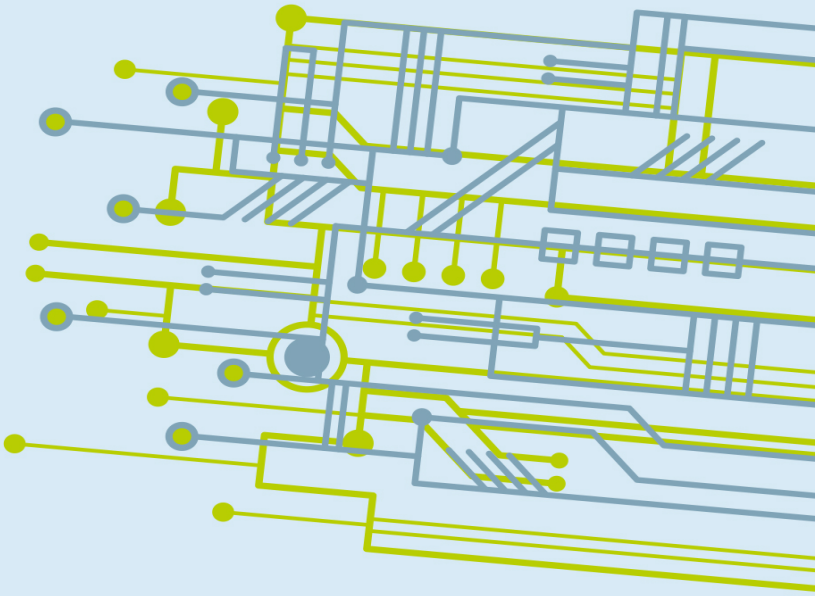
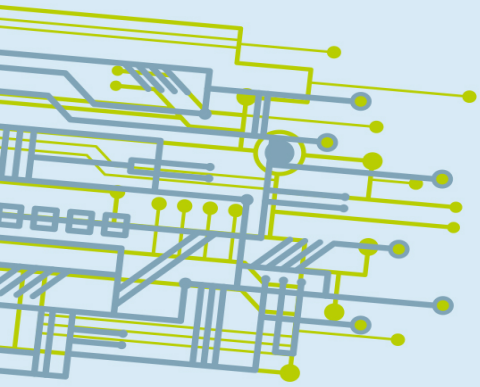


Luiz Ricardo Mantovani da Silva

INTRODUCTION TO COMPUTING



REPUBLIC 01

LUIZ RICARDO MANTOVANI DA SILVA

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REPUBLIC 01

Original Title: Introdução à Computação (2025).
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Maria Augusta Bookstore, Distributor, and Publisher

Editorial Direction: Isaac D. Abulafia
Editorial Management: Marisol Soto
English Translation: Freitas Bastos Publishing
Layout and Cover: Nilton Rezende
Copyediting: Lara Alves dos Santos Ferreira de Souza
Proofreading: Aléxia Souza da Silva e Rafaella Saioro

ISBN: 978-65-5675-768-1

support@freitasbastos.com

Table of Contents

INTRODUCTION TO COMPUTING
Chapter 1: Introduction
1.1 Initial Concepts
1.1.1 Some Technical Terms
1.1.2 The Importance of Computing
1.2 Impact of Computing on Society
1.2.1 Interdisciplinary Approach
1.3 Motivation
1.3.1 Development of Practical Skills
1.3.2 Problem Solving
1.3.3 Technological Innovation
1.4 History and Development of Computers
1.4.1 Early Mechanical Devices
1.4.2 19th Century: Foundations of Theoretical Computing
1.4.3 Early 20th Century: Theoretical and Practical Advances
1.4.4 World War II and the Post-War Period
1.4.5 Advances in Electronics
1.4.6 The Era of Personal Computers
1.4.7 Recent Developments
1.5 Organization of Computers
1.5.1 Architecture
1.5.2 Basic Computing Concepts
Chapter 1 QUESTIONNAIRE
Chapter 2: Basic Concepts
2.1. Definition of Computer
2.2. Basic Computer Composition
2.3. Number Systems
2.3.1. Binary System
2.3.2. Decimal System
2.3.3. Hexadecimal System
2.4. Fundamentals of Logic and Algorithms
2.4.1. Fundamentals of Logic
2.4.2. Algorithms

2.5. Programming Languages
2.5.1. Basic Concepts
2.5.2. Classification of Programming Languages
2.5.3. Examples of Programming Languages
2.5.4. Compilers and Interpreters
2.5.5. Current Trends in Programming Languages
2.6. Introduction to MATLAB
2.6.1. What is MATLAB?
2.6.2. Main Functionalities
2.6.3. MATLAB Applications
2.6.4. MATLAB Environment
2.6.5. Practical Examples
2.6.6. Benefits of Using MATLAB
Chapter 2 Questionnaire
Chapter 3: History of Computing
3.1. Evolution of Computerized Systems
3.1.1. Early Calculation Devices
3.1.2. Mechanical Machines
3.1.3. First Programmable Computers
3.1.4. Era of Electronic Computers
3.1.5. Transistors and Integrated Circuits
3.1.6. Personal Computers
3.1.7. Network Computing Era
Chapter 3 QUESTIONNAIRE
Chapter 4: Data Processing
4.1 Input, Processing, and Output
4.1.1 Input
4.1.2 Processing
4.1.3 Output
4.1.4 The Importance of Data Output
4.2 Definition of Data
4.2.1 What Is Data?
4.2.2 Characteristics of Data
4.2.3 Types of Data
4.2.4 Importance of Data
4.2.5 Practical Examples of Data
4.2.6 Challenges in Data Management

