Teaching and Assessment Resources for MATLAB and Simulink
prologue:

yay or yawn
As a teacher, what I want to do, is:

a) I want my students to derive (by hand), the transfer function and UNIT step response of the RC circuit.

b) I want my students to use this as an exercise to practice their MATLAB coding skills.

c) …. And I want to try something NEW.
   - I want my students to confirm their hand derivations against a FUN looking simulation environment called Simulink + Simscape
The old and something NEW:

- **DEMO #1:**
  - A set of typical MATLAB assignments
    - Ordinary Least Squares
    - An RC circuit

- **DEMO #2:**
  - A new thing that you’d like your students to try:
    - Simscape looks like FUN?
... And as a teacher, you’re now asking:

- How can I give my students some training on how to drive **Simulink + Simscape**?
  - Surely someone’s put together some curriculum content that I can use!
  - I don’t really want to spend 3 hours preparing more course notes and handouts.

- I’ve got 200 students
  - I want all of them to be confident using MATLAB
  - If I set them MATLAB programming assignments .... I’ve got some marking to do
  - Wish I could “take their temperature” quickly.
    - Perhaps a POP QUIZ before I hand out the first real assignment?
Act 0.0:

We can help
This session has 2 main themes:

**Assignment grading Resources**

*How can we help you*

**Teaching Resources**

*How can we help you*

Test and assess, how well your students understand MATLAB.

Find existing Curriculum content to supplement your own content.
Test and assess how well your students understand MATLAB.
Welcome to Cody Coursework™

http://coursework.mathworks.com

Log In  Sign Up

Don't have a MathWorks Account?
What is Cody Coursework™?

Online automated grading system for MATLAB assignments

- Create online private courses and assignments
- Students execute MATLAB code on the web
- Control the visibility of the test suites from students.
- Visualize solution results using MATLAB graphics
- Download all student attempts and report on grading data

http://coursework.mathworks.com
Are classical assessment techniques **FINISHED**?

- NO – of course not!
- But ….. Cody can act as a Supplement to your existing assessment formats

**Cody sweet spots:**
- Assess **MATLAB** programming assignments?
- Do you need to mark 100’s of 1\textsuperscript{st} or 2\textsuperscript{nd} year assignments?
- Do you want to see where your students are struggling before they submit?
Act 1.1: the student meets CODY
Student Workflow – the choices

Copy and paste CODE

OR

CODE directly in web page
If you have WEB access then demo it live!
The student gets invited by Professor to enrol in a COURSE

A free MathWorks account is required

The student inspects the invitation
The student enrols in your course
Student is now ready to do the Assignments.
Student Workflow

- Select a problem
- Enter a solution
- **Test** the solution
- Fix and **retest** the solution
- **Submit** their solution
The student experience

OK, let’s try and solve a problem
The student experience

So how do I know if this answer is correct? (which it isn’t!!)

… OK, I’ll type my answers in here
The student experience

Try … try … try again!!
The student experience

Yeah .. OK I’m ready to submit my answer for this question.
The student experience

Will I encounter scenarios where my Professor designs an assignment using language like:

Q3.) Use the results of Q1 and Q2, to ……

Yes absolutely.

But your Professor can also choose to cut you some slack
The student experience

LAB: Least Squares

Q1b.) Create the coefficient A matrix

BACKGROUND: We’re going to determine the quadratic polynomial \( y(t) = c + b \times t + a \times t^2 \), which is the best least squares approximation to the following measured data:

<table>
<thead>
<tr>
<th>( t )</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>( y )</td>
<td>8</td>
<td>11</td>
<td>12</td>
<td>20</td>
<td>22</td>
<td>13</td>
<td>21</td>
<td>13</td>
</tr>
</tbody>
</table>

YOUR QUESTION: Use MATLAB to create the coefficient matrix \( A \) for a least squares problem \( A \times x = y \), where \( x \) represents the column vector containing the parameters \( c, b, a \) (in that order).

ASSUMPTIONS: You may assume that the following MATLAB variables have already been created for you, and you do NOT need to redefine them again:

* tvec is a 8x1 column vector

Click on the SOLVE button and then enter your solution into the SOLUTION window.

Hey thanks Prof !
So you want me to DERIVE the analytical form of the transfer function?

