Experiences Teaching Advanced MATLAB using E-Learning and an Open-Ended Project

Jakob Sauer Jørgensen – Postdoc, DTU, Denmark
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Outline

1. Background & course analysis

2. Increase feedback using e-learning

3. Increase motivation by real-world open-ended project

4. Conclusion & perspectives
Outline

1. Background & course analysis
2. Increase feedback using e-learning
3. Increase motivation by real-world open-ended project
4. Conclusion & perspectives
DTU Course 02637: Advanced MATLAB Programming

Tools and techniques for fast and correct code

- Techniques: vectorization, array pre-allocation etc.
- Tools: Debugger, profiler
- Efficient data structures
- MEX & Parallel Computing Toolbox

Tools for advanced graphics

- Handle Graphics
- GUIs using GUIDE

```
%% Compare true golden angles to subsampling
clear
close all
clc

%% Parameters
ntheta = 17;
phi = (sqrt(5)-1)/2;

%% The ideal ntheta equi-angular angles
theta_ideal = 0:360/ntheta:360-360/ntheta;

figure
plot(cosd(theta_ideal).*sind(theta_ideal),'.','k','mar
axis equal
axis([1.1*[-1 1 -1 1]])
```
Before Spring 2015

Previous course design:
• 5 ECTS over 13 weeks.
• Weekly lecture + exercise session on specific topic, e.g. Handle Graphics.
• 2 projects in small groups.
• Assessment based on 2 project reports and brief final oral examination
• Both projects quite specific, well-defined tasks.

Status of the course:
• Same content and form for many years.
• Running quite well with minor issues.
• Vague feeling that some things might not be optimal.
UDTU: Education in University Teaching at DTU

Teaching education for new teachers at DTU:
- 4 modules, 250 hours over 1–1.5 years.
- Course design: Teaching and assessment methods.
- Final project: Try out techniques while teaching a course.

Redesign Advanced MATLAB Programming course:
- Analyze using UDTU theory.
- Introduce new teaching methods to address any issues found.
- Teach approx. 50 % of course (joint with Bernd Dammann, DTU)
- “Action research”: Gather data to document effects.
Course design theory: Constructive Alignment

Learning Objectives

Teaching and Learning Activities

Feedback and Assessment Methods

Motivation

Deep Learning

Biggs and Tang (2011)

NOTE: Not the machine learning kind!

Biggs and Tang (2011)
Challenges identified by Constructive Alignment analysis

**Misalignments:**
- Learning objectives not measurable
- Some learning objectives not assessed, e.g., MEX
- Lecture-heavy with little student engagement
- Little feedback given to students
- Oral examination based on reports

**Motivation:**
- Exercises and projects idealized and tutorial-like.
- Are we making students appreciate how to apply the wonderful MATLAB tools in their own work?
- Motivating enough?
Target areas

Increase feedback:
- Formative assessment: help students improve before final (summative) assessment
- Feedback to teachers on student learning to adjust teaching

Motivation to encourage Deep Learning:
- Activation of students
- Real-world problems
- Project ownership

Choose teaching methods and tools to support these aims.
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Feedback tool 1: Socrative

Socrative
• Question tool using smartphone app or browser
• www.socrative.com

Polls during lectures
• Make students think about lecture material and check their understanding

Quizzes after exercises
• Test learning of current topic

Feedback to teachers on student learning
• Useful to adjust teaching during course and for next run
Example of Socrative poll during lecture

Accessing the elements of a 2D MATLAB array is

A faster along rows,
B faster along columns,
C equally fast along rows or columns.