4.2.7 Tools and Technologies for Data Management
4.3. Definition of Information
4.3.1 What is Information?
4.3.2 Characteristics of Information
4.3.3 Types of Information
4.3.4 Importance of Information
4.3.5 Practical Examples of Information Usage
4.3.6 Challenges in Information Management
4.3.7 Tools and Technologies for Information Management
4.4. Definition of Knowledge
4.4.1 The Nature of Knowledge
4.4.2 Knowledge Creation
4.4.3 Knowledge Management
4.4.4 The Importance of Knowledge
4.4.5 Examples of Knowledge Application
4.4.6 Challenges in Knowledge Management
4.4.7 Tools and Technologies for Knowledge Management
4.5. Applicable Examples from the Chapter
4.5.1 Data Input in a Banking System
4.5.2 Data Processing in E-commerce
4.5.3 Data Output in Health Monitoring
Chapter 4 Questionnaire
Chapter 5: Hardware
5.1 Definition of Hardware
5.2 Architecture of Hardware Components
5.2.1 CPU
5.2.2 Main Memory (RAM)
5.2.3 Storage Devices
5.2.4. Input and Output Devices (I/O)
5.2.5. Motherboard
5.2.6. Power Supply Unit (PSU)
5.2.7. Cooling System
5.3. Input and Output Systems (I/O)
5.3.1. Communication Buses
5.3.2. Flow Control Techniques in I/O Systems
5.4. Relevant Examples
5.5. Concluding Remarks

Chapter 5 Questionnaire
Chapter 6: Software and System
6.1. Definition of Software
6.2. Definition of System
6.3. Differences Between Software and System
6.4. Relevant Examples from the Chapter
Chapter 6 Questionnaire
Chapter 7: Computer Networks
7.1. Definition
7.2. Network Types
7.2.1. Ethernet
7.2.2. Wi-Fi
7.3. Topology
7.4. Applicable Examples from the Chapter
Chapter 7 QUESTIONNAIRE
Chapter 8: Control Structures
8.1. Sequential Structures
8.2. Conditional or Selection Structures
8.2.1. Simple Conditional Structures
8.2.2. Compound Conditional Structures
8.3. Repetition Structures
8.3.1. Defined Repetition Structures
8.3.2. Undefined Repetition Structures
8.4. Applicable Examples from the Chapter
Chapter 8 Questionnaire
Chapter 9: Data Structures
9.1. Introduction
9.2. Homogeneous Composite Variables
9.2.1. One-Dimensional Composite Variables
9.2.2. Multidimensional Composite Variables
9.3. Heterogeneous Composite Variables
9.3.1. Records
9.3.2. Record Sets
Chapter 9 Questionnaire
Chapter 10: Modularization
10.1. Introduction
10.2. Modules and Tools for Modularization

10.3. Variable Scope
10.4. Module Context
Chapter 10 Questionnaire
Chapter 11: Files
11.1 Concept of a File
11.2 File Organization
11.2.1 Sequential Organization
11.2.2 Direct Organization
11.2.3 Indexed Organization
11.3 Declaration
11.4 File Handling
11.4.1 File Opening
11.4.2 File Closing
11.4.3 Copying a Record
11.4.4 Storing a Record
11.4.5 Deleting a Record
11.5 Sequential Organization
11.5.1 Input Command
11.5.2 Output Command
11.6 Direct Organization
11.6.1 Input Command
11.6.2 Output Command
11.7 Considerations on File Management
11.7.1 Version Control
11.7.2 Data Backup and Recovery
11.7.3 File Security
11.8 File System Architectures
11.8.1 FAT32
11.8.2 NTFS
11.8.3 ext4
11.8.4 HFS+
11.9 File Optimization Techniques
11.9.1 Data Compression
11.9.2 Defragmentation
11.9.3 Indexing
11.10 The Future of File Systems
11.10.1 Distributed File Systems

11.10.2 Cloud Storage
11.10.3 Blockchain
11.11 Final Considerations
Chapter 11 Questionnaire
Chapter 12: Innovations Technological Innovations (Current Affairs)
12.1 Emerging Technologies in Computing
12.1.1 Quantum Computing
12.1.2 Biocomputing
12.1.3 Neuromorphic Computing
12.2 AI and ML
12.2.1 Machine Learning
12.2.2 AI Applications
12.3 Cloud Computing
12.3.1 Service Models
12.4 IoT
12.4.1 IoT Applications
12.5 Cybersecurity and Data Protection
12.5.1 Protection Techniques
12.6 Applicable Examples from the Chapter
12.6.1 AI-Assisted Diagnosis
12.6.2 Industrial Automation
12.6.3 Personalized Education
Chapter 12 Questionnaire
Chapter 13: Answers to the Chapter Questions
Chapter 1 Questionnaire: Answers
Chapter 2 Questionnaire: Answers
Chapter 3 Questionnaire: Answers
Chapter 4 Questionnaire: Answers
Chapter 5 Questionnaire: Answers
Chapter 6 Questionnaire: Answers
Chapter 7 Questionnaire: Answers
Chapter 8 Questionnaire: Answers
Chapter 9 Questionnaire: Answers
Chapter 10 Questionnaire: Answers
Chapter 11 Questionnaire: Answers
Chapter 12 Questionnaire: Answers
References

INTRODUCTION TO COMPUTING

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Luiz Ricardo Mantovani da Silva

CHAPTER 1: INTRODUCTION

1.1 INITIAL CONCEPTS

Computing is a vast and continually evolving field whose influence extends across virtually all areas of modern life. From the mobile devices we use daily to the complex systems that govern critical infrastructures, computing is fundamental to the operation of the contemporary world. For students of Computer Science and Engineering, understanding the fundamentals of computing is essential, as this knowledge applies to various disciplines and technical projects.