I thought this was supposed to be about MATLAB programming?
Derive the Transfer Function of the given system, where $v_1$ is the system input and $v_2$ the system output.
Derive the Transfer Function of the given system, where $v_1$ is the system input and $v_2$ the system output.

\[
\frac{V_2}{V_1} = \frac{s + \left(\frac{1}{R_1 C}\right)}{s + \left(\frac{R_1 + R}{R R_1 C}\right)}
\]

OK Prof, I’ve derived your transfer function.

So what am I supposed to do with it now?
The student experience

OK … I’ll type it how I wrote it!!

Solution

Q1a.) Derive the ANALYTICAL solution for the Transfer Function

Derive the Transfer Function of the given system, where $v_1$ is the system input and $v_2$ the system output.

\[ C \]
\[ R_1 \]
\[ R \]
\[ V_1 \]
\[ V_2 \]

Specify your answer by writing out an expression in terms of the symbols (ie: NOT numerical values)

\[ x, R_1, C, R \]

An example of what we mean by “an expression” is _ (NOTE this is an example only and is NOT the answer)_

\[ the.H = (R.C + C)/((x^2 + R.C + R1.C^2) \]

Click on the SOLVE button and then enter your solution into the SOLUTION window.

Why are we doing this?

* Can you use derive the analytical expression for the system Transfer Function?
Typing in (copy paste) a few lines is OK ..... But I thought this was supposed to be about MATLAB programming?
The student experience

LAB: Linear systems
Q1b.) Calculate the Frequency Response of the system

Regarding the following system:

And using the values:

* R1 = 2000 (ohms), C = 0.001 (farads), R = 1000 (ohms)

Write a MATLAB function that computes the system Frequency Response.

Specifically the MATLAB function should receive 1 INPUT:

* a vector of frequencies at which to compute the frequency response. The frequency vector should be in units of (radians/sec)

Specifically the MATLAB function should return 3 OUTPUTS:

* a vector of the AMPLITUDES of the frequency response in units of [v/sec/v/sec]
* a vector of the AMPLITUDES of the frequency response in units of dB
* a vector of the PHASE of the frequency response expressed in units of (degrees)

Click on the SOLVE button and then enter your solution into the SOLUTION window - note that a "partially" completed function has been created for you.

WHY ARE WE DOING THIS?

* Can you use MATLAB to create a function?
* Can you use MATLAB to define the numeric values of the system frequency response?
The student experience

Solution

function [the_mag_vec, the_db_vec, the_phase_vec] = my_func_for_Q1b(the_w_vec)

% ATTENTION:
% 1.) do NOT change the NAME of the function, ie: leave it as "my_func_for_Q1b"
% 2.) your function INPUTS:
% the_w_vec: a vector of frequencies at which to compute the
% frequency response. The frequency vector should be
% in units of (radians/sec)
% 3.) your function OUTPUTS:
% the_mag_vec a : vector of the AMPLITUDES of the frequency response
% in units of [v/sec/v/sec]
% the_db_vec a : vector of the AMPLITUDES of the frequency response
% in units of dB
% the_phase_vec : a vector of the PHASE of the frequency response
% expressed in units of (degrees)

% INSERT YOUR CODE HERE:

end

Hey thanks Prof!
The student experience

**HIDDEN tests:**

All I see is a GREEN or an ORANGE (with a suggestion about my mistake)

**VISIBLE tests:**

I get to see my Professors code AND my professor can create MATLAB plots.
The student experience

Cool – I can quickly see what I’ve done correctly and what still needs to be improved
Act 1.2:

some warmup stretches
Pattern #1:

\textbf{is*()}

```matlab
% CHUNK_#1a: IS*
A = [1, 2, 3, 4, NaN];

tf_result_sca = iscalar(A)

tf_result_vec = isvector(A)

tf_result_row = isrow(A)

tf_result_nan = isnan(A)

tf_result_big = (A >= 3)
```

