PRESENTATION OF THE ICT RESEARCH MASTER DEGREE

Computer Science, Image processing and Medical Imaging

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1. Objectives

Scientific objectives

The research Master in ICT specialized in Computer science, Image processing and Medical Imaging aims at providing the students with a high level training in imaging areas. Imaging is a generic term gathering all the disciplines or techniques allowing image use. These disciplines may be as varied as optics, image processing and analysis, vision, robotics, system architecture, security, authentication of image database, or more generally content retrieval in multimedia objects. These disciplines may be applied in numerous domains such as remote sensing, agronomy, motion analysis, surveillance, medicine, video games and face recognition and identification.

This ICT master degree offers three different pathways around imaging:
- Computer Science (Information systems, distributed systems, image processing and analysis, image synthesis, image information systems),
- Electronics and Instrumentation Engineering (sensors, vision, embedded systems)
- Medical Imaging (X-rays, magnetic imaging, MRI).

Each pathway enables the students to acquire high-level skills in the targeted domain whatever the initial background of the students. The last semester is completely devoted to an internship of minimum 14 weeks in a laboratory, which offers a real opportunity to get familiar with research activities and team working.

Professional objectives

This master’s degree offers two professional tracts. In the first and the most important tract, the students can pursue their curriculum by completing a PhD in a university or a research institute laboratory, or in a research department of a company. In the second track, they can directly join a company in which they can make the most of their skills in imaging.

The application areas of research in image are numerous. One can for example include:

- Quality control by image analysis (analysis of defects in industrial products, ...),
- Image processing and Analysis (different applications fields)
- Biomedical Engineering (MRI, nuclear medicine, ...),
- Astrophysics (radio telescopes, ...),
- Geophysics, agriculture (Remote Sensing, ...),
- Geographic Information Systems and images,
- Security (identification, surveillance, supervision,...)
- heritage management,
- Applications linked to the vision and 3D (line robots, virtual reality, ...),
- Interpretation of images (content-based retrieval in the medical context, cultural, ..).

2. Presentation of teaching units and educational modalities (in the second year – S3 and S4)

Three different options are offered: Computer Science, Image Instrumentation and electronics, and Medical Imaging.

Three modules are proposed in each option. The student’s curriculum is composed of 5 modules chosen amongst 8 modules.

Each student must choose a main option and has to constitute his curriculum as follows:
- 1 compulsory module "Initiation to Research and Communication" which is followed by all the students.
- 2 compulsory modules of specialization in the main option of the curriculum.
- 2 modules chosen amongst 6 modules (from the two other options).

### OPTIONS

<table>
<thead>
<tr>
<th>Computer science</th>
<th>Instrumentation - Electronics.</th>
<th>Medical Imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c) CM1</td>
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<td></td>
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<tr>
<td>(c)</td>
<td>CS1 – CS2</td>
<td>IE1 – IE2</td>
</tr>
<tr>
<td>(o)</td>
<td>CM2 – Ml3 – IE1 – IE2 – Ml1 – Ml2</td>
<td>CM2 – Ml3 – CS1 – CS2 – Ml1 – Ml2</td>
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(c) : compulsory
(o): optional

CM1: Initiation to Research and Communication
CM2: Image processing
CS1: Combinatorics and Information Systems
CS2: Image computing
IE1: Sensors and vision
IE2: Multispectral imaging for industrial applications
MI1: Psychophysics of vision, X-ray and ultrasound imaging
MI2: RMN, scintigraphy
MI3: Dynamic imaging

3. Description of the teaching units (modules)

1. Module CS1: Combinatorics and Information Systems

The aim of this module is to introduce the most recent theoretical methods and practical techniques for modelling and processing information and data structures. Modelling information is a fundamental problem in computer science (especially in databases or artificial intelligence). Different model types will be considered. They will be compared in terms of goals, relevance and involved tools. We will focus on logical models (deductive languages based on rules, logical/Object Oriented languages, languages based on logical description), half-structured models (RDF, OEM) and graph-based approaches (conceptual graphs).

A particular attention is paid to the manipulation of trees since image is a common denominator to the master. Some very recent algorithms for random and exhaustive object generation are presented, as well as ranking algorithms for data compression. The second part of the module introduces content-based retrieval methods from image databases. This part articulates itself around methodologies for analysis and image retrieval, techniques for data management and distributed environments.

