TRAINING OFFER

PRESENTATION OF THE ICT RESEARCH MASTER DEGREE

Computer Science, Image processing and Medical Imaging

Head of the Master

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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			
	Computer science	Instrumentation - Electronics.	Medical Imaging
(c)	CM1		
(c)	CS1 – CS2	IE1 – IE2	MI1 – MI2
(o)	CM2 – MI3 – IE1 – IE2 - MI1 – MI2	CM2 – MI3 – CS1 – CS2 – MI1 – MI2	CM2 – MI3 – CS1 – CS2 – IE1 – IE2 -

(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.

Spectral response. Responsivity. Noise level. Signal-to-noise ratio.

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, distorsions
  - 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

Unit	Name	Credits	Head of the module	Total number of hours
CS1	Combinatorics and Information Systems	6	J. Pallo	50
CS2	Image computing	6	A. Dipanda	50
IE1	Sensors and vision	6	P. Gouton	50
IE2	Multispectral imaging for industrial applications	6	A. Mansouri	50
MI1	Psychophysics of vision, X-ray and ultrasound imaging	6	F. Brunotte	50
MI2	NMR, scintigraphy	6	Kasthler	50
MI3	Dynamic imaging	6	M. Paindavoine	50
CM1	Initiation to research and communication	6	N. Vassilief	50
CM2	Image processing	6	F. Marzani	50
TOTAL S1		30		250

Fourth semester

Name	Credits	Period
Research internship	30	March - September
TOTAL S2	30	

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.

Country	**University**	**Local correspondant**	**Type of convention**
Brasil	Sao Paolo University	Agma J.M. Traina	Partnership
Japan	Shisuoka University	Hiroshi Ishikawa	Partnership
Lebanon	Université des Antonins	Fadi Fadel	Double degree
Perou	San Pablo Catholic University	Ernesto Cuadros-	Partnership
Italy	University of Milan	Ernesto Damiani	Partnership
China	University Jiathong Shanghai	Ma Yinghua	Partnership
Thailand	Kasetsart University	Asanee Kawtrakul	Double degree
Belgium	Univerté Libre de Bruxelles	Peter Schelkens	Partnership
Cameroon	University Yaoundé I	Tonye Emmanuel	Double degree
Morocco	University Cady Ayyad	Aziz El Fazzikki	Partnership
Norway	Gjovick University College	Jon Hardeberg	Partnership
Turkey	University Galatasaray (anglophone –	Tankut Acarman	Double degree
Algéria	University of Biskra	Kamal Melkhemi	Partnership
Ethiopia	University Addis-Abeba	Solomon	Partnership