Chapter 1

THE ANALYSIS OF MEDICAL IMAGES

Introduction

- Medical images are different from other pictures- depict distributions of **various physical features measured from the human body.**
- They show attributes that are otherwise inaccessible- as a part of the clinical workflow.
- **Concepts, Notions, and Definitions Introduced in this Chapter**
- › Introduction to basic development strategies;
- › Common analysis tasks: delineation, object detection, classification;
- › Image analysis for cohort studies, clinical studies, diagnosis support, treatment planning, and computer-assisted therapy;
- › Tool types: viewers, workstation software, development tools.

Medical Images Vs Photography

- Medical images differ from photography in many ways.
- Common problems that have to be solved are:
- detect certain objects (e.g., persons). to recover the 3d information, i.e., missing depth information and the true shape,
- separate illumination effects from object appearance,
- to deal with partially hidden objects, and to track objects over time.

Analysis for a photography are based on a detection or tracking task

Medical Images Vs Photography

- Medical images are different.
- The appearance of the depicted object is not caused by light reflection but from the absorption of X-rays.
- Although detection of some structure may be goal of the analysis, exact delineation of the object and its substructures may be the first task.
- Variation of object shape and appearance may be characteristic for some evaluation and needs to be captured.
- Focus on analysis methods for medical images is different if compared to the analysis of many other images.
- **Delineation, restoration, enhancement, and registration for fusing images from different sources** are comparably more important than classification, reconstruction of 3d information, and tracking.

Analysis of medical images

- Computer-assisted analysis of medical images is meant to support an expert (the radiologist, the surgeon, etc.) in some decision task.
- It is possible to **associate analysis tasks to the kind of decision** in which the expert shall be supported.
- • Delineation of an object requires solving a segmentation task.
- • Detection of an object requires solving a classification task.
- • Comparison of object appearance from pictures at different times or from different modalities requires solving a registration task.