1.1.1 Some Technical Terms

To facilitate understanding of the following topics, it is important to become familiar with some technical terms frequently used in computing:

- **Algorithm:** a defined sequence of instructions designed to solve a specific problem. An algorithm is essentially a set of steps that describe how to systematically and efficiently perform a task or solve a problem. For example, an algorithm for sorting a list of numbers can be implemented in various ways, such as the insertion sort algorithm, the quicksort algorithm (*quicksort*), among others (Cormen *et al.*, 2009).
- **Bit**: the smallest unit of information in a computer, representing either 0 or 1. Each bit represents a binary position, and by combining multiple bits, larger data units are formed. For example, a combination of 8 bits constitutes a byte, enabling the encoding of 256 distinct values (Stallings, 2021a).
- **Byte:** group of 8 bits. A byte can represent 256 different values (ranging from 0 to 255) and is frequently used to encode a single text character in a computer. For example, the letter "A" is represented by the value 65 in ASCII code, which in binary form is 01000001 (Patterson; Hennessy, 2017).

- **Compiler:** program that translates source code from a programming language into machine code. The compiler converts human-readable source code into a format executable by the computer, enabling programs to run efficiently. There are different phases in a compilation process, such as lexical analysis, syntactic analysis, optimization, and code generation (Aho *et al.*, 2006).
- **Computer network:** a set of interconnected computers that share resources and information. Computer networks enable communication and data exchange between devices, which is essential for the internet and other distributed systems. Examples of networks include local area networks (LANs), which connect computers within a physically restricted location, and wide area networks (WANs), which connect computers geographically dispersed (Tanenbaum; Wetherall, 2011).
- **Operating system:** software that manages the computer's hardware and software resources, providing essential services for the execution of application programs. Examples of operating systems include Windows, macOS, and Linux. The operating system manages tasks such as process control, memory management, input and output device control, and file management (Silberschatz; Galvin; Gagne, 2018).
- **Programming language:** a set of rules and syntax used to write computer programs. Programming languages may be low-level, such as Assembly, which are closer to machine code, or high-level, such as Python, Java, and C++, which are more abstract and user-friendly for humans (Languages, 2020).
- **Database:** an organized system for the storage, management, and retrieval of data. Databases can be structured in various ways, such as relational, which utilize tables to depict data and their relationships, or NoSQL, which are more flexible and can store data in formats such as documents, graphs, or key-value pairs (Date, 2004).

This introductory chapter addresses the fundamental concepts that will be examined in greater detail in the subsequent chapters. Comprehension of these initial concepts is crucial for the thorough study of computing and its practical applications.

1.1.2 The Importance of Computing

Computing is not only an academic discipline but also a catalyst for innovation and efficiency across numerous sectors. Its applications include:

- **Communication:** networks and mobile devices which enable the exchange of information in real time. Computing facilitates instantaneous global communication via *emails*, videoconferences, social networks, and messaging applications, connecting people regardless of geographic distance (Tanenbaum; Wetherall, 2011b). Furthermore, mobile computing has revolutionized the way we interact, with *smartphones* and *tablets* providing continuous access to the internet and a variety of communication services (Liao *et al.*, 2015).

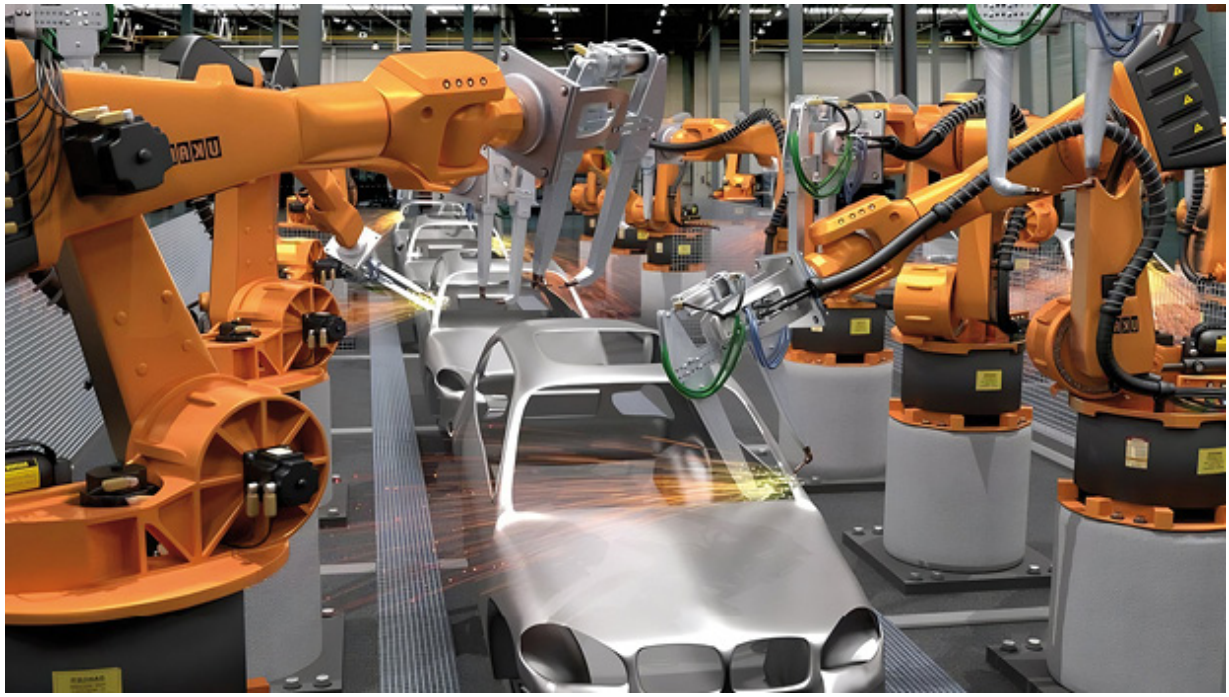
Figure 1.1 – People talking on a cell phone



Source: DALL-E AI.

