# Image Processing and Analysis

# Syllabus

Prepared by Prof. Oge Marques, PhD, Professor of Engineering and Computer Science at   
Florida Atlantic University - <http://www.eng.fau.edu/directory/faculty/marques/>

**Catalog description:**

Image processing and analysis principles, tools, techniques, and algorithms, with emphasis on latest developments in image processing and analysis using deep learning networks and algorithms. Use of image processing software tools (MATLAB® and selected toolboxes) for lab assignments and projects.

**Prerequisites**: This course can be taught as a senior undergraduate elective or a first-year graduate-level course. It does not require prior exposure to signal analysis, signal processing, image processing, or computer vision. It does, however, expect that students are capable of programming using a high-level language.

**Course objectives**:

By the end of the course students will be able to:

* Explain the main challenges behind the design of image processing and analysis solutions.
* Gain proficiency using MATLAB and its associated toolboxes to perform a wide variety of image processing and analysis techniques.
* Understand commonalities and practical differences between various image processing and analysis methods.
* Contextualize the latest advances in deep learning and their impact on the advancement of image processing and analysis.
* Become more discriminating in their assessment of published results in the field of image processing and analysis and related areas.

**Required materials:**

**Textbook:**

“**Practical Image and Video Processing Using MATLAB**”   
Oge Marques   
Wiley/IEEE Press, 2011   
ISBN-10: 0470048158 | ISBN-13: 978-0470048153

**Reference books:**

“**Image Processing Recipes in MATLAB**”   
Oge Marques and Daniel Zysman

(*to appear*)

**Access to MATLAB** (see details on next page)

**Course outline**:

1. Introduction to image processing and analysis
   * Basic concepts and terminology
   * Typical image processing and analysis workflow: before and after deep learning
   * Examples of techniques and applications
2. Image processing fundamentals
   * Elements of visual perception
   * Light, color, and the electromagnetic spectrum
   * Image sensing, acquisition, sampling, quantization
   * Digital image representation
   * Review of mathematical tools used in image processing and analysis
3. MATLAB and relevant toolboxes
   * MATLAB basics
   * Image Processing Toolbox
   * Computer Vision Toolbox
   * Statistics and Machine Learning Toolbox
   * Deep Learning Toolbox
   * Basic image manipulation using MATLAB
4. Geometric operations
   * Image scaling, re-sizing, cropping, flipping, and rotation
   * Affine transformations and image remapping
5. Intensity transformations
   * Intensity transformation functions
   * Using look-up tables (LUTs) for image processing
   * Adjusting contrast and brightness (including gamma correction)
   * Leveling non-uniform illumination
6. Summary statistics of images and histogram processing
   * Histograms and statistics of grayscale images
   * Histogram equalization
   * Histogram matching
   * Computing and displaying histograms of color images
   * Finding the dominant color in an image
7. Image filtering and enhancement
   * Image smoothing (low-pass filters)
   * Image sharpening (high-pass filters)
   * Combining image processing methods into a pipeline
8. Deep Learning basics
   * Artificial neural networks (ANNs): basic concepts
   * Training deep networks: cost functions, optimization, backpropagation
   * Improving deep networks: regularization, data augmentation, batch normalization, dropout
   * Deep Learning and computer vision: overview of architectures, applications, and success stories
   * Deep Learning in MATLAB
9. Image denoising
   * Noise models
   * Noise reduction using spatial-domain techniques
   * Image denoising using deep learning techniques**[[1]](#footnote-1)**
10. Color image processing
    * The psychophysics of color
    * Color models and conversion
    * Pseudocolor image processing
    * Color image smoothing and sharpening
    * Automatic image colorization
11. Image segmentation
    * Global and adaptive thresholding
    * Region-based segmentation
    * Segmentation using active contours
    * Semantic image segmentation using deep learning
12. Global feature detection and extraction
    * Boundary feature descriptors
    * Region feature descriptors
13. Local feature detection, extraction and matching
    * SIFT (Scale-Invariant Feature Transform)
    * SURF (Speeded Up Robust Features)
    * Corner detection using Harris–Stephens algorithm
    * HOG (Histogram of Oriented Gradient)
    * LBP (Local Binary Pattern)
    * Feature point matching
    * Bag of Visual Words representation
14. Image classification
    * Traditional pipeline (using hand-crafted feature extraction)
    * Image classification using CNNs
    * Transfer learning
15. Applications, case studies, and ongoing research topics
    * Single image super-resolution using deep learning
    * Visual style transfer
    * Biomedical image classification
    * Generating images using GANs
    * Image annotation tools and applications

