Bachelor in Computers Engineering

Titles, contents and timetable

Escuela Técnica Superior de Ingeniería Informática

Universidad Rey Juan Carlos

Contents

Prologue

This document contains information about titles, contents and timetable of subjects taught in the Bachelor in Computers Engineering, offered at Rey Juan Carlos University, Escuela Técnica Superior de Ingeniería Informática. This information pretends to be helpful to international students interested in visiting our University.

Contents in this document referred to subjects taught during course 2021-2022. More information can be consulted in

`https://www.urjc.es/estudios/grado/647-ingenieria-de-computadores`

1

First Course

1.1 First Semester

1.1.1 Logic and Discrete Mathematics

Mathematical Fundamentals, induction and logic. Arithmetic and modular arithmetic. Combinatorics. Graph Theory.

6 ECTS credits.

1.1.2 Computers Technology

Computer's introduction. Binary numerical representation. Hardware description language. Combinational systems. Boolean Algebra. Combinational systems specification and synthesis. Basic combinational modules. Sequential systems. Finite state machines. Memory elements. Basic sequential modules. Basic computer system structure.

6 ECTS credits.

1.1.3 Physical Fundamentals of Computer Science

Electromagnetism. DC circuits. AC circuits. Semiconductor physics Diodes. Bipolar transistor. Field effect transistor. Digital systems.

6 ECTS credits.

1.1.4 Statistics

Descriptive statistics: Description of data Basic concepts. Types of variables. Graphical summary of data. Numerical summary of data. Description of bivariate data. Summary of bivariate data. Covariance, correlation. Regression. Probability: random events, definition and interpretation of probability. Properties. Conditional probability. Independence of events. Total Probability and Bayes theorem. Random variables. Definition of random variable. Types of variables. Mass function and density function.

Distribution function. Mean and variance. Special distributions. Statistical Inference: Introduction. Sampling. Central Limit Theorem. Estimation for means, proportions and variances. Hypothesis tests

6 ECTS credits.

1.1.5 Introduction to Programming

Simple types, control structures, modularization and recursion. Programming concepts. Problems, algorithms and programs. Programming paradigms and languages. Systematic application development. Basic elements of Pascal. History of Pascal. Basic data types. Programmer-defined data types. Compatibility between types. Program documentation. Structured instructions. Composite instructions. Selection instructions. Iteration instructions. Subprograms. Syntactic structure of subprograms. Design aspects. Parameter subprograms. Validity and scope. Methodological aspects. Introduction to recursion. Basic concepts. Linear recursion. Multiple recursion. Mutual recursion. Complex data structures: Arrays. Array type: description and operations. One-dimensional arrays. Two-dimensional arrays. String type. Algorithms with arrays. Records and files. Record type: description and operations. File type: description and operations. File types. Manipulation of files and directories.

6 ECTS credits.

1.2 Second Semester

1.2.1 Algebra

Matrices. Linear systems of equations. Linear maps. Kernel and image. Vector spaces. Basis. Dimension. Diagonalization. Euclidean space. Linear codes.

6 ECTS credits.

1.2.2 Computer Structure

The Computer Structure course is the second in the sequence of courses focused on the study of computer structure and architecture. Its main objective is to deepen the concepts presented in the Computer Technology course, as well as to introduce more advanced topics. In this course, the classical computer model, known by many as the "Von Neumann Model", is presented, describing its fundamental elements. Then some concepts related to operating systems are introduced. Next, various performance measures that will be used throughout this course, as well as in later courses of this subject, are discussed, followed by the study of the basic mechanisms of the representation of numeric and alphanumeric information in computers. Next, the concept of the instruction set architecture (or computer architecture) is presented as a crucial element when approaching the design and programming of the computer. From there on, the course continues with the study of low-level computer programming and the design of its central processing unit.

6 ECTS credits.

1.2.3 Data Structures

Abstract Data Types and Algorithmics. Lists, Stacks, Queues, and Sets. Trees. Graphs.

6 ECTS credits.

1.2.4 Calculus

Functions, limits and continuity. The real line. Complex numbers. Functions: Overview. Limits and continuity. Differential calculus in one variable. Derivatives. Derivative computation. Taylor polynomial. Study and graphical representation of functions. Integral calculus in one variable. Primitive computation. Definite integrals. Numerical sequences and series. Numerical sequences. Series of numbers.