Different tasks in medical image analysis

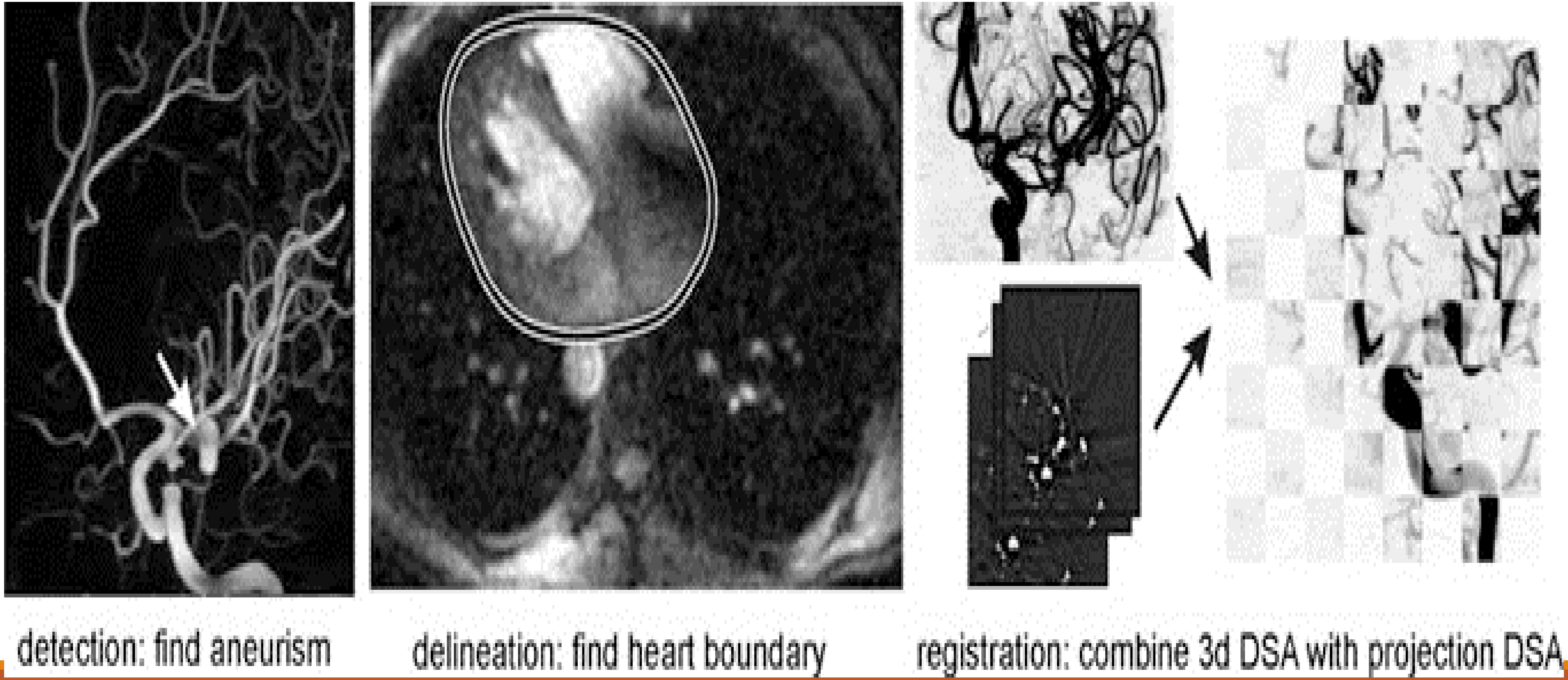


Image analysis - understanding

Before deciding on the kind of methodology that is needed, it is important to understand the technical questions associated with the practical application. Several aspects need to be discussed:

- Analysis in the clinical work flow: How does the analysis fit into the clinical routine within which it has been requested?
- Strategies to develop an analysis tool: How can it be assured that an efficient and effective solution has been chosen?
- Acquisition of necessary a priori information: What kind of information is necessary to solve the analysis task and how can it be acquired?
- Setup of an evaluation scenario: How can the quality of the analysis method be tested?
- Tools to support an analysis task: How can tools be used to spend as little effort as necessary to solve the analysis task?

Image Analysis in the Clinical Workflow

- The developer will not only have to create the method but also needs to provide environment in which the method can be applied. The type of environment depends on the problem that has to be solved. At least **five different scenarios** can be Differentiated:
- For a **clinical study,** images are analyzed outside a clinical routine task to understand or confirm findings based on images. In this case, images that are part of the study are often copied to some workstation where the study is taking place.
- large cohort studies in epidemiology: Analysis methods should be largely automatic since the number of subjects is very large.
- For diagnosis support (computer-aided detection, computer-aided diagnosis), single cases which may consist of several studies containing images are analysed on a medical workstation. Diagnosis support systems often involve interaction.
- Analysis in treatment planning precedes treatment.
- Image analysis for computer-assisted surgery

Table 1.1 Different scenarios for computer-assisted image analysis have very different requirements

	Cohort study	Clinical study	Computer aided diagnosis	Treatment planning	Computer-assisted surgery
No. of cases	Very large	Large	Small	Small	Small
Time-constraints	Low	Low	Medium	Medium	High
Location	Anywhere	Anywhere	Office, reading room	Office, ward	Operating room
Interaction	Not acceptable	Not acceptable	Acceptable	Acceptable	Acceptable
Archival requirements	Very high	High	High	Medium	Medium

Description Details

- Reviewing underlying assumptions for an analysis method later helps to identify sources of error. Such description should contain the following information:
- • Description of the images on which the analysis is performed, i.e., kind of images, technical parameters.
- • Description of the patient group on which the analysis is performed.
- • All image features that are used for the analysis method, including any assumptions about reliability of the features.
- • All a priori information that is used as domain knowledge to perform the analysis.

Using Tools

- Fortunately, developing an analysis method does not mean that everything has to be created from scratch. Different types of software greatly support speedy development:
- • viewer software
- • analysis software
- • rapid prototyping software
- • software libraries

An extensive list of free software (either open source software or at least free to use for academic and/or educational purposes) to view, export, analyze, and transfer images is found at **https://www.idoimaging.com.**

