MATLAB Expo 2018 – Munich

MATLAB for Engineers @ Universities
From the Basics to the Professionalized Use in Research & Industry

Manuel Stich
Goal of the MATLAB Course

“Develop a 3 days course for engineering studies which should support the content of lectures in the fields of science, research and (medical) engineering.” (as an introduction and as further preparation)
Goal of the MATLAB Course

MATLAB Course

MATLAB Basics + MATLAB Applications in Engineering
Key Features

a) Applications: Exercises, integration in research projects
b) Interdisciplinarity: Eligible to a broad spectrum of studies
c) Future potential: Online learning!
Interdisciplinarity

Engineering Studies

- Electrical Engineering
- Mechanical Engineering
- Applied Computer Sciences

- Medical Engineering
- Environmental Engineering
- Industrial Engineering

- Plastics Engineering
- Industry 4.0 Informatics
- Geoinformatics
Interdisciplinarity
Interdisciplinarity

Intersection

- Data Analytics & Data Visualization
- Signal & Image Processing
- Vibrations Theory
- Mobile Sensors
- Neural Networks
Which programming language should we choose?
## Programming Language

<table>
<thead>
<tr>
<th>MATLAB</th>
<th>Python</th>
<th>Wolfram Mathematica</th>
</tr>
</thead>
<tbody>
<tr>
<td>Widely used in research and industry</td>
<td>Widely used programming language</td>
<td>Good documentation</td>
</tr>
<tr>
<td>Provides very cool and useful toolboxes</td>
<td>Inexpensive, free</td>
<td>Only used in academic – week usage in industry</td>
</tr>
<tr>
<td>Best documentation ever!</td>
<td>Lame documentation</td>
<td>$$$, no licenses available</td>
</tr>
<tr>
<td>$$$</td>
<td>Version divergence</td>
<td>Not a gold standard in numerical computing</td>
</tr>
</tbody>
</table>
MATLAB EXPO 2018

Programming Language

Heavily used in research and industry

Provides cool and useful toolboxes

Best documentation ever!

Powerful in numerical computing + MuPAD®

Mathematical syntax, easy for non-programmers

Embedded code generation possible
"As a process engineer I had no experience with neural networks or machine learning. I worked through the MATLAB examples to find the best machine learning functions for our predictive metrology use case. I couldn’t have done this in C or Python—it would’ve taken too long to find, validate, and integrate the right packages."

— Emil Schmitt-Weaver, ASML

„Easy and straightforward introduction in Neural Networks for unexperienced users who want to apply Neural Networks to certain problems in engineering“
MATLAB Course

MATLAB for Engineers @ Universities

MATLAB Basics

MATLAB: a programming language

Applications in Engineering

MATLAB in Research Projects

~10h

~10-12h

~5h

OPTIONAL
MATLAB Course: MATLAB Introduction

MATLAB Basics

▪ First launch: MATLAB IDE and GUI
▪ Variables and value assignment
▪ MATLAB – MATrix LABoratory: Vectors and matrices
  ❖ Examples from linear algebra
  ❖ From command window to MATLAB scripts
▪ Data visualization
  ❖ Data and function plotting
  ❖ Ways to visualize data and create a nice figure for publication
▪ MATLAB Documentation
▪ MATLAB Onramp Course part 1: Ch. 1-7 (in lecture or at home)

Day 1: ~4-5h
MATLAB: a programming language

- Questions concerning the last lecture
- Branching
  - If-else
  - Switch-case
  - Try-catch
- For- and while loops
- MATLAB functions
  - Subfunctions
  - Nested Functions
  - Function Handles
- Debugging
- Exercise: Sinus series expansion
- MATLAB Onramp Course part 2: Ch. 9-12 (in lecture or at home)

Day 2: 5-6h
Getting Help!

Documentation
- Definitions
- Many examples
- Table of content
- Content suggestions
- Offline accessible

Webinars
- Introductory topics
- Application topics
- Weekly updates
- Special webinars for academics

Matlab Central
- Helpful community
- Forum
- Code (file exchange)
MATLAB Course: MATLAB Introduction

Applications in Engineering

- Data Analytics & Data Visualization (5h)
- Signal Processing & Image Processing (4h)
- Theory of Vibration (3h)
- Mobile Sensors (2h)
- Neural Networks (4h)

MATLAB EXPO 2018, Munich
MATLAB Course: Applications

MATLAB: Application in Engineering
Data Analysis & Data Visualization

Data Preprocessing

1. Data import / export
2. Data wrangling
3. Preanalysis, descriptive-preanalysis)
4. Data cleansing
5. Data reduction

Data Visualization

- Histograms
- Scatter-plots
- Box-plots/Whisker-plots

Data Analysis

- Cross correlation/covariance
- Data curve fitting
- Data models

Einführung in MATLAB
MATLAB Course: Applications

MATLAB: Application in Engineering
Signal and Image Processing

DICOM Images
Read “image.dcm” data

Image Enhancement
Sobel-filter: Edge-sharpening

Image Analysis
Segmentation

Properties
SNR
CNR
MATLAB Course: Applications

MATLAB: Application in Engineering
Theory of Vibration

1. Set up DE
   a) \( \frac{1}{C} \cdot Q + R \cdot \dot{Q} + L \cdot \ddot{Q} = 0 \)
   b) \( D \cdot x + y \cdot \dot{x} + m \cdot \ddot{x} = 0 \)