- **Industry and manufacturing:** automation of production processes, quality control, and operations management. The implementation of computing systems in industries enables the automation of production lines, resulting in increased accuracy and efficiency. Technologies such as industrial robotics and Distributed Control Systems (DCS) are widely used to monitor and control complex industrial processes, ensuring quality and productivity (Groover, 2014).

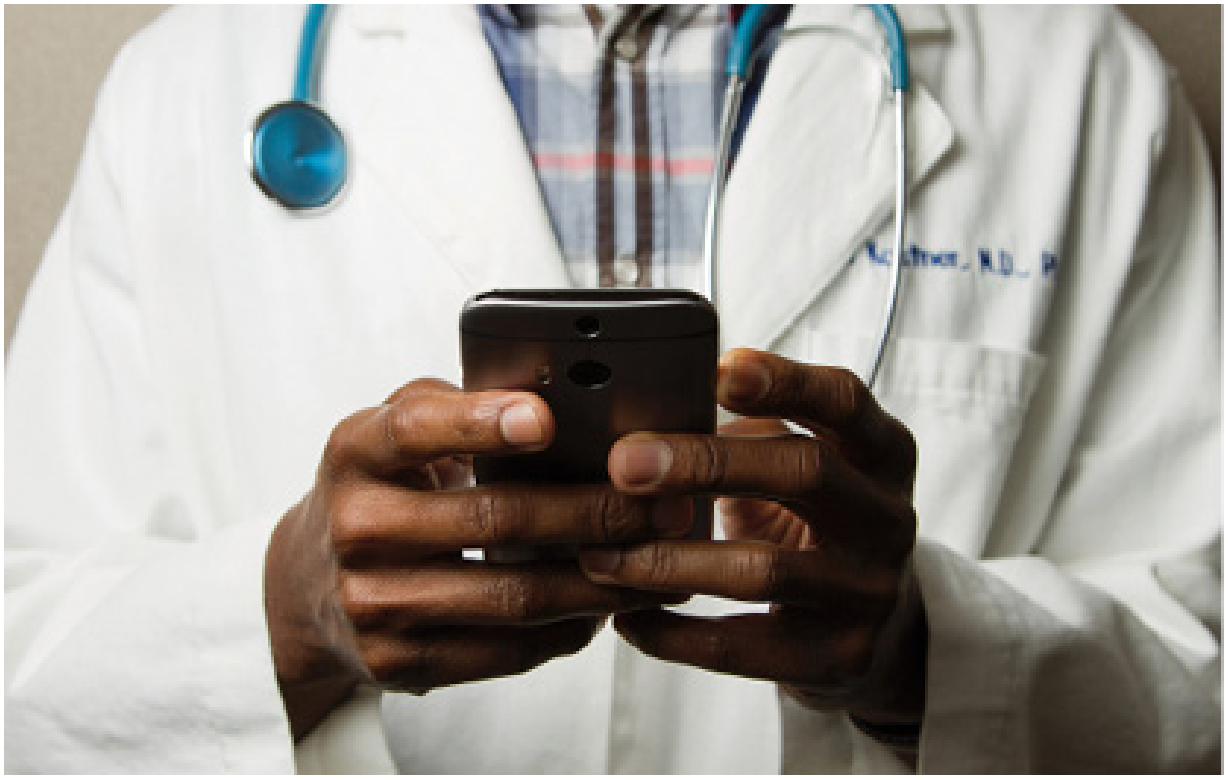
Figure 1.2 – Automated industrial process



Source: Robotics Lab, 2020.

- **Health:** computer-assisted diagnosis, medical records management, and biotechnological research. Computing systems are crucial for the development of advanced medical technologies such as magnetic resonance imaging (MRI), computed tomography (CT), and ultrasound systems. Moreover, electronic health records (EHR) enhance efficiency and accuracy in managing medical information, while bioinformatics employs computing for the analysis of genomic data and the development of new therapies (Shortliffe; Cimino, 2013).

Figure 1.3 – Computer-assisted diagnosis



Source: Federal Institute of Ceará, 2020.

- **Education:** online learning tools, interactive simulations, and the management of educational institutions. Computing has transformed education by enabling the creation of virtual learning environments and online courses (*e-learning*), thereby providing access to knowledge for a global audience. Tools such as learning management systems (LMS) assist in the administration of courses and assessments, while interactive simulations and virtual laboratories offer practical experiences in disciplines such as physics, chemistry, and engineering (Bates; Sangra, 2011).

Figure 1.4 – LMS Platforms



Source: Una Aguja en un Pajar, 2021.

- **Infrastructure:** management of electrical grids, intelligent transportation systems, and environmental monitoring. Computing systems are indispensable for the operation and maintenance of critical infrastructures. In the management of electrical grids, supervisory control and data acquisition (SCADA) systems monitor and regulate the distribution of electric power. Intelligent transportation systems (ITS) enhance the efficiency and safety of urban traffic through signal control, traffic monitoring, and public transportation management. Furthermore, remote sensing technologies and geographic information systems (GIS) are used in environmental monitoring to track changes in ecosystems and respond to natural disasters (Taubenböck *et al.*, 2012).

1.2 IMPACT OF COMPUTING ON SOCIETY

Computing has a profound and multifaceted impact on society, transforming the way we live, work, and communicate. Some examples of impact include:

- **Digital economy:** companies such as Amazon, Google, and Microsoft have revolutionized commerce, advertising, and cloud services, creating new business and employment opportunities. The digital economy enables rapid and secure financial transactions, access to global markets, and the creation of new business models, such as *online marketplaces* and

subscription services. Furthermore, digital advertising provides precise audience targeting, thereby increasing the effectiveness of advertising campaigns (Tapscott, 2014).