\textbf{tf_result_sca =}

0

\textbf{tf_result_vec =}

1

\textbf{tf_result_row =}

1

\textbf{tf_result_nan =}

0 0 0 0 0 1

\textbf{tf_result_big =}

0 0 1 1 0
Pattern #2:

all()
Pattern #3: length() size()

```
len_A_B =
3  5

r =
2

c =
3

>>

%% CHUNK_#3: LENGTH() and SIZE()
A = [1,2,3];
B = [1,2,3,4,5];

len_A_B = [ length(A), length(B) ]

MAT = [1,2,3;
      4,5,6];

[r,c] = size(MAT)
```
Pattern #4: 

assert()

```plaintext
%% CHUNK_4a: ASSERT()

A = [1,2,3,4, 5];
B = [1,2,3,4, 5.01];

test_val = all( abs(A-B) < 0.1 );
assert( test_val, 'HEY!!!: A and B seem to have different values');
display('HELLO Bob')
```

everything is OK

```plaintext
%% CHUNK_4b: ASSERT()

A = [1,2,3,4, 5];
B = [1,2,3,4, 5.01];

test_val = all( abs(A-B) < 1e-4 );
assert( test_val, 'HEY!!!: A and B seem to have different values');
display('HELLO Bob')
```

everything is NOT ok
So what?

- These patterns (and a few others):
  - `is*()`
  - `all()`
  - `length()`
  - `size()`
  - `assert()`
  - `==, ~=, <, >`

YOU (the professor) use these concepts to author the test suites in Cody Coursework.
Act 1.4:
the Professor meets CODY
CODY terminology

- Course
- Assignment
- Problem
Cody Coursework for Instructors

- Follow these steps to prepare a course:

  Create a course
  Create assignments
  Create problems
  Invite students!

  Define the problem
  Add a solution template
  Write a reference solution
  Write and verify test suites
  Publish

So you own the creation of tests that get applied to your students' answers.

- For an example of preparing a course, see the Instructor Walkthrough
Cody Coursework for Instructors

- Follow these steps to prepare a course:

  - Start from scratch
  - Use examples from our Catalog

Create a course → Create assignments → Create problems → Invite students!

- Define the problem
- Add a solution template
- Write a reference solution
- Write and verify test suites
- Publish
The professor experience:

- Login to CODY coursework

https://coursework.mathworks.com
If you have WEB access then demo it live!
The professor experience:

- Create a course
The professor experience:

- Configure the course – part 1 of 2

Which products will your students have access to.
The professor experience:

- Configure the course – part 2 of 2

Use edit box and formatting widgets
The professor experience:

- Add and configure an Assignment
The professor experience:

- Add a problem to your assignment
The professor experience:

- Configure a **problem** – part 1 of 6

**Use edit box and formatting widgets to state the problem.**
The professor experience:

- Configure a **problem** – part 2 of 6

Do you want your students to work on a **SCRIPT** or **FUNCTION**?

What’s the starting point for your students?
The professor experience:

- Configure a **problem** – part 3 of 6

Define the **GOLDEN REFERENCE** that we will compare our students answers against.

While you’re developing your **TEST SUITE** you can create some example responses that a student might submit.
The professor experience:

- Configure a **problem** – part 4 of 6

---

Do you want your students to SEE the code that you are using to test their answers?
The professor experience:

**Define your TESTS**

**Test pattern for SCRIPT problems**

*Category* • Function • Script

**MUST start with a %%**

```matlab
%% Test the values of yvec

Run the students solution

run('solution')

Run your GOLDEN reference solution

reference.solution

Perform some kind of test

some_tf_list = abs(GR.yvec - yvec) < GR.tol;

**ASSERT that your test was TRUE**

assert(all(some_tf_list), 'your <yvec> values are NOT correct');
The professor experience:

**Test pattern for FUNCTION problems**

*Category: Function  Script*

**MUST start with a %%**

%% TEST for a general input vector

\[
t = [0:0.001:20]';
\]

\[
\text{[studs}_v2]\text{]} = \text{my_func_for_Q1d}(t);
\]

**Run the students solution**

**Run your GOLDEN reference solution**

**Perform some kind of test**

% now do some detailed tests and echo feedback

\[
\text{assert( length(studs}_v2\text{))==length(t), 'your answer should have the same number of elements as t values');}
\]

\[
\text{the}_e = \text{abs(v2}(:) - \text{studs}_v2(:));
\]

**ASSERT that your test was TRUE**

\[
\text{assert( all(the}_e < 1e-6), 'your step response values seem wrong');}
\]
The professor experience:

**Define your TESTS**

*Test Suite | Results*

- % define the SHARED data

```
%% TEST 0a: the existence of of tvec
run('solution');
assert( 1 == exist('tvec'), 'you need to assign your answer to <tvec> ');
```