**Combinatorial algorithms:**

*Algorithm complexity*
- Asymptotic analysis
- Randomized algorithms
- CAT algorithms

*Generating algorithms*
- Exhaustive generation
- Ranking algorithms
- Unranking algorithms
- Random generation
Applied combinatorics
- Hashing techniques and Gray codes
- Combinatorial graphs
- Text algorithms

Information systems:
- Image representation models
- Indexing and storage structures
- Image indexing
- Content-based retrieval images
  - Semantics-based image retrieval
  - Feature-based image retrieval
- Image database management systems
  - Data modelling
  - Query language
  - Visual language
- Multimedia database management systems
- Image management in distributed and interoperable environments

2. Module CS2: Image computing
This module introduces the main elements for image computing. It consists of two parts:
The first part deals with the basic methods for constructing 3D models: elements of geometric modeling and computer graphics.
Key elements:
- Faceted representation and meshes:
  - Data structures: Winged-edge and half-edge structures, maps, atlases
  - Consistency: Mesh topology and verification operators
  - Simplification (traditional algorithms for dynamic simplification and decimation)
  - Compression (wavelets, etc ...)
  - Visualization (with specific algorithms)
  - Conventional clouds of 3D point reconstruction to 3D triangulations, alpha shapes, balloons,
  - Surface interpolation and approximation

The second part concerns the elements of image analysis:
- Pattern Recognition,
- Markovian approach,
- Inverse Problems,
- Optimization algorithms,
- Multiresolution analysis,
- Evolutionary algorithms for image analysis.

3. Module IE1: Sensors and vision
CCD imaging arrays
Photometric and radiometric quantities
Architecture of linear and bi-dimensional CCD arrays
CCD array performance.
CCD cameras.
Camera operation. Video formats.
Camera performance. Camera dynamic range.
Modulation transfer function.
Imaging systems. Use in Astronomy. Low-light level cameras. Spectroscopy
Imaging of fast moving objects. Biomedical applications. Endoscopic imaging.

4. Module IE2 : Multispectral imaging for industrial applications
The aim of this module is to present the different steps involved in color/multispectral images acquisition, processing/analyzing and how their exploitation in different applications

Syllabus of the module:
Color and multispectral imaging in proximate context
Introduction to radiometry and photometry
Color image formation
Computational theories of color imaging
Demosaicing
Color constancy
Segmentation and quality evaluation
Multispectral imaging
Principles of acquisition systems
Reflectance estimation algorithms
Color and reflectance as attributes of analysis
Quality control
Pattern recognition

5. Module MI1: Psychophysics of vision, X-ray and ultrasound imaging
Head: F. Brunotte ECTS credits: 6 duration (lectures: 40h)
Objectives: The first part of the module aims to familiarize the user and the producer of images in terms of perception of the human eye and to show participants the need to take into account the physical and physiological characteristics of the eye for choices to be made in the representation and interpretation of images from all sources. The second part deals with various medical imaging modalities using X-rays and ultrasound. The purpose of this second part is to provide the foundations of physics necessary for the implementation of these imaging techniques. The section on X-ray treats reconstruction from projections (including filtered back projection) used in CT.
Psychophysics of vision. 12 hours. Teacher: François Brunotte
MR spectroscopy. 3:hours Teacher: Paul Walker
Post-processing of cardiac images. 3 hours Teacher: Alain Lalande
Radio pharmaceuticals. 3 hours Teacher: Mr.
X-Ray Scanner. 4 hours. Teacher: Sebastien Aubry
Physics of ultrasound. Thermography 10 hours. Teacher: Philippe Nardin
Ultrasound. Doppler.5 hours Teacher: Sebastien Aubry

6. Module MI2: NMR, Scintigraphy
The physical principles of MRI taught in this course. In the first part will discuss the concept of nuclear magnetism, the phenomenon of magnetic resonance, relaxation phenomena tissue contrast in T1, T2 and proton density, the basic spin echo sequence, sequence of events and acquisition time. In a second part will be addressed spatial encoding and reconstruction of image, k space, the factors of image quality, fast imaging, flow phenomena and MR angiography
tissue suppression techniques, MRI artifacts and functional imaging. At last will be considered MR instrumentation, practical Imaging modalities and the basis for image
interpretation.
NMR
TEP Imaging. Rear projection and tomographic reconstruction
Gamma Imaging.

7. Module MI3: Dynamic imaging
This module aims to present the sensors and cameras that are suitable for analyzing the real
time motion of objects.
Sensors and cameras CCD-CMOS for fast image acquiring.
Camera performance.
Camera dynamic range
Algorithms for dynamic image analysis.
Embedded systems for dynamic image analysis.