**Weekly schedule[[2]](#footnote-2)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Week** | **Topic** | **Required reading** | **Assignments** |
| 1 | 1 | Textbook – Chapter 1 |  |
| 2 | 2 | Textbook – Chapters 2, 5, and 6, and Appendix A |  |
| 3 | 3 | Textbook – Chapters 3 and 4  Reference book – Recipes 1-4  MathWorks "MATLAB Onramp" | A1 out |
| 4 | 4  5 | Textbook – Chapter 7  Reference book – Recipes 5-6  Textbook – Chapter 8  Reference book – Recipes 11-14 | A1 due  A2 out |
| 5 | 6 | Textbook – Chapter 9  Reference book – Recipes 7-10 | A2 due  A3 out |
| 6 | 7 | Textbook – Chapters 10 and 11  Reference book – Recipes 15-16 |  |
| 7 | 8 | MathWorks Deep Learning eBooks  MathWorks " Deep Learning Onramp" | A3 due  A4 out |
| 8 | 9 | Textbook – Chapter 12 |  |
| 9 | 10 | Textbook – Chapter 16  Reference book – Recipes 25-28 | A4 due  A5 out |
| 10 | 11 | Textbook – Chapter 15  Reference book – Recipes 17-19 | A5 due  Term Project out |
| 11 | 12 | Textbook – Chapter 18  Reference book – Recipes 20, 21, 24, 35-36 |  |
| 12 | 13 | Reference book – Recipes 37-42 |  |
| 13 | 14 | Textbook – Chapter 19 | Exam |
| 14 | 15 | N/A | Term Project due |

**MATLAB access**

This course is MATLAB-oriented, and you are expected to have frequent access to a computer running MATLAB and some of its toolboxes for your assignments and projects.

* Essential toolboxes include: *Image Processing Toolbox*, *Computer Vision Toolbox*, *Statistics and Machine Learning Toolbox*, and *Deep Learning Toolbox*.
* Optional (but recommended) toolboxes include: *Image Acquisition Toolbox*, *Signal Processing Toolbox*, and *Bioinformatics Toolbox*.

Here are two **options** to consider:

1. **Purchase your own copy** of the student version of MATLAB.   
   For more details, go to: <http://www.mathworks.com/academia/student_version/>
2. **Use your university's Campus-Wide** **MATLAB license**.   
   Follow the instructions at <https://www.mathworks.com/academia/tah-support-program/eligibility.html> to check if your school has a Campus-Wide License.

**Assessment summary:**

* Five (5) MATLAB-based hands-on assignments (5 x 10%): 50%
* Exam: 20%
* Term project[[3]](#footnote-3) (MATLAB code + report): 30%w

# Additional notes for instructors

The proposed syllabus attempts to reflect the state of the art in digital image processing and analysis "in the deep learning era".

Consequently, it combines traditional topics with contemporary approaches to several tasks, notably image classification, image denoising, and semantic image segmentation.

Assignment components listed above have been suggested based on my experience teaching these materials. Other graded items (depending on the course duration and format) could include paper summarization, oral presentations, participation (in class or online discussion boards), etc.

The total number of assignments (and their complexity and scope) may, of course, be adjusted by the instructor.

Exams, quizzes, and/or tests are highly recommended to gauge the theoretical and conceptual understanding of the material.

Possible topics for the Term Project include[[4]](#footnote-4):

* Single image super-resolution using deep learning
* Skin lesion classification
* Image classification: cats vs. dogs
* Object detection
* Visual style transfer
* Scene classification
* Data augmentation in image classification

1. Selected topics for which Dr. Marques has prepared slides, MATLAB scripts, and associated assignments, appear underlined. [↑](#footnote-ref-1)
2. Suggested schedule for a regular (14-week) semester [↑](#footnote-ref-2)
3. Topic should be chosen from a list provided by the instructor. [↑](#footnote-ref-3)
4. In a separate document, I provide additional resources for the first three topics in this list. [↑](#footnote-ref-4)