2. Solve DE

Electronics vs. Mechanics

Electronics ↔ Mechanics

\( Q \leftrightarrow x \)
\( 1/C \leftrightarrow D \)
\( R \leftrightarrow y \)
\( L \leftrightarrow m \)
MATLAB Course: Applications

MATLAB: Application in Engineering
Neuronal Networks

Deep Learning

CNN
AlexNet
PRETRAINED MODEL

Object Detection
MATLAB Course: Applications

MATLAB: Application in Engineering
Neuronal Networks

CNN
MyNet
OWN-TRAINED MODEL

Transfer Learning

TRAIN

Training Data

Object Detection

84% BURGER
91% HOTDOG
63% CUPCAKE
MATLAB Course: Applications

MATLAB: Application in Engineering

Neuronal Networks

Deep Learning

- Use of AlexNet
- Pre-trained model
- Working on a high abstraction layer
- ~ 20 lines of code

Transfer Learning

- Own-trained neuronal net
- Choose correct training data set
- Working on a lower abstraction layer

Face Detection

- Combination of pre-trained and own-trained model
- Low abstraction layer
- Application
- ~ 200 lines of code

Complexity
MATLAB Course: Research Project

MATLAB in research projects

• In-vitro investigation on the influence of ionizing radiation on active medical implants (energy range: 50kV – 15MV, realistic application/test set-up).

• Development of a standardized test method for the functional control of AIMDs under the influence of ionizing radiation.

Cooperation partners: MR:comp KLINIKUM ST. MARIEN AMBERG

Supported by:

ZIM Zentrales Innovationsprogramm Mittelstand
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Manuel, Stich
11.04.2018/ 23
MATLAB Course: Research Project

MATLAB in research projects

- Oversensing
- Device resets (to initial state)
- Pulse generator damage
- Damage of lead tissue interface
- Reset to factory programming
- Decrease in pacing amplitude
- Decrease in shock energy (ICD)
- Shock coil failure (ICD)
- Total, catastrophic defect
MATLAB Course: Research Project

MATLAB in research projects

III-RAY
Influence on Implants using Ionizing Radiation
MATLAB Course: Research Project

MATLAB in research projects

Data Acquisition

Data Analysis
MATLAB Course

MATLAB Live Editor

MATLAB Live Script: Lecture 01 (Manuel Stich) Statistics & Data Analytics for Medical Engineering

Study subject: parameters in descriptive statistics & data visualization

In der ersten Einheit beschäftigen wir uns mit der deskriptiven Statistik. Die Präsentationsfolien werden durch dieses MATLAB Live-Skript ergänzt. Dabei unterstützten die Textkommentare die Aufgaben und Übungen in MATLAB.

1. Wichtige deskriptive Parameter

```matlab
clear all;
close all;
clc;

%% Load a new MATLAB sample data set
load carbig
```

- Manuscript and code in one document
- Equation/image/text embedding
- Code sectioning and easy structuring
- Result appear next to code
Digital MATLAB Course

Classroom Training

• All participants must be in the same place at the same time
• All participants should have the same relevant prior knowledge so that general learning progress is not hindered
• The learning pace is not individualizable

E-Learning

• Independent of time and place
• No personal contact between the students and the lecturer
• No discussions possible
Digital MATLAB Course

MATLAB Knowledge Base Environment
Traditional Classroom Training + Online Content

Signal Processing
Image Processing
Statistics
Biomechanics

Classroom Training + Online Content

MATLAB Course

Classroom Training / Online Content

Online for external users

Traditional or online exam
Digital MATLAB Course

Currently integrated subjects

- Mechanics
- Theory of Vibration
- Biomechanics
- Image Processing
- Diagnostic Imaging
- Therapeutical Systems
- Statistics
- Software Engineering
- Pattern Recognition
- Internships
- BA/MA Thesis
- etc.
Digital MATLAB Course

https://michiganross.umich.edu
Digital MATLAB Course

Questions + Exercises

Contact

- Message-system
- (Online) office hours
MATLAB for Engineers @ Universities

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- Prof. Dr. Clemens Bulitta  
  Dean, Faculty of Industrial Engineering

- Prof. Dr. Ralf Ringler  
  Professor for Medical Physics,  
  Great MATLAB Supporter, My Supervisor

- MathWorks, Munich  
  Providing Help, Support with Material

_all my students_ for their great participation, support and good suggestions for improving of the course!