```
%% TEST 0b: the existence of of yvec
run('solution');
assert( 1 == exist('yvec'), 'you need to assign your answer to <yvec> ');
```

```
%% TEST 1a: the length of tvec
run('solution');
reference.solution; % call the REFERENCE solution. It creates the GR struct
N = length(tvec);
assert(isequal(GR.N, N), 'your <tvec> does NOT have the correct length!!');
```

```
%% TEST 1b: the length of yvec
run('solution');
reference.solution; % call the REFERENCE solution
N = length(yvec);
assert(isequal(GR.N, N), 'your <yvec> does NOT have the correct length!!');
```

**IFF necessary, define any data that ALL of your test cases can see**

A whole bunch of test cases
The professor experience:

% define the SHARED data

%% TEST 0a: the existence of of tvec
run('solution');
assert( 1==exist('tvec'), ' you need to assign your answer to <tvec> ');

%% TEST 0b: the existence of of yvec
run('solution');
assert( 1==exist('yvec'), ' you need to assign your answer to <yvec> ');

%% TEST 1a: the length of tvec
run('solution'); % call the REFERENCE solution. It creates the GR structure
N = length(tvec);
assert(isequal(N,N), 'your <tvec> does NOT have the correct length!!');

%% TEST 1b: the length of yvec
run('solution'); % call the REFERENCE solution
N = length(yvec);
assert(isequal(N,N), 'your <yvec> does NOT have the correct length!!');

Define your TESTS

OR

OR

BOTH
The professor experience:

- Configure a **problem** – part 5 of 6

Get confidence in your TESTS.

**Do they work?**
Publish The Problem

Once the problem is defined and tested, click the **Publish** button to make the problem available as part of the assignment.

You can also save the problem as a **draft** and return to work on it later.

Clicking on the **Preview** button, allows you to see what it will look like to the students.

- **Configure a problem** – part 6 of 6
Repeat this creation process for each problem
Act 1.5: Professor invites students to his CODY course
Invite Students

Inviting Students to participate in the course is as easy as …

1. Click on PEOPLE

2. Select Invite People tab

3. Select Student from the drop down box

4. Enter the email addresses of the students in the edit box

5. Click Send
Invite Students

Inviting Students to participate in the course is as easy as …

1. Click on PEOPLE
2. Select Invite People tab
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5. Click Send
Invite Students

Inviting Students to participate in the course is as easy as …

1. Click on PEOPLE

2. Select Invite People tab

3. Select Student from the drop down box

4. Enter the email addresses of the students in the edit box

5. Click Send

By hand … or COPY and paste from file
The student gets your invitation

A free MathWorks account is required

The student inspects the invitation
The student enrols in your course

BH0123: MATLAB, Science and systems

Hello, and welcome to BH0123. Together we're going to learn about MATLAB and solve some interesting problems in science and engineering.

There are some wonderful resources that we'll use along the way. Resources such as:

- Step-by-Step Guides to MATLAB and Simulink: [http://au.mathworks.com/academia/student_center/tutorials/?s_tid=dpport_tut_sp_01](http://au.mathworks.com/academia/student_center/tutorials/?s_tid=dpport_tut_sp_01)

[Enroll button]
And now they are ready to do the Assignments
Course enrolment only needs to be done ONCE!

- Once enrolled in a course
  - Assignment HYPERLINKS can be used for student access to new assignments

- Use these Assignment HYPERLINKS in your LMS
Act 1.6:

Professor monitors student group progress
Progress being made on **Problems** in the **Assignment**

For each problem, the status bar shows:
- number of students who solved a problem correctly.
- number of students who have only submitted an incorrect solution.
- number of students that didn’t submit any solutions for a problem.
Solution map for a Problem

Assignment 1
2e: Calculate the Frequency Response of the system

Regarding the following system:

\[ \frac{C}{R} \]

Student Solutions

Code size

Order of arrival

Incorrect
Correct
Leading
The **interactive** Solution map for a **Problem**

- **Click on a submission**
- **See the code of the submission**
- **See which tests were passed and failed**

![Interaction map diagram](image)
Generate a report for your class’s Assignment
Generate a report for your class’s **Assignment**
This session has 2 main themes:

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*How can we help you*

**Teaching Resources**

*How can we help you*

Test and assess, how well your students understand MATLAB.

Find existing Curriculum content to supplement your own content.
Find existing Curriculum content to supplement your own content.
Educators:

- A dedicated site for supporting teachers.

MATLAB Courseware

Second-Year Courseware

- **Applied Numerical Methods with MATLAB**
  - Professor Steven C. Chapra
  - Tufts University

- **Heat Transfer with MATLAB**
  - Professor Tien-Mo Shih
  - Xiamen University

- **Electromechanical Engineering Systems**
  - Professor Kevin Craig
  - Marquette University

- **Model-Based Design Series: Basic Component Modeling**
  - By Professor Doug Nelson
  - David Ord
  - Virginia Polytechnic Institute and State University

- **Model-Based Design Series: Battery Systems**
  - Donald Docimo
  - Mohammad Ghataapishie
  - Professor Hosam Fathy
  - Pennsylvania State University

- **Model-Based Design Series: Supervisory Control & Fault Diagnosis**
  - Professor Shawn Midlam-Mohler
  - Eric Gallo
  - The Ohio State University

"System Dynamics with Simscape" Curriculum Materials

MathWorks and McGraw-Hill have developed a set of system dynamics models and lecture slides introducing Simscape to accompany William Palm's System Dynamics text.

Lecture Slides, MATLAB Code, and Models Using Simulink and Simscape

This downloadable package includes five sets of lecture slides introducing and applying Simscape to system dynamics problems in electromechanical, hydraulic, and thermal systems based on examples from Palm's textbook. Each set of lecture slides is accompanied by a physical model developed with Simscape and a step-by-step guide on how to create it. More than 40 MATLAB and Simulink examples are also included. All materials were developed by Palm or under his supervision, based on his own course materials.

Educators – Classroom resources:

- Search the entire resource library
- Find a broad range of resources:
  - A few scripts, functions
  - Libraries, toolboxes

Learn MATLAB at your own pace.

http://au.mathworks.com/academia/student_center/tutorials

MATLAB Fundamentals Academic Tutorial

The MATLAB Fundamentals academic tutorial teaches students the basic skills required to become successful MATLAB users and complete homework assignments. Lessons and quizzes are short, and students can view and return to them whenever they like.

Requires Adobe Flash Player (version 8 or above)

Explore MATLAB Fundamentals

Video tutorials
MATLAB Academy ---- MATLAB Onramp

https://matlabacademy.mathworks.com/

Interactive tutorials

Learn MATLAB for Free

Launch MATLAB Onramp now

Watch MATLAB Onramp preview 1:10
MATLAB Academy ---- MATLAB Onramp

https://matlabacademy.mathworks.com/

MATLAB Onramp 3% complete

Task 1

Info: MATLAB is designed to work naturally with arrays. For example, you can add a scalar value to all the elements of an array.