8. Module MC1: Initiation to research and communication
In this module, seminars are proposed to the student. A large part of this period is dedicated to
personal work in order to prepare the final project which will take place during the second
semester. A state of art on the final domain is to be set up.
The second part of the module consists on lesson on communication. The aim is to provide
the students with the skills to write a research or technical and oral presentation. At the end of
the semester, the students must submit a report and make an oral presentation (in French) of
their work.

9. Module MC2: Image processing
The goal of this module is to introduce the students to the basic methods in signal and image
processing. The first part presents the basics in signal processing. The second part deals with
the basics in computer graphics. Then, the third part tackles the methodology of image
processing, with a priority for practical works. Finally, the last part shows some applications
of image processing in medical imaging and agronomy.
Main items:

- **Signal Processing**
  - Signals
  - Filtering (analog, digital)
  - Fourier transform
  - Wavelet transform

- **Fundamentals of computer graphics**
  - Basic items in geometric modelization (facet, CSG, implicit and parametric surfaces)
  - Basic items for visualization (empiric models, ray tracing)

- **Fundamentals of image processing**
  - Visual perception (reflection, color systems), image acquisition systems: smattering of optics, camera principle, distortions
  - Digital image (pixel, kinds of image, coding)
  - Basic processing (histogram, arithmetic, logic and geometric operations)
  - Image enhancement by filtering and boundary detection
  - Image segmentation by thresholding: area and boundary approaches
  - Mathematic morphology (erosion, dilation, opening, closing)
  - features and evaluation for image quality
Applications
- Image processing for agronomy scope
  - Motion estimation and particle tracking
  - Analysis of color texture
  - Fast imaging
- Non-conventional imaging applied to light/tissue interaction (lectures: 6h)
  - Definitions (multispectral imaging, hyperspectral cube, reflectance)
  - Optical properties of pathological cells compared to healthy ones
  - Application to dermatology: from dermoscopy to multispectral imaging
  - Application to gastroscopy: narrow band imaging

Distribution of credits
Regular courses include lectures and laboratory assignments. A total of 30 credits must be validated in each semester.

**Third semester**

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<th>Name</th>
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<td>Multispectral imaging for industrial applications</td>
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Fourth semester

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<tr>
<td>internship</td>
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<td>TOTAL S2</td>
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Initiation to the research/Oral presentation

- yes □ no

Duration: 10 weeks (partial time)

Period: October 15 – January 15

Internship - second semester

- yes □ no

Duration: >14 weeks

Period: March – September

3. International partners

Numerous universities are partners in the framework of this Master either for setting up a double degree convention or for student exchanges. Visiting professors and teachers of the partner universities will be involved in the Master2 ICT modules according to their specialty during their visits in Dijon or by videoconferences for seminars. International students of the Master will be mainly selected by our partners, which will ensure excellence in recruitment.

For the double degree, the students must attend classes in Dijon during the first semester, and return in their country in a local laboratory for the internship during six months. They can apply for a mobility grant from the Regional Council during this period.

<table>
<thead>
<tr>
<th>Country</th>
<th>University</th>
<th>Local correspondent</th>
<th>Type of convention</th>
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<tbody>
<tr>
<td>Brazil</td>
<td>Sao Paolo University</td>
<td>Agma J.M. Traina</td>
<td>Partnership</td>
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<tr>
<td>Japan</td>
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<td>Hiroshi Ishikawa</td>
<td>Partnership</td>
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<td>Lebanon</td>
<td>Université des Antonins</td>
<td>Fadi Fadel</td>
<td>Double degree</td>
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<td>Peru</td>
<td>San Pablo Catholic University</td>
<td>Ernesto Cuadros-Vargas</td>
<td>Partnership</td>
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<td>Italy</td>
<td>University of Milan</td>
<td>Ernesto Damiani</td>
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<td>China</td>
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<td>Thailand</td>
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<td>Asanee Kawtrakul</td>
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<td>Belgium</td>
<td>Université Libre de Bruxelles</td>
<td>Peter Schelkens</td>
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<td>Cameroon</td>
<td>University Yaoundé I</td>
<td>Tonye Emmanuel</td>
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<td>University Cady Ayyad</td>
<td>Aziz El Fazzikki</td>
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<td>Norway</td>
<td>Gjovick University College</td>
<td>Jon Hardeberg</td>
<td>Partnership</td>
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<td>Turkey</td>
<td>University Galatasaray (anglophone – )</td>
<td>Tankut Acarman</td>
<td>Double degree</td>
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<tr>
<td>Algérie</td>
<td>University of Biskra</td>
<td>Kamal Melkhemi</td>
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<td>Ethiopia</td>
<td>University Addis-Abeba</td>
<td>Solomon</td>
<td>Partnership</td>
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