- **Science and research:** computational simulations and *big data* analyses accelerate scientific discoveries and technological innovations. In science, computing enables the modeling of complex phenomena which would be unfeasible to replicate experimentally, namely weather forecasting and the simulation of chemical reactions. Furthermore, the analysis of large volumes of data, such as those generated by particle physics experiments or genomic sequencing, is fundamental for advancing knowledge across various academic disciplines (Hey; Tansley; Tolle, 2009).
- **Security and privacy:** cybersecurity has become essential for protecting sensitive information against threats and cyberattacks. With the increasing digitization of personal and corporate data, safeguarding against data breaches, fraud, and espionage has become a priority. Security solutions encompass encryption, *firewalls*, intrusion detection systems, and authentication protocols. Privacy is also a growing concern, with legislation such as the General Data Protection Regulation (GDPR) in Europe establishing strict guidelines on how personal data should be collected, stored, and used (Schneier, 2015).
- **Education and Learning:** Computing has transformed the field of education by introducing digital tools and platforms that facilitate teaching and learning. Online courses, open educational resources (OER), and virtual learning environments (VLE) enable students worldwide to access quality education. Technologies such as artificial intelligence and adaptive learning personalize the learning experience, assisting in identifying areas of difficulty and providing targeted resources to enhance student performance (Bates; Sangra, 2011).
- **Health and medicine:** computing plays a crucial role in the modernization of healthcare, from managing electronic health records (EHR) to analyzing *big data* for medical research. Technologies such as telemedicine enable patients in remote areas to access specialized medical care, while data analysis tools support the identification of trends and the prediction of

disease outbreaks. Artificial intelligence is employed in the development of assisted diagnostic systems that enhance both the accuracy and speed of medical diagnosis (Shortliffe; Cimino, 2013).

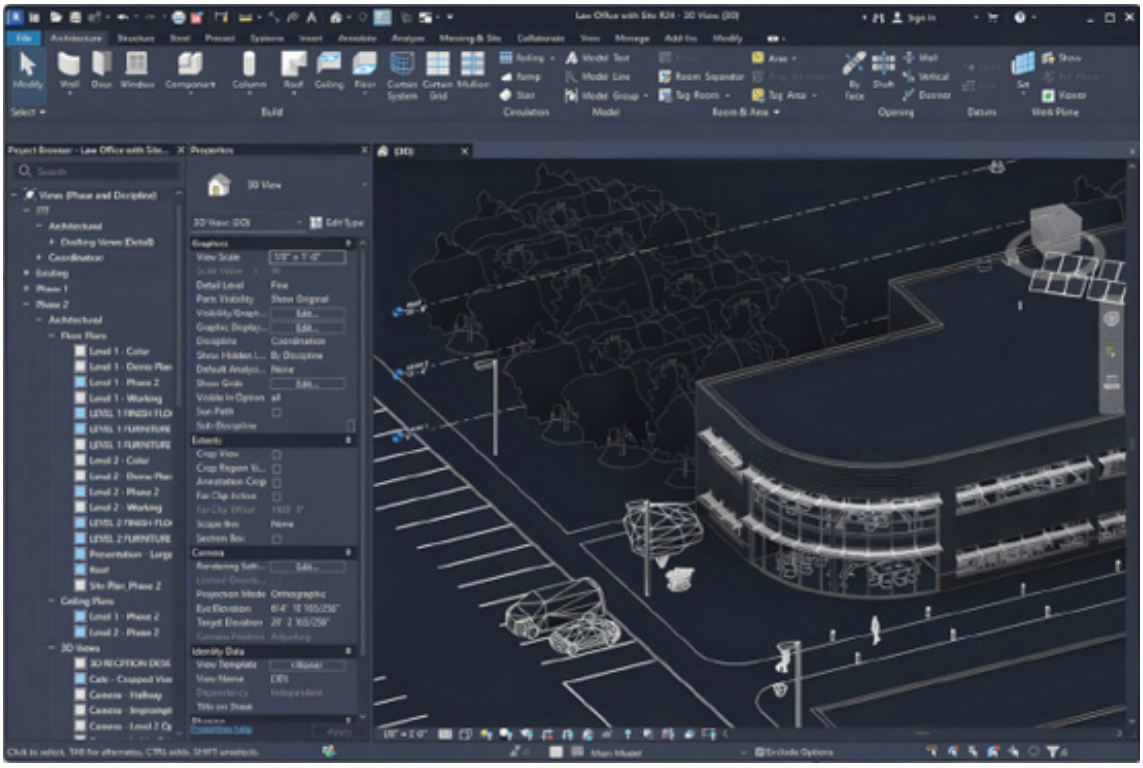
- **Entertainment and media:** computing has revolutionized the entertainment industry, ranging from the creation of sophisticated visual effects in films to the digital distribution of music, books, and games. Streaming platforms, such as Netflix and Spotify, utilize recommendation algorithms to personalize content, thereby improving the user experience. Moreover, augmented reality (AR) and virtual reality (VR) are facilitating the development of immersive and interactive forms of entertainment (Manovich, 2001).
- **Transportation and Logistics:** computing has optimized transportation and logistics systems, enhancing efficiency and reducing costs. Transportation management systems (TMS) and traffic control systems utilize real-time data to optimize routes and mitigate congestion. Autonomous vehicles and drones are under development to render goods transportation safer and more efficient. Furthermore, the Internet of Things (IoT) is applied in fleet management and real-time monitoring of cargo conditions (DHL, 2016).

