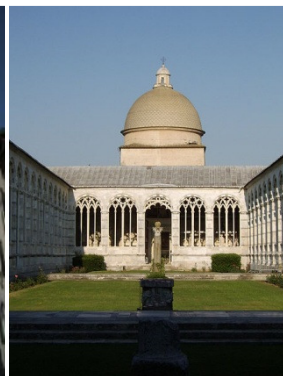


Graduate Program in Information Science and Technology



Courses and Exams

The Master of Science in Computer Science is aimed at training professionals provided with both an in-depth understanding of the theoretical principles of computer science, and a specific collection of knowledge related to one of the following areas:

- The area *Software technologies* provided students with the knowledge required to deal with the analysis, the design and the development of large-scale software systems, with a particular emphasis on properties such as quality, correctness and security.
- The area *Systems and networks* provides students with the ability of designing and understanding large systems composed of a distributed collection of interacting entities. Examples include both technological systems such as distributed systems and networks, as well as complex relational systems such as social networks.
- The area *Data media and knowledge* provides students with the knowledge required to extract, manage and present information, with courses related to machine learning, advanced information systems and the web.
- The area *Embedded systems and ambient intelligence* is focused on the methodologies for the development of software applications for embedded systems, one of the fastest growing areas in ICT. Applications range from automatic controls used in industrial, automotive and avionic systems, to recent infotainment systems (e.g. smart phones), to domotics and ambiente intelligence.

Students complete their 2 year studies by **132** credits, **66** credits taken each year. The courses include *mandatory courses* that must be taken by the student regardless his choice; *elective courses* that can be chosen from the list proposed; *free choice courses* that give the student a chance to choose the course according to his likes and field of interest, including courses offered by any of Faculties of the University of Trento.


The degree is completed with 6 credits for the stage activity and 18 credits for the final thesis.


Data, Media & Knowledge

The specialization has a number of compulsory courses aiming to teach students about the Web, the Information Systems, and many important foundations of Computer Science. Furthermore, it trains students in two areas that are becoming critical for the design of the future innovative systems: automated reasoning and knowledge extraction. The specialization includes an additional number of optional courses that complement the communicated knowledge with topics about Speech Recognition, Video Processing, Computer Graphics and Semantic Web.

Students complete their studies by 30 credits as free-choice. An additional collection of eligible courses for the Data, Media & Knowledge specialization is suggested here; other courses may be selected from the complete list of courses.

DMK Profile 1

 Courses taken in Pisa

 Courses taken in Trento

| 1st year (66 credits) | | |
|---|---------------|----------------|
| Course | Sector | Credits |
| Mandatory Courses | | 48 |
| Concurrent Programming | ING/INF05 | 6 |
| Real-time systems | ING/INF05 | 6 |
| Object Oriented Software Design | ING/INF05 | 12 |
| 3D Graphics for Virtual Reality | ING/INF05 | 6 |
| Security | ING/INF05 | 6 |
| Optimization methods for IT | MAT/09 | 6 |
| Probability and Statistics In Computer Science | MAT/06 | 6 |
| Elective courses | | 18 |
| Interaction with Virtual Environments | ING/INF05 | 6 |
| Laboratory of embedded systems | ING-INF/05 | 6 |
| Model Based Techniques for Software Development | ING/INF05 | 12 |
| 2nd year (66 credits) | | |
| Course | Sector | Credits |
| Mandatory Courses | | 24 |
| Advanced Information Systems | ING/INF 05 | 6 |
| Data Mining for Knowledge Management | ING/INF 05 | 6 |
| Computability | MAT01 | 6 |
| Computational complexity | INF01 | 6 |
| Elective courses | | 18 |
| Web Architectures | INF01 | 6 |
| Concurrency theory | INF01 | 6 |
| Network Security | ING/INF05 | 6 |
| Agent-oriented Software Engineering | ING/INF05 | 6 |
| Real Time operating systems and middleware | ING/INF05 | 6 |
| Advanced Networking | ING/INF05 | 6 |
| Logics for Data and Knowledge Representation | ING/INF05 | 6 |
| Thesis | | 18 |
| Stage (Optional) | | 6 |