```matlab
>> y = x + 2
```

Try adding `1` to each element of `v1` and store the result in a variable named `r`.

```matlab
>> load datafile
>> density = data(:,2);
>> v1 = data(:,3);
>> v2 = data(:,4);
    Task 1
>>
```

Free

Interactive tutorial
The Final Act:

Next Step?
This session had 2 main themes:

Assignment grading Resources

Teaching Resources

How can we help you

https://coursework.mathworks.com

What you need!

http://au.mathworks.com/help/coursework/

License Requirements

To use Cody™ Coursework™, you need *either* of these licenses:

<table>
<thead>
<tr>
<th>To create a course, you need:</th>
<th>To enroll in a course, you need:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Either of these licenses:</td>
<td></td>
</tr>
<tr>
<td>• A professional or academic license for MATLAB® &amp; Simulink® that is current with MathWorks® Software Maintenance Service. For more information about the benefits of Software Maintenance Service, visit MathWorks Software Maintenance Service.</td>
<td>A MathWorks Account.</td>
</tr>
<tr>
<td>• A license for MATLAB student-use software. This license does not require Software Maintenance Service.</td>
<td>A MATLAB license is not required.</td>
</tr>
</tbody>
</table>

A MathWorks Account associated with a license.

If you do not have a MathWorks Account, the application allows you to create one and to associate it with your license. Alternatively, create an account at the MathWorks website, http://au.mathworks.com, and follow these steps to associate your license with your account:

1. On the MathWorks website, click **My Account**.
2. In the **License Center** pane, click **Manage Licenses**.
3. Click **Add License** and follow the instructions.