a digital twin. The BTech program on Computational Engineering is meant to develop manpower with this skill set. The program will train students capable in using computing modelling and simulation tools for various engineering applications.

Computational Engineering is envisaged to be an interdisciplinary BTech program. Fig 2 shows the four main components in the curriculum layout of Computational Engineering. These four important components include: (a) Applied Mathematics, (b) Core Engineering, (c) Data Structures & Analytics and (d) Computational Applications. Through these four pillars of the program, the student will gain proficiency not only to use the various engineering methodologies, but also get trained in some of the important curriculum of core engineering so that the bridge between computational solutions and physical principles is established.

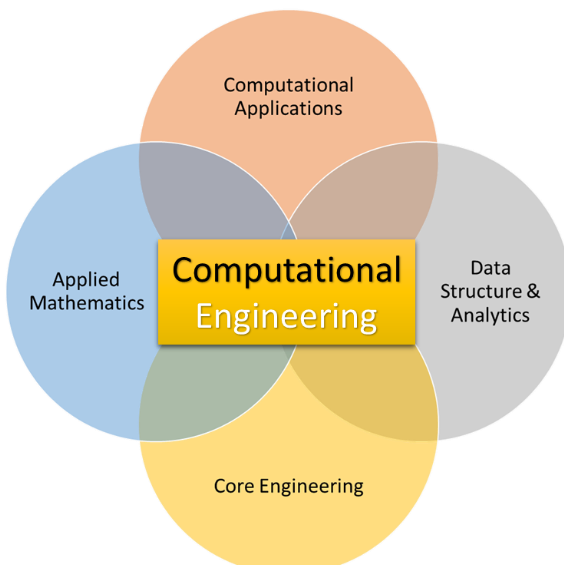

Fig 2. Computational Engineering curriculum layout

Curriculum Design

The curriculum of Computational Engineering has been design keeping in mind the ***T*** shape. ***Breadth*** of the curriculum is achieved by having courses in *Core Engineering* and *Applied Mathematics*. These courses will help the students learn the fundamental concepts of some common core engineering subjects and the associated mathematics. The ***Depth*** of the curriculum is achieved by introducing the students to various computational methods that include fundamentals in scientific computing, data structure and its analytics and application of computational tools. The breadth courses are expected to give insight to the fairness of the solutions obtained using the methodologies taught in the depth courses. Hence, the depth courses need to be supplemented by the breadth courses. Fig 3 illustrates this design of the curriculum.

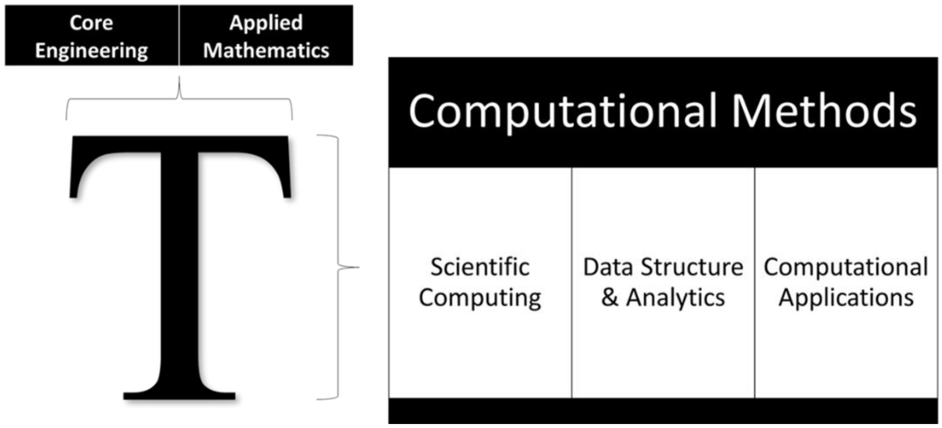

*Fig 3. The **T** design of Computational Engineering curriculum*

Curriculum Details

Based on the above curriculum design paradigm, a detailed curriculum has been developed. A total of 8 credits has been allocated to Engineering Mathematics to lay the foundation of mathematics that a student of this program is expected to know. 29 credits has been allocated to Core Engineering courses. These courses cover fundamental topics of Engineering Drawing; Thermodynamics; and Mechanics of solids and fluids along with the transport of heat and mass through these medium. As biology forms an important aspect of modern engineering, courses on bioengineering and biomechanics have also been included. The core depth courses in Computational Methods have been allocated 53 credits. Scientific Computing lays foundation of the numerical methods typically used in engineering modelling and simulation; Data Structure & Analytics exposes the student to modern analysis tools of AI/ML and optimization; Computational Applications exposes the student to a vast array of methodology typically used in engineering analysis. Cognizant of the modern curricula to be flexible, 15 credits of elective courses has been allocated. Fig 3 summarizes all the major courses of this curriculum.

Engineering Mathematics (8 Credits)

- Calculus – I (MA1110)
- Calculus – II (MA1220)
- Elementary Algebra (MA 1140)
- Differential Equations (MA1150)
- Introduction to Probability (MA2110)
- Transform Techniques (MA2120)
- Complex Variables (MA2130)
- Introduction to Statistics (MA2140)

Core Engineering (33 Credits)

- Engineering Drawing (ID1041)
- Digital Circuits (EE1202)
- Digital Fabrication (ID1054)
- Engineering Mechanics (ME1030)
- Bioengineering (BM1030)
- Thermodynamics (ME2120)
- Fundamentals of Physical Metallurgy (MS2220)
- Solid Mechanics (ME2110)
- Fluid Mechanics (ME2240)
- Heat & Mass Transfer (ME3110)
- Molecular and Cellular Biology (BT2060)
- System Biology (BT5010)

Computational Methods (53 credits)

Scientific Computing

- Fundamental of Scientific Computing (CO1010)
- Computer Aided Numerical Methods – I (COXXXX)
- Computer Aided Numerical Methods – II (COXXXX)
- Intro Hardware Description Language (EExxxx)

Data Structure & Analytics

- Introduction to Parallel Programming (ID1063)
- Data Structures & Applications (ID2230)
- Basics of Machine Learning (COXXXX)

Computational Applications

- Optimization (CH4020)
- Basic Bioinformatics (BT1020)
- Computational Methods in Material Sci (MS2300)
- Modelling & Simulation (ME3030)
- FEM & CFD Theory (ME3180)
- FEM & CFD Labs (ME3445, ME3455)
- Atomistic Modelling & Simulation (COXXXX)
- Machine Drawing & Solid Modelling (ME3413)

List of Potential Elective Courses

- Process Control
- System Identification
- Advanced CFD
- Advanced FEM
- Introduction to Parallel Scientific Computing
- Material Informatics
- Computational Thermodynamics & Kinetics
- Molecular Thermodynamics
- Electironic Structure Calculations
- Big data biology & Biological databases
- Biochemical Engineering
- Bio-reaction Engineering
- Protein structure, function and disease
- Molecular Biophysics
- Computer Aided drug design
- Algorithms for Molecular Dynamics Simulations

Fig 4. List of technical courses offered under Computational Engineering