1.2.1 Interdisciplinary Approach

Computing integrates with various other disciplines, providing tools and techniques that improve efficiency and foster innovation across multiple fields of engineering:

- **Civil Engineering:** structural modeling, project management, and environmental impact analysis. Software tools such as AutoCAD, Revit, and Civil 3D enable the creation of detailed and precise structural models, facilitating effective project planning and execution.

Figure 1.5 – Revit Interface 2024

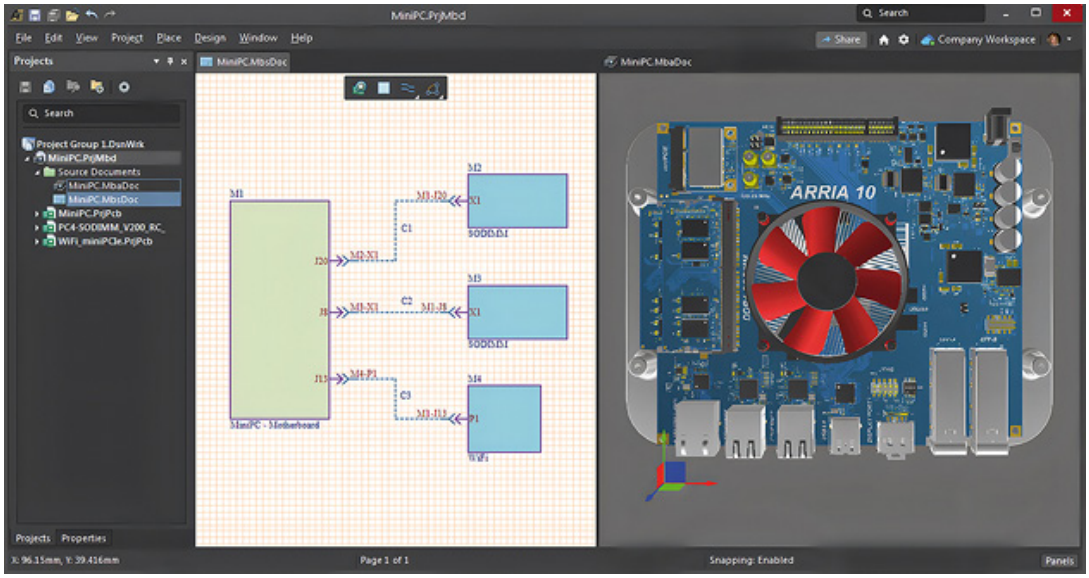


Source: PASS26, 2024.

Furthermore, project management systems such as Primavera and Microsoft Project facilitate the coordination of resources, schedules, and costs, ensuring projects are completed on time and within budget. Computational simulations are also employed to evaluate the environmental impact of new projects, supporting sustainable decision-making (Yanez *et al.*, 2010).

- **Electrical Engineering:** design and control of electronic circuits, power systems, and telecommunications. Computer-Aided Design (CAD) software, such as Altium Designer and PSpice, is utilized to design and simulate complex electronic circuits.

Figure 1.6 – Altium Designer interface

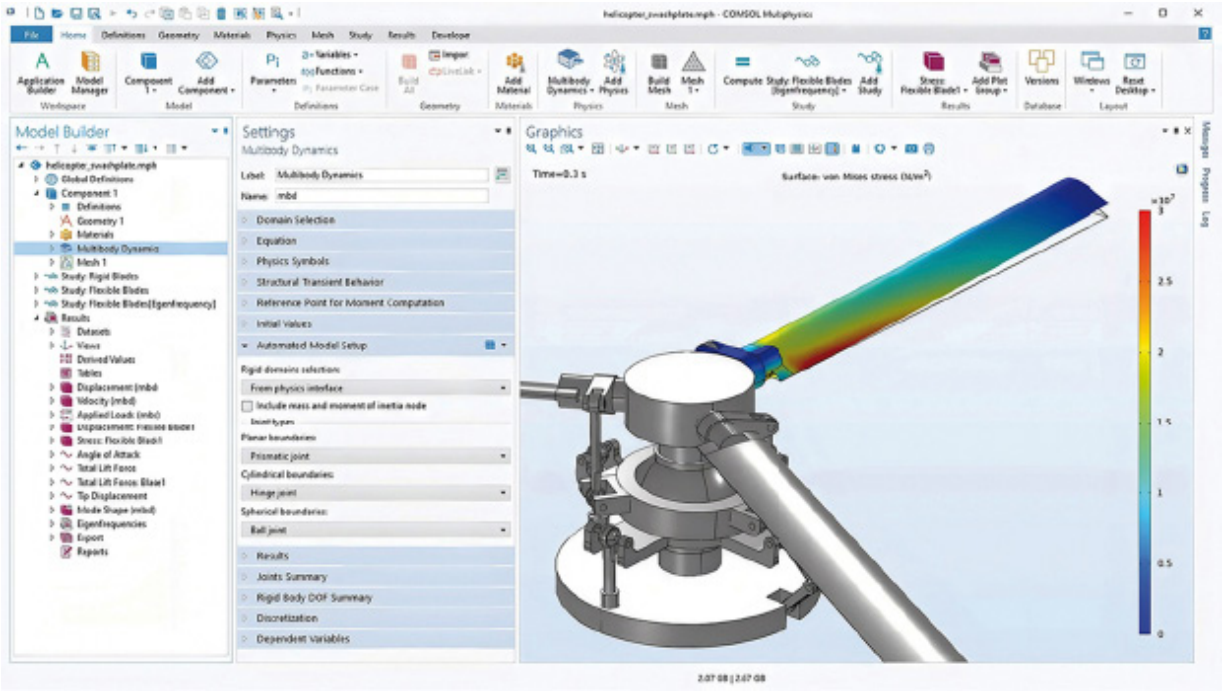


Source: Altium, 2024.