6 ECTS credits.

1.2.5 Informatics and Society

Principles of the Information Society. The development of Informatics. History of Informatics. Hardware and software evolution. Digitization and Information Management. Epistemic foundations of the information society. Knowledge, Science and Society. Comprehension and communication of information The fragmentation of the Information Society. Information and communication technologies. Web 2.0, digital journalism and post-truth. Internet and its influence on society. Free culture and Free Software. Transformations in the Information Society. Economic transformations. Digital transformation of organization. New business models and the challenge of corporate sustainability. Towards the Fourth Industrial Revolution. Social and political transformations . Technology and the Sustainable Development Goals (SDGs). Digital Democracy. Humanism and Transhumanism.

6 ECTS credits.

2

Second Course

2.1 First Semester

2.1.1 Object Oriented Programming

Introduction: Motivation of OOP. Basic concepts of object oriented programming: Classes, objects and references. Methods and messages. Attributes and state. Constructors. Arrays. The Java language: history, basic syntax, programming environments. Object-oriented design principles: UML Class Diagrams. Simple design problems. Elements of Java: Classes and Interfaces. Packages. Instance and Static Attributes and Methods. Final attributes. Accessibility. Utility Classes (Strings, Wrappers). Unit tests in Java. Inheritance and Polymorphism: Inheritance concept and mechanisms. Inheritance in Interfaces. Dynamic linking: Polymorphism. Object-oriented applications: Java APIs: Collections, input/output, Exceptions, introduction to graphical interfaces and event-driven programming, Generics.

6 ECTS credits.

2.1.2 Computer Organization

Memory Hierarchy: basic concepts, memory characteristics, types of memories, concept of locality, levels of memory hierarchy. Main Memory: main memory technologies, memory maps, in-memory data access, main memory configuration and interconnection, error control. Cache Memory: direct mapping, data access; management policies, associativity, cache performance, multilevel caches. Virtual Memory: basic concepts, operating system, processes and memory management, page location, page misses, TLB, memory management unit. Introduction to I/O systems: characteristics and performance of the I/O systems. Pheripherical devices: Characteristics of the I/O devices, types of peripherals, storage peripherals. Interconnection using buses: basic concepts, bus characteristics, bus hierarchy, bus types, synchronism, arbitration, priority management. I/O management techniques: basic concepts, peripheral models, peripheral control, I/O operation management, active standby, interrupts, DMA.

6 ECTS credits.

2.1.3 Basic Legal Principles, Professional Deontology and Equality

Ethics, engineering and human being.. Ethical and social responsibility. Basic legal principles. Introduction to Law. Basic legal principles of the Spanish legal system. Fundamental elements of Computer Law. Professional ethics and deontology of computers engineering. The importance of professional ethics. The profession of Software Engineer. Software licenses and business models.

6 ECTS credits.

2.1.4 Databases

Basics of Databases. Information Systems and Databases: Concept and components of an Information System. Database Concept File Systems and Database Management Systems. File management systems. Concept and functions of the Database Management System. Operation of the Database Management System. ANSI / X3 / SPARC architecture. Physical / Logical Independence. Data Models. Concept of Data Model. Model vs. Scheme. Classification of Data Models. Elements of a Data Model. Data Models in Database Design. Relationship between Data Model and Data Languages. Extended E / R Model. Entity. Relationship. Domain and value. Attribute. Generalization. Conceptual modeling. Conceptual data modeling in the software development process. Stages of conceptual modeling. Relational Model. Static: Elements of the relational model. Relationship. Keys. Constraints. Dynamics: Relational Algebra. Database Design. Logical design. Database design methodology. Theory of normalization. Implementation of Databases. SQL language. Data Definition Language (DDL). Data Manipulation Language (DML). Data Control Language (DCL).