Viewer Software

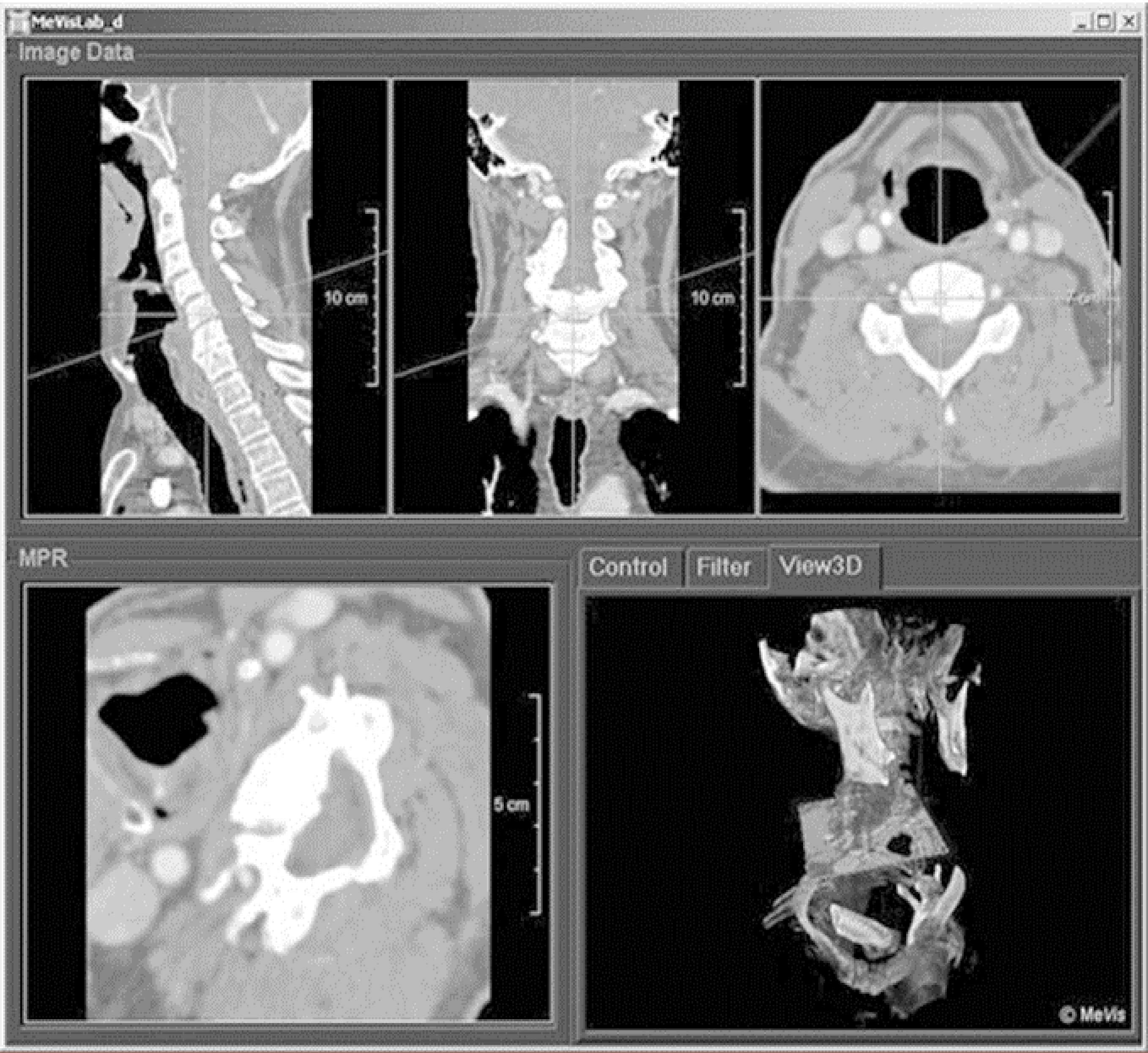
- Useful for :
- way of accessing and looking at the image data,
- it helps to get a first impression on the kind of data,
- to organize a small data base on which the development of an analysis method is based, and
- to discuss the problem and possible solutions with the data expert.

- The free MicroDicom viewer (www.microdicom.com) allows viewing DICOM images and simple operations such as annotations and some filtering operations

Viewer Software

Analysis software

- Analysis software is different from viewer software in that it is intended to provide the user with a set of **parameterizable analysis modules**
- that perform different steps of image analysis ranging from image enhancement methods to segmentation, registration, or classification tools.
- An example for such analysis software is **MevisLab**, which exists in a commercial and a non-commercial version.
- suitable to solve some specific problem using an intuitive graphical user interface