DMK Profile 2

| 1st year (66 credits) | | |
|--|---------------|----------------|
| Course | Sector | Credits |
| Mandatory Courses | | 48 |
| Concurrency theory | INF01 | 6 |
| Real-time Operating Systems | ING/INF05 | 6 |
| Web languages | INF01 | 12 |
| Organizational Information Systems | ING/INF05 | 6 |
| Logics for Data and Knowledge Representation | ING/INF05 | 6 |
| Computability | MAT01 | 6 |
| Computational complexity | INF01 | 6 |
| Elective courses | | 18 |
| Agent-oriented software engineering | ING/INF05 | 6 |
| Web Architectures | INF01 | 6 |
| Signals and Systems | ING/INF05 | 12 |
| Data Mining for Knowledge Management | INF01 | 6 |
| 2nd year (66 credits) | | |
| Course | Sector | Credits |
| Mandatory Courses | | 24 |
| Object Oriented Software Design | ING/INF05 | 12 |
| Optimization methods for IT | MAT09 | 6 |
| Probability and Statistics In Computer Science | MAT06 | 6 |
| Elective courses | | 18 |
| Concurrent Programming | ING/INF05 | 6 |
| Security | ING/INF05 | 6 |
| Real-time systems | ING/INF05 | 6 |
| Model Based Techniques fo Software Development | ING/INF05 | 12 |
| 3D Graphics for Virtual Reality | ING/INF05 | 6 |
| Interaction with Virtual Environments | ING/INF05 | 6 |
| Concurrent Programming | ING/INF05 | 6 |
| Thesis | | 18 |
| Stage (Optional) | | 6 |


Systems & Networks


The System and networks specialization is aimed at educating professionals capable to dominate the inherent complexity of future networks, designing and managing the interconnected systems of the future society. The portfolio of offered courses covers all aspects of the distributed systems area, from low-level communication protocols to high-level applications and services, including also theoretical courses where the general problem of analyzing, managing and organizing large-scale, complex systems is discussed. Students are free to create their preferred mixture of courses by carefully preparing their study plan.

Possible suggestions for study plans are as follows:

- A study plan more oriented towards distributed systems, web, and complex systems: Machine Learning, Web Mining, Performance Evaluation, Distributed Systems, Complex Systems, Web architectures, Organizational Information Systems.
- A study plan more oriented towards networking: Advanced networking, Nomadic communications, Performance evaluation, System security, Network security, Distributed systems, Web architectures.

System and Networks. Profile 1

 Courses taken in Pisa

 Courses taken in Trento

| 1 st year (66 credits) | | |
|--|-----------|-------------|
| Course | Sector | Credits |
| Mandatory Courses | | 42 |
| Concurrent Programming | INF01 | 6 |
| Real-time systems | ING/INF05 | 6 |
| Object Oriented Software Design | ING/INF05 | 12 |
| Model Based Software Development | ING/INF05 | 12 |
| Optimization methods for IT | MAT09 | 6 |
| Elective courses | | 6-12 |
| Probability and Statistics in Computer Science | Math06 | 6 |
| Mathematical Methods for network optimization | MAT09 | 6 |
| Laboratory of embedded systems | ING/INF05 | 6 |
| 3D Graphics and virtual reality | ING/INF05 | 6 |
| Security | ING/INF05 | 6 |
| Free Choice Courses | | 18 |
| 2nd year (66 credits) | | |
| Course | Sector | Credits |
| Mandatory Courses | | 24 |
| Computability | MAT01 | 6 |
| Computational complexity | INF01 | 6 |
| Web Architectures | INF01 | 6 |
| Advanced Networking | ING-INF05 | 6 |
| Elective courses | | 0-6 |
| Nomadic communication | ING/INF05 | 6 |
| Network Security | ING/INF05 | 6 |
| Distributed Systems | INF01 | 6 |
| Machine Learning | INF/01 | 6 |
| Computer Security | ING/INF05 | 6 |
| Performance Evaluation | ING/INF05 | 6 |
| Wireless Sensor Networks | ING/INF05 | 6 |
| Web Mining | INF/01 | 6 |
| Mathematical Logic | INF01 | 6 |
| Concurrency theory | INF01 | 6 |
| Machine Learning | INF01 | 6 |
| Free Choice Courses | | 12 |
| Thesis | | 18 |
| Stage (Mandatory) | | 6 |