Energy management systems and smart grids utilize optimization algorithms and *machine learning* techniques to enhance energy efficiency and network reliability. In telecommunications, network simulation tools assist in planning and optimizing communication networks, ensuring optimal coverage and performance (Rasheed *et al.*, 2019).

- **Mechanical Engineering:** fluid mechanics simulation, stress analysis, and the development of new materials. Simulation software such as ANSYS, SolidWorks, and COMSOL Multiphysics enable the modeling and analysis of complex mechanical systems, including fluid dynamics, heat transfer, and structural stresses.

Figure 1.7 – COMSOL Multiphysics Interface

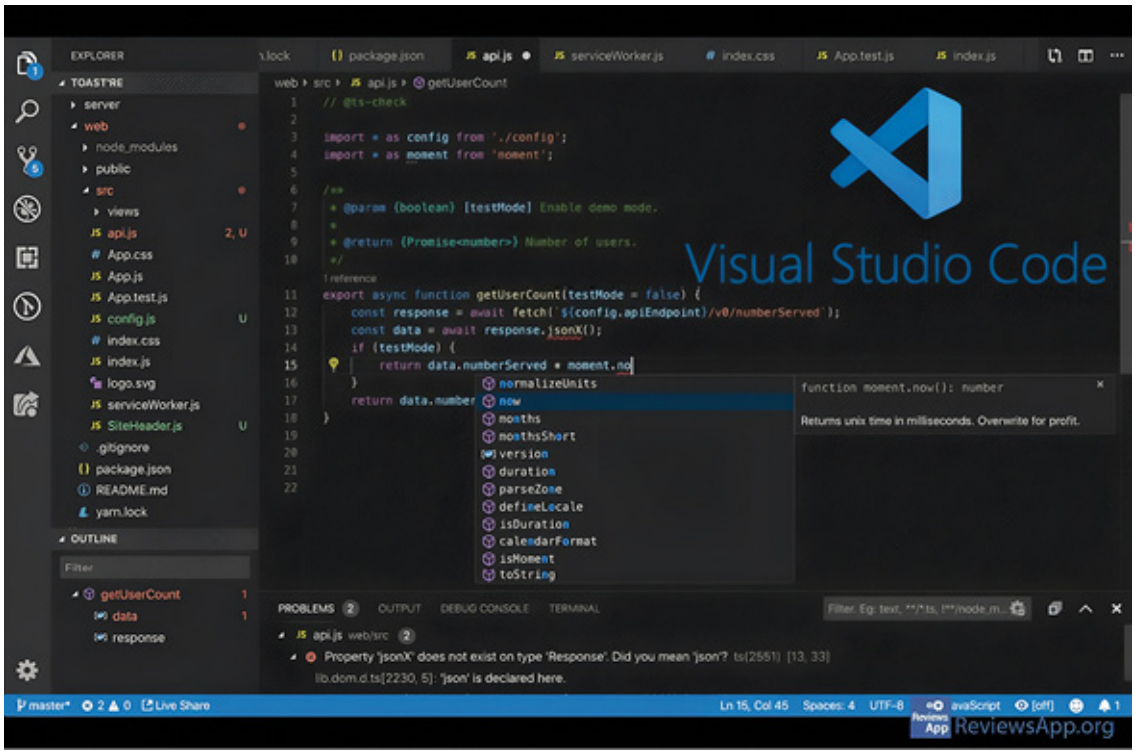


Source: COMSOL, 2024.

These tools are essential for the development and optimization of new products and materials, enabling virtual testing prior to physical production. Furthermore, computer-aided engineering (CAE) techniques contribute to enhancing the accuracy and efficiency of the design process (Friedrich, 2002).

- **Software Engineering:** development of complex systems, agile methodologies, and software project management. Integrated development environments (IDEs), such as Eclipse, Visual Studio, and IntelliJ IDEA, facilitate coding, debugging, and software testing.

Figure 1.8 – Visual Studio Code interface



Source: Reviewsapp, 2024.

Agile methodologies, such as Scrum and Kanban, foster collaboration and flexibility, enabling development teams to respond swiftly to changes in project requirements. Version control systems such as Git and Subversion aid in managing changes to source code and enable efficient collaboration within large teams (Pressman, 2014).

- **Environmental Engineering:** monitoring and management of natural resources, pollution modeling, and mitigation of environmental disasters. Geographic Information Systems (GIS) and remote sensing tools are utilized to monitor and analyze environmental data, including water, air, and soil quality. Computational models assist in predicting pollutant dispersion and evaluating the environmental impacts of new construction projects or industrial activities. These technologies are vital for the development of mitigation strategies and emergency response plans (Chen *et al.*, 2012).
- **Biomedical Engineering:** the development of medical devices, medical image analysis, and bioinformatics. Computational tools are employed in

the design and simulation of medical devices, including prostheses, implants, and diagnostic equipment. Medical image analysis utilizes image processing algorithms to improve the detection and diagnosis of diseases. Within bioinformatics, data analysis techniques are applied to the study of DNA and protein sequences, facilitating the discovery of new treatments and therapies (Enderle; Bronzino, 2012).

1.3 MOTIVATION

An understanding of computing is essential not only for professionals in the discipline but also for any individual who interacts with technology. The motivation to study computing is extensive and multifaceted, encompassing the development of practical skills, the resolution of complex problems, technological innovation, and interdisciplinarity. Let us explore each of these aspects with greater depth.