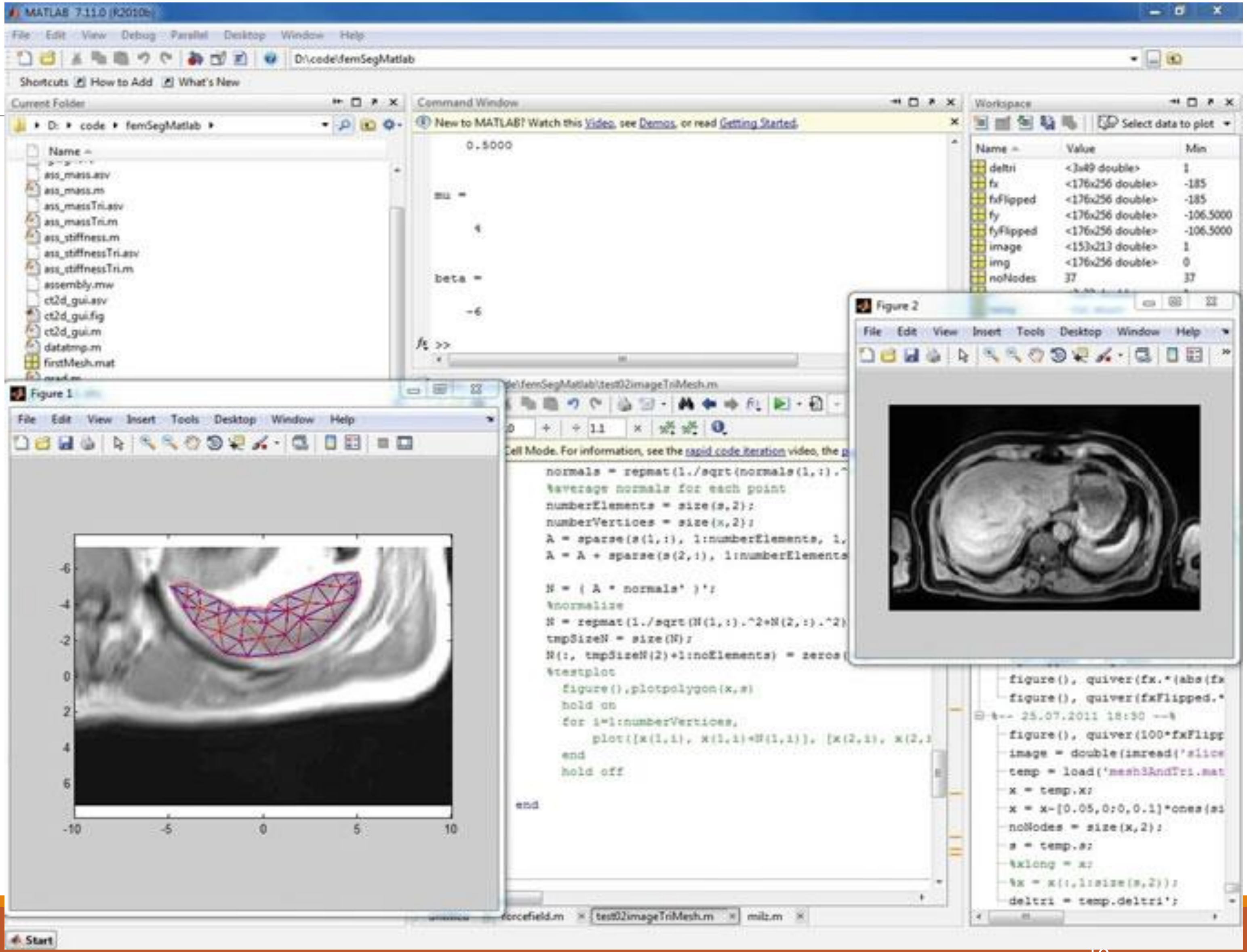


3D Slicer

- An open source software for segmentation, registration, and other analysis methods for medical images is 3D Slicer, **www.slicer.org** (Fedorov et al. 2012).
- 3D Slicer is an open platform with many contributors adding modules.
- Similar to MevisLab, it provides the user with user interfaces for a variety of modules that can be carried out stand-alone or combined to form a processing pipeline.
- Different to MevisLab, modules are rather high-level (e.g., a registration module), and it thus does not provide a tool for combining low level submodules to arrive at a new high-level module.

Rapid prototyping programming language

- rapid prototyping programming language such as **MATLAB or IDL.**
- These are interpreter languages that are geared toward rapidly processing arrays.
- It makes them particularly suitable to be used for working with 2d and 3d image arrays.



Software Libraries

- For analysis tasks in medical imaging, mainly two environments are of interest: **OpenCV and ITK**.
- OpenCV started its life to promote Intel's chips by providing an extensive and fast image processing library for Windows and Intel chips. OpenCV is intended to support general image processing and computer vision tasks. Input is assumed to consist of one or several 2d images.
- Analysis can be almost anything in the field of computer vision including, image enhancement, segmentation, stereo vision, tracking, multi-scale image analysis, and classification.
- For medical image analysis its **main disadvantage is processing of 3d or 4d scenes is not supported.**
- This is different for ITK (Insight Toolkit), which focuses on segmentation and registration of medical images.
- it also contains plenty of auxiliary methods for accessing and enhancing images. Furthermore, registration methods not included in OpenCV for rigid, and non-rigid registration are part of the software. Segmentation, which plays a much bigger role in medical imaging compared to the analysis of other images, is extensively covered by including state-of-the-art methods.