MPHY0030: Programming Foundation for Medical Image Analysis

Teaching Plan (2021/22)

Syllabus

Part 1 (10%) Introduction to Python programming (Dr Min Zhe)

- Python overview
- Datatypes and data structures

  Native datatypes, string, lists, tuples, comprehensions
- Flow controls and iterators

  Conditions, loops, iterators and iterables, generators
- Object-oriented programming

  Scripts, Functions, Classes, Modules, Packages, Objects, Inheritance, Polymorphism
- Standard library

  os, sys, argparse, re, random, math, time, threading, zipfile

Part 2 (10%) Scientific computing with Python

- Development tools
  - Python IDEs, editors, development and debug
  - A brief introduction to software development, versioning and testing
  - Medical image visualisation tools
- Numerical computing and software
  - Interpreted programming language, parallel computing
  - Scripts and functions
  - Data types, strings, numerical data types
  - Memory still matters, allocation, yield
  - Numerical optimisation
  - A brief introduction to good programming practice, style and documentation
  - Using existing libraries, NumPy, SciPy, open source code
- Working with matrices and arrays
  - Arrays and matrices, indexing, vectorisation, loops (list comprehension),
  - Matrix arithmetic, linear algebra
  - Other data structures

Part 3 (60%) Medical image analysis

- Format and visualisation
  - Image types, file format, file IO, and higher-dimensional medical images
  - Intensity, contrast, image size and voxel size,
  - Image patches, masks and volume rendering
  - A brief introduction to graphic user interface (matplotlib, slicer…)
- Basic processing
  - Image statistics, intensity normalisation, cropping, padding

- Intensity mapping and histogram equalisation
- Morphological operations

- Filtering
  - Filtering with convolution, denoising, edge detection, scale space
  - Filtering in frequency domain
  - Image smoothing
  - Image restoration and enhancement
  - Local feature detection, linear and nonlinear edge detection
  - Hessian-based local structure detection
- Coordinate transformation
  - Spatial transformation and resampling, anatomical planes, scanner, image and homogenous coordinates, projecting, inverting, composing
  - Cropping, padding, re-sizing and Re-slicing
  - Conversion between image, physical and other (e.g. tracking) coordinates
  - Non-orthogonal transformation, e.g. polar, spherical and tracking
  - Other spatial transformation (*see registration)

- Segmentation
  - Manual segmentation
  - Intensity classification, e.g. threshold, region growing and clustering
  - Boundary searching methods, e.g. Statistical shape models, snakes and level sets
  - Registration-based atlas
  - Convolutional neural networks
  - Medical image segmentation validation

- Registration
  - Image alignment and fusion
  - Spatial transformation models
  - Similarity measures
  - Optimisation-based registration algorithms
  - Deep-learning-based registration algorithms
  - Medical image registration validation

- Related subjects
  - Introduction to computer graphics, point sets and meshes,
  - Introduction to machine learning applications, classification, regression and unsupervised clustering
  - Introduction to clinical applications, disease diagnosis, treatment monitoring and longitudinal analysis

Part 4 (20%) Topics in medical image analysis (guest lectures)

- Spatial transformation and resampling (Adria Casamitjana)
- 3D Slicer (Zac Baum)
- Parallel computing (Qianye Yang)
- Advanced applications (Fernando Perez-Garcia)

Hands-on tutorials

- Three-dimensional image filtering
- Maximum intensity projection
- Iterative closest point algorithm
- Augmented reality on medical images