1.3.1 Development of Practical Skills

Computing skills are in high demand in the labor market, and their importance is expected to grow continually with technological progress. Studying computing facilitates the development of practical competencies, such as:

- **Programming:** acquiring programming languages like Python, Java, and C++ is essential for developing software, applications, and systems. Programming is the foundation of computing, enabling the creation of customized solutions and automation of tasks. These languages are extensively used across various applications, from embedded systems development to mobile applications and enterprise solutions (Lutz, 2013).
- **Web Development:** the understanding HTML, CSS, and JavaScript enables the creation of websites and interactive web applications. Web development is an essential skill in today's digital world, allowing businesses and individuals to develop *online* platforms for commerce, communication, and information. *Frameworks*, such as React, Angular, and Vue.js, enhance efficiency and functionality in the development of user interfaces (Castro, 2012).

- **Database:** proficiency in database management is essential for storing, organizing, and accessing large volumes of data. Database management systems (DBMS), such as MySQL, PostgreSQL, and MongoDB, are employed to ensure data integrity and accessibility, supporting critical operations within businesses of all sizes. An understanding of SQL (*Structured Query Language*) and data modeling techniques is fundamental for effective data analysis and manipulation (Date, 2004).
- **Networks and security:** expertise in computer networks and cybersecurity is vital to protect information and ensure secure communication between systems. Computer networks constitute the backbone of IT infrastructure, enabling connectivity and communication. Cybersecurity, in turn, safeguards against threats and vulnerabilities, ensuring data integrity, confidentiality, and availability (Stallings, 2021b).
- **Data analysis:** data analysis tools and techniques facilitate the extraction of valuable *insights* from large datasets. Data analysis is essential across multiple disciplines, including business, science, and engineering, facilitating informed and evidence-based decision-making. Tools such as R, Python (with libraries like Pandas and NumPy), and data visualization software such as Tableau are extensively utilized (Han; Kamber; Pei, 2011).

These practical skills are not only highly demanded in various industries but also applicable to many facets of everyday and professional life. The capacity to program, manage data, develop web applications, and secure networks and information establishes a robust foundation to confront technological challenges and capitalize on opportunities in the labor market.

1.3.2 Problem Solving

Computing offers a systematic and efficient approach to solving complex problems. Some of the ways computing facilitates the solution of problems include:

- **Algorithms and data structures:** efficient algorithms and well-designed data structures are fundamental to solving problems quickly and effectively. For example, search and sorting algorithms are used to manipulate large data sets, while data structures such as trees, graphs, and *hash tables* organize data for fast, efficient access (Cormen *et al.*, 2009).

- **Simulation and modeling:** simulation tools enable the modeling of complex phenomena, ranging from weather forecasting to the behavior of financial markets. Simulation assists in predicting system performance under various conditions, thereby facilitating informed decision-making without necessitating physical experimentation (Law, 2014).
- **Automation:** the development of *scripts* and programs automates repetitive tasks, enhancing productivity and minimizing the margin of error. Automation is employed across multiple domains, including software testing, system administration, and data analysis, thereby freeing time for more complex and creative activities (Russell; Norvig, 2016).
- **Pattern analysis:** techniques of machine learning and artificial intelligence identify patterns in large data sets, providing solutions to problems that were previously intractable. These techniques are used in areas such as voice recognition, computer vision, and product recommendation, improving the accuracy and personalization of the services offered. (Goodfellow; Bengio; Courville, 2016).

1.3.3 Technological Innovation

Knowledge in computing is a catalyst for the creation of new technologies and innovative solutions. Studying computing opens doors to innovation in various areas, as we will see below.

- **Artificial Intelligence (AI)**

Artificial intelligence (AI) is among the most dynamic and promising fields within computing. It encompasses the development of intelligent systems capable of learning, adapting, and making decisions based on data. Applications of AI are present across various sectors, including:

- **Image Recognition and Computer Vision:** AI systems can identify and classify objects in images and videos, with applications ranging from security to medicine, such as tumor detection in medical imaging (Goodfellow; Bengio; Courville, 2016).
- **Natural Language Processing (NLP):** Techniques of NLP enable machines to comprehend and respond to human language. Examples

include virtual assistants such as Siri and Alexa, and machine translation systems (Russell; Norvig, 2016).

- **Recommender systems:** AI algorithms analyze user behavior to suggest products, movies, or music, thereby enhancing the user experience on platforms such as Amazon, Netflix, and Spotify (Ricci *et al.*, 2011).

- **Internet of Things (IoT)**

The Internet of Things (IoT) refers to the interconnection of smart devices that communicate with each other to create more connected and efficient environments. Examples of application include:

- **Smart homes:** IoT enables remote control for devices such as thermostats, lights, and security cameras, providing convenience and energy efficiency (Evans, 2011).
- **Smart cities:** IoT is used to enhance urban management—such as traffic control, efficient public street lighting, and environmental monitoring—contributing to sustainability and quality of life (Gubbi *et al.*, 2013).
- **Industry 4.0:** IoT is transforming manufacturing through automation and optimization of production processes; predictive maintenance of equipment; and real-time asset tracking (Lee *et al.*, 2015).

- **Virtual Reality (VR) and Augmented Reality (AR)**

Virtual Reality (VR) and Augmented Reality (AR) are creating novel forms of interaction and experience:

- **Entertainment and gaming:** VR and AR offer immersive experiences in gaming and entertainment, enabling users to explore virtual worlds and participate in interactive activities (Sherman; Craig, 2018).
- **Education and training:** VR and AR are employed to create interactive learning environments and training simulators for professions such as medicine, engineering, and aviation, thereby enhancing the effectiveness of practical learning (Dündar; Akçayir, 2017).
- ***Design* and architecture:** VR and AR are employed by professionals to visualize projects in 3D, facilitating a deeper understanding and enabling modifications prior to construction (Portman et al., 2015).