Live results:

<table>
<thead>
<tr>
<th>HOW'D WE DO?</th>
<th>43/44 students answered</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A is faster</td>
</tr>
<tr>
<td>B</td>
<td>B is faster</td>
</tr>
<tr>
<td>C</td>
<td>The are equally fast</td>
</tr>
</tbody>
</table>
Example of Socrative exercise quiz results

<table>
<thead>
<tr>
<th>Name</th>
<th>Score</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anon 14d44</td>
<td>33%</td>
<td>B</td>
<td>D</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anon 15e13</td>
<td>83%</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>D</td>
<td>C</td>
<td>C</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>Anon 19ea4</td>
<td>67%</td>
<td>B</td>
<td>C</td>
<td>B</td>
<td>D</td>
<td>C</td>
<td>C</td>
<td>D</td>
<td>.</td>
</tr>
<tr>
<td>Anon 208ee</td>
<td>67%</td>
<td>B</td>
<td>D</td>
<td>A</td>
<td>D</td>
<td>C</td>
<td>C</td>
<td>D</td>
<td>It was A</td>
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<tr>
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<td>B</td>
<td>C</td>
<td>A</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Anon 2dd4d</td>
<td>83%</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>Anon 35980</td>
<td>100%</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>E</td>
<td>I liked</td>
</tr>
<tr>
<td>Anon 42a20</td>
<td>50%</td>
<td>B</td>
<td>D</td>
<td>D</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>A</td>
<td>I think</td>
</tr>
<tr>
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<td>50%</td>
<td>B</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>C</td>
<td>the live</td>
</tr>
<tr>
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<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>D</td>
<td>.</td>
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<tr>
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<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>D</td>
<td>The live</td>
</tr>
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<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>E</td>
<td>Live cod</td>
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<tr>
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<td>D</td>
<td>D</td>
<td>B</td>
<td>C</td>
<td>C</td>
<td>good lec</td>
</tr>
<tr>
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<td>67%</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>Test ans</td>
</tr>
<tr>
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<td>67%</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>D</td>
<td>E</td>
<td>For anot</td>
</tr>
<tr>
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<td>100%</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>E</td>
<td></td>
</tr>
</tbody>
</table>

**Class Total**: 100%  63%  69%  60%  73%  80%
How did it work?

From student feedback and own observations:

- Lecture polls engage students to adjust understanding early
- Exercise quizzes: very mixed student opinions
- Feedback to teachers very valuable for adjusting teaching

Socrative as tool:

- Simple to set up (teacher) and use (students)
- Free version, max 50 students at a time.
- Other similar tools available
Feedback tool 2: CodeJudge

What is CodeJudge?
- Online framework for testing code
- Developed at DTU
- www.codejudge.net

Benefits for students:
- Immediate feedback on correctness of code
- Points to any errors, orange smiley face
- If correct, green smiley face as reward
- Standardized test environment (code works also on someone else’s computer)

Benefits for teachers:
- All code submissions available
- Monitor progress of individual students
- Reports and statistics for all students
Feedback tool 2: CodeJudge

Test03

Test Script

```matlab
1  % Test 3 - sum exceeds 1 in some pixels
2  N = 20;
3  r1 = [5 15 5 15 0.4];
4  r2 = [0 12 0 12 0.9];
5  get_test_image(N,r1,r2)
```

Output

Error: expected 1.0000 but was 1.3000

<table>
<thead>
<tr>
<th>Your Output</th>
<th>Expected Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>ans =</code></td>
<td><code>ans =</code></td>
</tr>
<tr>
<td>Columns 1 through 7</td>
<td>Columns 1 through 7</td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0</td>
</tr>
<tr>
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<td>0</td>
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<tr>
<td>0</td>
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<td>0</td>
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<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

...
# Feedback tool 2: CodeJudge

## Submissions

<table>
<thead>
<tr>
<th>Id</th>
<th>Time</th>
<th>User</th>
<th>Exercise</th>
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<tbody>
<tr>
<td>194276</td>
<td>23-03-2015 20:58</td>
<td>Asmus Graumann Moser (s082570)</td>
<td>cimmino</td>
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<td>Asmus Graumann Moser (s082570)</td>
<td>cimmino</td>
</tr>
</tbody>
</table>
How did it work?

