**** Title ****
Formal and Hybrid Methods for Medical Imaging (MIM)

**** CFU ****
6 [complementary]

**** Learning outcomes ****
The aim of the course is to introduce the theoretical and practical grounds of medical imaging, with a focus on the use of formal / declarative, and hybrid methods for dataset-oriented medical image analysis in a hands-on, application-directed manner. The basics of classical imaging, including programming, and the use of specific libraries, will be described, to provide the required knowledge of the application domain, and better understand the technical aspects of the remaining part of the course. State-of-the-art methods at the frontier between research and applications, such as formal/declarative methods, and in particular spatial logic and spatial model checking, will be learnt. It will be discussed how formal approaches can complement, through their role in the elicitation of domain knowledge, systems based on machine learning, some of which will be examined, from an application point of view but also in their interaction with classical methods and including the due professional and ethical considerations.

At the end of the course, the student will be able to use state-of-the-art techniques and tools for image analysis in the medical field, in particular: traditional programming via dedicated libraries; novel formal/declarative methods; and some machine learning-based approaches. The student will also have acquired a greater awareness of the importance of complementing declarative and machine learning-based methods, as well as a deeper understanding of the implementation of imaging tools, including the peculiarities of the health care domain.

**** Syllabus ****
The course is based on lectures and laboratory sessions. The lab exercises make it possible to test the group's awareness of the importance in practice of the topics covered during the course, while the oral test, if any, assesses the individual's ability in the general framing of the specific.

Basics of medical image analysis
- Digital images
- Medical images, typology and peculiarities
- Digital topology, digital morphology, connected components, segmentation.

Programming for Medical Imaging
- File formats
- ITK/SimpleITK and OpenCV libraries
- Medical Imaging exercises in Python

Declarative image analysis
- Introduction to formal methods and model checking
- Spatial logic for images
- The spatial model checker VoxLogicA
- Declarative image analysis exercises

Machine learning and hybrid AI
- General considerations and ethical / professional aspects

- A fully automatic neural network dedicated to image segmentation
- Exercises on the joint use of VoxLogicA and neural networks

Course organization & Assessment

- Lectures: 75%
- Laboratory/practice: 25%

The exam consists of a written/practical exam, and possibly an oral test, with the aim of ascertaining that the student has acquired sufficient familiarity with the various state-of-the-art techniques for computerized analysis of medical images. The tests are intended to ascertain that the student has acquired sufficient familiarity with the basic concepts of programming analysis methods and the use of formal methods.

**** Prerequisites ****

Some basic knowledge of propositional logics and programming.