6 ECTS credits.

2.2 Second Semester

2.2.1 Computer Architecture

Instruction set architecture. CISC vs. RISC instruction sets. Operand storage. Types of operands. Addressing modes. Other characteristics. Instruction set codification. Optimizations. Mechanism of the execution of an instruction. Execution of the typical RISC instructions in simple sequential processors: mono cycle and multicycle. Basic concepts of pipelined processors. Concept of instruction-level parallelism. Definition of pipe lining. Benefits of pipe lining. One-function pipelined processors: control unit and data path. Risk resolution. Multifunctional pipelined processors. Rationale for multifunctional pipelined processors. Control unit and datapath. Risk resolution. Dynamic instruction scheduling. Dynamic data risk resolution. Scheduling of memory-access instructions. Centralized instruction scheduling (scoreboarding). Distributed instruction scheduling (Tomasulo). Dynamic branch prediction. Dynamic control risk resolution. Hardware structures for branch prediction. Predictors and prediction algorithms. Multiple instruction issue. VLIW processors. Vectorial processors. Superscalar processors. Speculation. Multithreading. Limitations of instruction-level parallelism. Concepts of thread-level parallelism. Current processors. Multicore processors. Specific processors (GPU's, video consoles, communications). Future trends.

6 ECTS credits.

2.2.2 Operational and Statistical Management Methods

Introduction: The company and its purposes. Organization and structure of the company. The role of operations research in the companies. Mathematical Programming: Optimization models for management. Introduction to the solution methods. Postoptimization. Examples. Decision Theory: Introduction. Decision analysis. Multiobjective decision making. Examples. Project Management: Planning a project. Critical activities. Gantt chart. Cost balance and resource constraints. Other management methods. Quality management and design of experiments: X-R control charts. Design of experiments in quality control.

6 ECTS credits.

2.2.3 Computer Networks

Computer networks concepts: protocols and technologies organized in a layered architecture. In this way, students will be able understand the different concepts and protocols and how all the parts fit together. Introduction to Internet. The Application Layer. Highlighting the technologies that support the Web, e-mail and P2P file sharing. The Transport Layer. It will be addressed explaining the reliable communication over an unreliable network layer, connection establishment and closure, and the agreement process, congestion and flow control, and multiplexing. The Network Layer. Fundamental topics such as route determination between two routers will be studied and the interconnection of a large number of heterogeneous networks. The Data Link Layer and the Physical Layer. Fundamental problems such as the sharing of a multiple access channel, addressing, local area networks and the physical media used to transmit information.

At the end of the course, the student should be able to adequately design a computer network for a company, taking into account cost, performance and needs criteria.They should also be able to understand the technical description or documentation of a communications product, as well as the physical means used to transmit information.

6 ECTS credits.

2.2.4 Operating Systems

This subject shows the operation of operating systems. Specifically, the student will understand the concepts basic operating systems and will become familiar with their programming, understanding their principles and ways of app. In addition, the student will acquire knowledge related to the management of processes, memory and file system.

6 ECTS credits.

2.2.5 Fundamentals of Software

Introduction. Algorithm Analysis and Design: Quality attributes. Design principles. Design patterns and architectural patterns. Test design. Analysis and Design of Algorithms. Complexity of Algorithms: Definition. Bounds. Properties. Instruction count. Recurrence expansion. General complexity resolution techniques for recursive algorithms. Test design: Types of tests. White box testing. Black box testing. Divide and conquer technique: Definition. Programming scheme. Complexity analysis. Classic examples. Greedy algorithms: Definition. Programming scheme. Classical examples. Backtracking: Definition. Scheduling schemes: all solutions, one solution, optimal solution. Classical examples. Details of efficient programming. Design Principles and Patterns. Design principles: Quality metrics. Architectural patterns. SOLID principles. Other principles. Design patterns. Creational patterns. Structural patterns. Behavioral patterns. Definition, documentation, UML, practical examples.

6 ECTS credits.

3

Third Course

3.1 First Semester

3.1.1 Concurrent Programming

Introduction to the concurrent paradigm. Relations between processes: competition and cooperation. Interactions between processes. Atomic instructions, collation and indeterminism. Validation of concurrent programs. Security between threads. Sharing of objects. Blocks of construction. Execution of tasks. Performance and scalability.