Systems and Networks. Profile 2

| 1 st year (66 credits) | | |
|--|-----------|-------------|
| Course | Sector | Credits |
| Mandatory Courses | | 42 |
| Concurrency theory | INF01 | 6 |
| Web Architectures | INF01 | 6 |
| Advanced Networking | ING/INF05 | 6 |
| Computability | MAT01 | 6 |
| Computational complexity | INF01 | 6 |
| Machine Learning | INF01 | 6 |
| Nomadic Communications | ING/INF05 | 6 |
| Elective courses | | 6-12 |
| Mathematical Logic | MAT01 | 6 |
| Wireless Sensor Networks | ING/INF05 | 6 |
| Web Mining | INF/01 | 6 |
| Network Security | ING/INF05 | 6 |
| Distributed Systems | INF01 | 6 |
| Computer Security | ING/INF05 | 6 |
| Free Choice Courses | | 18 |
| 2nd year (66 credits) | | |
| Course | Sector | Credits |
| Mandatory Courses | | 30 |
| Object Oriented Software Design | ING/INF05 | 12 |
| Optimization methods for IT | mat09 | 6 |
| Real-time systems | ING/INF05 | 6 |
| Laboratory of embedded systems | ING/INF05 | 6 |
| Elective courses | | 0-6 |
| Concurrent Programming | ING/INF05 | 6 |
| Security | ING/INF05 | 6 |
| Probability and Statistics in Computer Science | MAT06 | 6 |
| Mathematical Methods for network optimization | mat09 | 6 |
| 3D Graphics and virtual reality | ING/INF05 | 6 |
| Model Based Techniques for Software Design | ING/INF05 | 12 |
| Free Choice Courses | | 12 |
| Thesis | | 18 |
| Stage (Mandatory) | | 6 |

Software Technologies


This curriculum address the challenges of the analysis, design and software development of large scale socio-technical systems with proven quality of assurance, correctness, security and usability. The curriculum can be essentially designed in three main stream


- **Design:** the courses part of this stream complements the traditional part of Software Engineering in BSc courses with the analysis of organizational requirements behind the development of software systems (Requirements Engineering) and new development methodologies (Agent-Oriented Software Engineering) and usability (Human Computer Interaction).
- **Assurance and Security:** here the courses focus on the analysis of trust and security at organizational and business process level (Computer Security) and lower level (Network Security) that are . Also in this case usability considerations (Human-Computer Interaction) play a key role.
- **Correctness:** this stream faces the challenges of the design of a correct software systems through the technology of testing (Software Analysis and Testing, and Laboratory of Software Analysis) and the complementary techniques of formal verification and model checking (Formal Methods).

The curriculum can be complemented with a number of courses from other curricula among the suggested alternatives students can explore the issue behind the design of Organizational Systems where socio-technical issues are considered more thoroughly. Further we have envisaged the aspects of Software Management, for students that intends to continue their careers in Industry, and Research Projects in Software Technologies, for students interested in deepening their knowledge of applied research topics.

Students interested to pursue specialization in the areas of Design, Assurance and Correctness are also encouraged to take the advanced 3credits courses in each of the above area that are offered in the framework of the PhD program (Conceptual Modeling and Ontological Analysis, Access Control and Information Theory, Advanced Software Verification).

Software Technologies. Profile 1

 Courses taken in Pisa

 Courses taken in Trento

| 1 st year (66 credits) | | |
|--|------------|--------------|
| Course | Sector | Credits |
| Mandatory Courses | | 48 |
| Concurrent Programming | INF/01 | 6 |
| Real-time systems | ING-INF/05 | 6 |
| Object Oriented Software Design | ING-INF/05 | 12 |
| Model Based Software Development | ING-INF/05 | 12 |
| Optimization methods for IT | MAT/09 | 6 |
| Elective courses | | 6-12 |
| Security | ING-INF/05 | 6 |
| Laboratory of embedded systems | ING-INF/05 | 6 |
| 3D Graphics and virtual reality | ING-INF/05 | 6 |
| Interaction with Virtual Environments | ING/INF05 | 6 |
| Probability and Statistics In Computer Science | MAT/06 | 6 |
| Free Choice Courses | | 12-18 |
| 2nd year (66 credits) | | |
| Course | Sector | Credits |
| Mandatory Courses | | 24 |
| Requirements Engineering | ING-INF/05 | 6 |
| Computer Security | ING/INF/05 | 6 |
| Computational complexity | INF/01 | 6 |
| Computability | MAT/01 | 6 |
| Elective courses | | 0-6 |
| Nomadic communication | ING-INF/05 | 6 |
| Formal Methods | INF/01 | 12 |
| Real-time Operating Systems | ING-INF/05 | 6 |
| Concurrency Theory | INF/01 | 6 |
| Automatic Control | ING-INF/04 | 6 |
| Software analysis and testing | ING/INF05 | |
| WSN | ING-INF/05 | 6 |
| Advanced Architectures | ING-INF/01 | 6 |
| Research Project in Software Technologies | ING-INF/05 | 12 |
| Free Choice Courses | | 12 |
| Thesis | | 18 |
| Stage (Mandatory) | | 6 |