The good:

• Ensured almost all students had working code.
• Student feedback very positive: helpful for debugging.
• Nice overview of student progression for teachers

The bad:

• Too much help? Difficult to give low grades.
• Only possible to test functions with known interface.
• Too much testing prevents students thinking and testing for themselves.
• Deep learning?
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Motivation

Student pre-test feedback – What motivates you?

- Good projects where I can perform something close to “real world”
- Stuff that can be implemented in the real world – practical stuff
- Getting a tough challenge which most people can’t solve

UDTU theory: What helps motivation?

- Real-world problems
- Challenges
- Ownership
Previous projects and new project

Concerns wrt motivation:

- Exercise-like, specific tasks.
- Not too difficult, most students completed almost everything.
- Limited room to shape project and demonstrate independence.
- No real data.

Changes introduced:

- Keep first project (to use with CodeJudge)
- Replace second by very open-ended project with a big real data set.
- Inspired by my own research area: X-ray Computed Tomography (CT).
Kinder Surprise in CT scanner at DTU
New open-ended project

Build visualization tool to investigate the toy inside the Kinder Surprise egg.

Challenges encountered:
- No fixed requirements.
- Handle large data set: 1.5 GB, ca $1000^3$-voxel volume.
- Deal with noise in data.
- Find suitable 3D visualization methods.
- Implement efficient data processing.
- Design GUI to balance visualization options and user-friendliness.

Deliverables:
- MATLAB App
- Report explaining functionality, design choices, pictures of toy
Some student solutions of Kinder Surprise data
Student feedback – What was good about Project 2?

– “Its room for creativity made it fun, because it created a feeling of ownership of the project. Furthermore, it made it possible for each group to almost adjust the level of difficulty to their match their own skills. [...]"

– “That it wrapped up quite nicely all the disciplines we’ve through doing the course. That is was open-ended and you had the ability to show off your skills. It was really fun to work with the data, as you can really relate to it, and you fell the urge to cut out the toy to find out what it is.”

– “I liked the freedom – where everything was up to you and your decisions. Those decisions were the hard part not the programming st self.”
Student feedback – What could be improved?

– “Better guide-lines, it is hard to know what your expectations are and if the project is good enough to get a good grade. [...]”

– “[...] became slightly frustrating in the end, because we didn’t know when the GUI was good enough. Have we included enough functionality and son on? One way to avoid this could be to define some required functions more clearly.”

– “A feedback session halfway through the project would be good.”
How did it go?

Own observations:

• Students worked enthusiastically – and hard!
• Several groups with average first reports really stepped up.
• Very impressive solutions – and VERY different!
• Less frustration than I had feared.

Increased motivation and Deep Learning?

• Judging from student feedback – yes!
• Report and oral examination demonstrated high fulfillment of learning objectives.
• How to balance freedom and guidelines?
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Conclusions

Feedback:
- Lecture polls helpful
- Weekly quizzes – mixed views
- Automatic code testing popular with students – supports deep learning?
- Systematic feedback to teachers on student learning very useful

Motivation:
- Real-world application theme: Highly motivating
- Open-ended project: Highly motivating

Constructive Alignment:
- Useful, systematic, actionable strategy for course development
- Action research: Collect data on teaching and learning along the way
Perspectives

Still not perfectly aligned:
- Learning objectives on e.g. MEX and Parallel Computing Toolbox not assessed.
- Lecture format most suited for teaching programming?
- Final individual oral examination appropriate?

A possible solution:
- Fully project-based, e.g. 4 projects of increasing complexity covering all topics.
- Final assessment as project presentations.
- No lectures. Perhaps supply short videos explaining specific topics.
- Use Mathworks tools, e.g., MATLAB Academy?

Tools to support teaching methods and learning objectives!
Thanks for your attention! Questions?

Contact info:
• Jakob Sauer Jørgensen – Postdoc, DTU, Denmark
• jakj@dtu.dk

Resources:
• UDTU: www.learninglab.dtu.dk/english/kurser/undervisere/udtu
• 02637 Advanced MATLAB Programming course: www.kurser.dtu.dk/02637
• Socrative: www.socrative.com
• CodeJudge: www.codejudge.net