6 ECTS credits.

3.1.2 Advanced Computer Networks

Introduction to local networks, Network security, IPv6, wireless networks, multimedia networks

6 ECTS credits.

3.1.3 Human-Computer Interaction

User-centred design. HCI Introduction. Visual programming of interfaces. Designing user interfaces and assistance systems. Usability and accessibility. Usability. Accesibility. Evaluation of user interfaces. Heuristic and empirical evaluation

6 ECTS credits.

3.1.4 Embedded Systems Design

Embedded systems Introduction. Basic concepts of Embedded systems. AD, DA converters. Sensors and actuators. Microcontrollers. Embedded systems design. Basic interconnections methods. Embedded systems programming. Arduino basics. Digital inputs and outputs. Analog inputs and outputs. Communication inter IC systems (wired and wireless comms) Internet of things. IoT basic concepts

6 ECTS credits.

3.1.5 Advanced Concepts on Operating Systems

Advanced concepts on operating systems: Kernel and administration; Security and protection; Virtualization. Operating systems for high performance architectures: Distributed operating systems; Synchronization and communication in distributed systems; Coordination, control and fault tolerance in distributed systems; File systems and input/output in distributed systems; Operating systems for specific purposes: Operating systems for mobile devices; Real time operating systems.

6 ECTS credits.

3.2 Second Semester

3.2.1 Intelligent Systems

Introduction to Artificial Intelligence, Problem solving through search (Uninformed search, Heuristic search, Advanced heuristic search, Multiagent search, Constraint satisfaction problems), Knowledge Representation (Description logic, Ontologies and Web services, Reasoning with imprecision), Machine Learning (Supervised learning/Decision Trees, Neural Networks, Reinforcement learning /Q-learning)

6 ECTS credits.

3.2.2 Programming Languages

Introduction to Programming Languages. Definition of programming language. Characteristics of programming languages. Main programming paradigms. Evolution. Compilers and interpreters. Functional Programming (Haskell). Introduction to functional programming. Basics of functional programming. Evolution. Concept of function. Characteristics of functional programming. Data types. Definition of functions. Predefined types and their functions. Tuples. Case expressions. Lists. Pattern matching. Local definitions. Recursive functions. Higher-order functions. Lambda expressions. Polymorphism. Synonyms for types. Definition of data types. Classes. Python: a dynamically-typed language. History and characteristics of the Python language. Introduction to the Python programming language. Basic syntax of the Python programming language. Advanced Python concepts. Flow control. Structures. Python ecosystem: libraries, frameworks and tools.

6 ECTS credits.

3.2.3 Development of Distributed Applications

Introduction. Advantages, properties and classification of distributed systems. Problems of distributed systems. Architectural patterns for distributed systems. Development of applications and services on the Internet. Application communication. Sockets. Communication protocols. Message queues. REST services. Databases. Scalability and fault tolerance. Distributed systems and cloud computing: virtualization and cloud. Containers. Elasticity and fault tolerance. Scalable architectures: client/server, caches, load balancers, data replication. Data replication. Data consistency. Consistency models. Database replication. Application deployment and update. The deployment problem. Upgrades. Configuration management. Monitoring.

6 ECTS credits.

3.2.4 High-Performance Computing

Need for high-performance computing in a multitude of current business, military, industrial, biomedical or scientific applications. Basic concepts of computer architecture, introduction to computer networks, parallel architectures, multiprocessors (shared memory) and multicomputer (shared memory) systems. Design alternatives currently available for multiprocessors, clusters, and systems based on the grid paradigms. Examples with real architectures and applications, metrics and methodologies for the evaluation of the performance of this type of systems. Evaluation of the performance of this type of architectures. Review of the new trends in high-performance computing.

6 ECTS credits.

3.2.5 Project Management

Fundamentals of project management and software engineering. Software engineering workflows: requirements, analysis, design and testing. Project management methodologies. Project planning and estimation. The project management team.

6 ECTS credits.

4

Fourth Course

4.1 First Semester

4.1.1 Computer Security

In our technological and networked society, Computer Security impacts every aspect of our lives. The goal of this course is to provide a basic knowledge of the main cybersecurity concepts and techniques. First we will analyze what makes Computer Security so important and its main components: confidentiality, integrity and availability. Second we will review the main related concepts, such as risk, vulnerability, incident or attack. Next we will study how public and private institutions should organize to guarantee the security of their information systems. Then we will analyze the main techniques that can be used to attack both networks and systems or applications, and the countermeasures that can be deployed to defend from these attacks. Finally, we will examine new trends in Computer Security, such as APTs, cloud security, etc. Prospective students should have a working knowledge of computer programming and data structures, relational databases and computer networks.