Software Technologies. Profile 2

| 1st year (66 credits) | | |
|---|---------------|----------------|
| Course | Sector | Credits |
| Mandatory Courses | | 48 |
| Concurrency theory | INF 01 | 6 |
| Real-time Operating Systems | ING-INF/05 | 6 |
| Requirements Engineering | ING-INF/05 | 6 |
| Computer Security | ING-INF/05 | 6 |
| Formal Methods | INF/01 | 12 |
| Computability | MAT/01 | 6 |
| Computational complexity | INF/01 | 6 |
| Elective courses | | 6-12 |
| Nomadic Communication | ING-INF/05 | 6 |
| Automatic Control | ING-INF/04 | 6 |
| WSN | ING-INF/05 | 6 |
| Advanced Architectures | ING-INF/01 | 6 |
| Research Projects in Embedded systems | ING-INF/05 | 12 |
| Free Choice Courses | | 6-12 |
| 2nd year (66 credits) | | |
| Course | Sector | Credits |
| Mandatory Courses | | 18 |
| Object Oriented Software Design | ING-INF/05 | 12 |
| Optimization methods for IT | MAT/09 | 6 |
| Elective courses | | 0-6 |
| Laboratory of embedded systems | ING-INF/05 | 6 |
| Model Based Techniques for Software Development | ING-INF/05 | 12 |
| Probability and Statistics In Computer Science | MAT/06 | 6 |
| Real-time systems | ING-INF/05 | 6 |
| Concurrent Programming | ING-INF/05 | 6 |
| 3D Graphics and virtual reality | ING-INF/05 | 6 |
| Interaction with Virtual Environments | ING/INF05 | 6 |
| Security | ING-INF/05 | 6 |
| Free Choice Courses | | 18 |
| Thesis | | 18 |
| Stage (Mandatory) | | 6 |

Embedded Systems and Ambient Intelligence

Electronic technology has become the mainstay of any engineering system with complex functionality. Automobiles, air-planes, even everyday use objects such as pens and domestic appliances have an important electronic dimension, which is typically transparent to the users. For this reason, the electronic devices immersed in larger systems are called embedded systems. Among the most important functions embedded systems enable are control and monitoring of the operation of mechanical systems such as automotive engines or suspensions, chemical systems such as distillation towers, and communication systems such as cellular phones. The pervasiveness of these components is well illustrated by the following examples:


- the European automotive sector has a turnover of around 500 Billions Euro and it employs 2.7 million people in the EU. As of today, the 20% of the value of each car is due to embedded electronics. This ratio is expected to increase to 35-40% by 2015 creating more than 600.000 jobs in the automotive embedded systems alone (source ARTEMIS initiative)
- in the year 2005 the total amount of money spent in the EU for R&D activities in the Embedded systems areas is estimated in 20.000 millions Euro (19.750 from private investment and 250 from public investments). It is expected that in 2010 the total expenditure will overcome 28500 Millions Euro.

The development of EC is a very complex activity for a variety of reasons. The first problem is the presence of tight safety requirements. A failure of the system can even result in the loss of human lives. Moreover, fixing a problem in a system shipped in thousands of units can result in enormous additional costs for its manufacturer. Other issues such as time-to-market, cost of the deployed architecture, power consumption and memory footprint are also known to play a role of increasing importance. In short, designers and engineers are confronted with a challenge of overwhelming complexity: reliable (and often safety-critical) applications have to be developed in a short time using low-cost components. In order to cope with these challenging issues, an engineer operating in this domain must be provided with a wide body of knowledge, spanning over diverse scientific and technological disciplines. To build this knowledge, the faculty proposes a curriculum consisting of mandatory and optional courses. The mandatory courses cover the following cultural domains:

- Hardware/software platforms: the developer of embedded software has cost containment among his/her primary concerns. Hence, he/she needs foundational information on the main trade-offs present in hardware design and on how real-time computations can be performed even on low cost platforms. This information is conveyed by “advanced architectures” and “real-time operating systems”.
- Production of safety critical code: the correctness of the produced code is really the name of the game. Basic methodological skills on functional and temporal correctness will be offered in the “formal methods” and in the “real-time operating systems” courses.
- Networking: tomorrows embedded systems will be networked to an unprecedented extent. Particularly, wireless networking will take the lion share. Advanced information on wireless networking will be offered in the “nomadic communications” course
- Signal and Systems: most embedded systems are used to process signals and implement control systems. A basic knowledge on this wide discipline will be offered in the Signal and Systems course.