6 ECTS credits.

4.1.2 Mobile Devices Laboratory

Introduction: Ubiquitous Computing. Principles and Concepts. Mobile Computing. Types of Mobile Devices. Review of technologies and systems. Development of mobile applications: environments and programming languages. Application development and interaction with mobile devices. Development of User Interfaces for Mobile Devices. Persistent storage. Project creation. File manifest and AVD. Layout creation. Activity and View. Main Widgets. Android storage concepts. File systems. Preferences and other storage. Databases with mobile device. Advanced programming. Multimedia content management. Game programming for mobile devices. Multimedia concepts. multimedia APIs. Audio and video processing. Recording of contents. Animation and game programming.

6 ECTS credits.

4.1.3 Advanced Algorithms

This subject is only taught at Mostoles Campus.

Introduction. Specifications and algorithms. Basic and advanced algorithm design techniques. Combinatorial and optimization problems. Exact and approximate algorithms. Principles of experimentation with algorithms. Advanced aspects of greedy algorithms. Implementation decisions. Optimality proofs and counterexamples. Examples and applications. Heuristic and approximation algorithms. Definitions. Experimenting with optimality. Examples and applications. Advanced aspects of search-based design techniques. Application of backtracking to optimization problems. Technique of branch-and-bound. Experimenting with time efficiency. Examples and applications. Removal of redundant recursion. Analysis of redundancy. Techniques for removal of redundant recursion: tabulation, memorization. Dynamic programming. Development methodology. Examples and applications. Probabilistic algorithms. Definitions. Classes of probabilistic algorithms. Examples and applications.

6 ECTS credits.

4.2 Second Semester

4.2.1 Computer graphics

Computer graphics. Image processing. Graphics pipeline. 3D Object representations. Methods and models. Geometric transformations. Geometrical transformations. Composition of transformations. Color. The human visual system. Color perception. Representation of color values. Illumination and Shading. The Phong Lighting Model. Shading models. Visual realism. Visible surface determination. Textures. Other methods.

6 ECTS credits.

4.2.2 Computer Vision

Introduction to Computer Vision. Applications of Computer Vision Light and colour: their perception and representation. Physiology of human vision. Image capture: fundamentals of digital cameras. Optics and lens models. Characteristics of digital images. Pre-processing and filtering of digital images. Operations at pixel level. Histogram of an image. Applications of the histogram: contrast enhancement and equalisation. Operations at neighbourhood level. Spatial domain filtering: low-pass and high-pass filters. Mathematical morphology. Geometric operations on images. Filtering in the frequency domain: the Fourier transform. Detection and description of interest points in images. Interest points: concepts and properties. Most important point detectors: Harris, SIFT, BRIEF, ... Applications of interest points: visual words. Detection of simple geometric structures: Detection of lines: Hough transform. Detection of lines: RANSAC. Detection of circles: Hough transform for circles. Region detection: global and adaptive thresholding -Region detection: connected components. Region detection: MSER. Pattern classification: Concepts, properties and types of classifiers. Distance-based classifiers: Euclidean, Mahalanobis and knn. Bayesian classifier. Artificial neural networks. Support Vector Machines (SVM). Unsupervised classification: k-means. Dimensionality reduction techniques -Performance evaluation of classifiers.

6 ECTS credits.

4.2.3 Sequential Machines, Automata and Languages

Introduction. Language, grammars and automata. Chomsky Hierarchy. Regular languages. Finite automata. Non-deterministic finite automata. Regular grammars. Equivalences. Regular expressions. Equivalances. Properties of regular languages Context-independent (CI) languages. Pushdown automata (PD). Deterministic PD automata. Properties of CI languages: pumping lemma, decision algorithms. Turing Machines.

6 ECTS credits.

4.2.4 Robotics and Home Automation

The subject presents basic topics related to Robotics and Home Automation, focusing on practical application and creation of a functional project of both fields.

Upon successful completion of this course, students will be able to: Describe the general principles of operation and design of the systems; Explain the kinematic and dynamic description of a robotic system; Describe the main sensors and actuators that can be found in a robotic system; Describe the main characteristics of the functional units of the robot; Explain the design of a simple robot; Explain the structure and operation of the simple programming of a robot / home automation systems; Describe the principles of design of mobile robotics systems; Describe the fundamental principles on which home automation is based; Explain the applications to be made based on home automation; Solve problems with initiative, decision making and creativity; Interpret technical documentation related to Robotics and Home Automation.

6 ECTS credits.