Embedded Systems. Profile 1

 Courses taken in Pisa

 Courses taken in Trento

| 1 st year (66 credits) | | |
|--|------------|-------------|
| Course | Sector | Credits |
| Mandatory Courses | | 42 |
| Concurrent Programming | ING/INF05 | 6 |
| Real-time systems | ING/INF05 | 6 |
| Object Oriented Software Design | ING/INF05 | 12 |
| Model Based Software Development | ING/INF05 | 12 |
| Optimization methods for IT | ING/INF05 | 6 |
| Elective courses | | 6-12 |
| Security | ING-INF/05 | 6 |
| Laboratory of embedded systems | ING-INF/05 | 6 |
| 3D Graphics and virtual reality | ING-INF/05 | 6 |
| Interaction with Virtual Environments | ING/INF05 | 6 |
| Probability and Statistics In Computer Science | MAT/06 | 6 |
| Free Choice Courses | | 18 |
| 2nd year (66 credits) | | |
| Course | Sector | Credits |
| Mandatory Courses | | 24 |
| Signals and systems | ING-INF/05 | 6 |
| Laboratory of Embedded Control Systems | ING/INF/05 | 6 |
| Computational complexity | INF/01 | 6 |
| Computability | MAT/01 | 6 |
| Elective courses | | 0-6 |
| Nomadic communication | ING-INF/05 | 6 |
| Formal Methods | INF/01 | 12 |
| Real-time Operating Systems | ING-INF/05 | 6 |
| Concurrency Theory | INF/01 | 6 |
| Automatic Control | ING-INF/04 | 6 |
| Research Project in Embedded systems | ING-INF/05 | 12 |
| WSN | ING-INF/01 | 6 |
| Advanced Architectures | ING-INF/05 | 6 |
| Free Choice Courses | | 12 |
| Thesis | | 18 |
| Stage (Mandatory) | | 6 |

Embedded Systems. Profile 2

| 1st year (66 credits) | | |
|---|---------------|----------------|
| Course | Sector | Credits |
| Mandatory Courses | | 48 |
| Concurrency theory | INF 01 | 6 |
| Real-time Operating Systems | ING-INF/05 | 6 |
| Signal and systems | ING-INF/05 | 6 |
| Laboratory of Embedded Control Systems | ING-INF/05 | 6 |
| Formal Methods | INF/01 | 12 |
| Computability | MAT/01 | 6 |
| Computational complexity | INF/01 | 6 |
| Elective courses | | 6-12 |
| Nomadic Communication | ING-INF/05 | 6 |
| Automatic Control | ING-INF/04 | 6 |
| WSN | ING-INF/05 | 6 |
| Advanced Architectures | ING-INF/01 | 6 |
| Research Projects in Embedded systems | ING-INF/05 | 12 |
| Free Choice Courses | | 6-12 |
| 2nd year (66 credits) | | |
| Course | Sector | Credits |
| Mandatory Courses | | 18 |
| Object Oriented Software Design | ING-INF/05 | 12 |
| Optimization methods for IT | ING-INF/05 | 6 |
| Elective courses | | 6 |
| Laboratory of embedded systems | ING-INF/05 | 6 |
| Model Based Techniques for Software Development | ING-INF/05 | 12 |
| Probability and Statistics In Computer Science | MAT/06 | 6 |
| Real-time systems | ING-INF/05 | 6 |
| Concurrent Programming | ING-INF/05 | 6 |
| 3D Graphics and virtual reality | ING-INF/05 | 6 |
| Interaction with Virtual Environments | ING-INF/05 | 6 |
| Security | ING-INF/05 | 6 |
| Free Choice Courses | | 18 |
| Thesis | | 18 |
| Stage (Mandatory) | | 6 |

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