

## Introduction to Autograding with MATLAB Grader



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#### **Curicculum Vitae**



[2006-2029] Disting Hours and History (1999) and the second of the secon





#### Agenda

- Interactive MATLAB notebooks as teaching materials
  - Introduction to interactive teaching materials with MATLAB
  - MATLAB-based interactive teaching materials in action
- Flipped classroom concept
  - Fundamentals of the Flipped Classroom Concept
  - Flipped Classroom in Practice
- Auto-grading with MATLAB Grader
  - Standard and auto-grading methods
  - The Learner- and the Instructor-View of MATLAB Grader
  - Integration of MATLAB into OpenOlat via the LTI 1.3 interface



#### Interactive MATLAB notebooks as teaching materials

MATLAB

Overview Getting Started Features & Capabilities ~ For Students



#### Create an Executable Notebook

Create scripts that combine code, output, and formatted text. Divide code into manageable sections that can be run independently. View output and visualizations next to the code that produced them. Enhance your code and results with formatted text, headings, images, and hyperlinks. Insert equations using the interactive editor or create them using LaTeX. Save code, results, and formatted text in a single executable document.



#### \*<u>https://www.mathworks.com/products/matlab/live-script-gallery.html</u>



#### Introduction to interactive teaching materials with MATLAB



Fig. Traditional teaching materials



Fig. Digitized/interactive teaching materials \*

\*Apostolatos et al. "Courseware on Finite Element Methods", MATLAB File Exchange



#### MATLAB-based interactive teaching materials in action

🖹 CVinteractive_Teaching_MaterialsCourseware-on-Finite-Element-Methods/main.mk 🗆 🗙	🖺 Cluterachie, Teaching, Materiah Courseware-on-Finite-Element-Methods/4, TransverseSheart.coking/4,
Image: Section Break     Image: Section Break       New Open Seve     Image: Section Break       Image: Section Break     Image: Section Break       Ima	Image: Control in the section of t
which are well-known from mathematical optimization. The accompanying files contain a comprehensive set of Live Scripts which allow for experimenting with the different Finite Element Methods (FEMs) in an interactive way. Author: Andreas Apostolatos, PhD (aspostol@mathworks.com) Date: 20.02.2023 Quick guide Chapter 1 main_Chapter1_BasisFunctions.mlx Chapter 2 main_Chapter2_AlineerStreightTimoshenkoBeemElement.mlx Chapter 4 main_Chapter4_Transvers6ShearLocking_TimoshenkoBeem.mlx main_Chapter4_Locking_ReissnerWindlinGaurePlate.mlx Chapter 5 main_Chapter4_Locking_ReissnerWindlinGaurePlate.mlx Chapter5 main_Chapter5_WashBoundsaufConditions_TimoshenkoBeem_mly	For this problem there is no known analytical solution in terms of the vertical deflection and the cross-sectional rotation fields. As a reference solution it is used the precomputed solution of the same problem there is no known analytical solution in terms of the vertical deflection and the cross-sectional rotation fields. As a reference solution it is used the precomputed solution of the same problem there is no known analytical solution in terms of the vertical deflection and the cross-sectional rotation fields. As a reference solution it is used the precomputed solution of the same problem there is no known analytical solution in terms of the vertical deflection and the cross-sectional rotation fields. As a reference solution it is used the precomputed solution of the same problem there is no known analytical solution. The method ontails researce that the precomputed solution of the same used to alloviate locking. The method ontails researce that additional evaluation points within each element while assuming a "natural" form of the otrain components in the element level bofero computing the discretization. It is first shown the distribution of the transverse shear forces q, along the diagonal line shown above and it is highlighted the spurious transverse shear forces, especially for the low-order discretization.
Chapter 6	Zoom UDV6 UTF6 LF script
main_thapter6_HellingerReissnerFormulation_Timoshenko8eam.mix main_thapter6_HellingerReissnerFormulation_Timoshenko8eam_Study.mlx Appendix A main_AppexA_EfficiencyCondiderationsTimoshenko8eam.mlx main_AppexA_EfficiencyCondiderationsReissnerHindlinPlate.mlx	C Syntematikes, East bing, Material Courseware-on-Finite - Element - Methods/S, WorkBickhelderBounderyCandBiters/Linkes/CanderyCandBiters, TimesherikoBeam.mik
Unit tests main_unitTests.mix Chapter 1: Decis Functions	Try       Image: Change the value of parameter choiceShapeFunctionsPrimal from the dropdown list to get either a linear two-noded or a quadratic three-noded Finite Element mesh         S0       choiceShapeFunctionsPrimal = (quadratic interpolati •); syms: Nu(xi)
In this chapter it is introduced the notion of the basis functions typically used in the frame of the <i>Pinite Element Method</i> . The basis functions introduced herein are the following ones.	Linear (hat) shape functions $N_{i}(z) = \frac{1-z}{2},  (10.1)$ $N_{i}(z) = \frac{1+z}{2},  (10.2)$ $\frac{csse 1}{hu(xi) = [1/2^{e}(1 - xi) 1/2^{e}(1 + xi)];}$ Quadratic shape functions $N_{i}(z) = \frac{\xi(z)}{2},  (11.1)$ $N_{i}(z) = \frac{\xi(z)}{2},  (11.2)$
This I kus Societ takes about a minute to avanute Takes 1 Take	$N_{M}(g) = -(g-1) (g+1),$ (11.3)
	200m. 100% 01% 01% 01% 01% 01% 01% 01% 01% 01

#### \*<u>https://www.mathworks.com/matlabcentral/fileexchange/125135-courseware-on-finite-element-methods</u>



### Flipped Classroom



• <u>https://ctl.utexas.edu/instructional-strategies/flipped-classroom</u>



### Fundamentals of the Flipped Classroom Concept



Traditional teaching approach



<u>https://ctl.utexas.edu/instructional-strategies/flipped-classroom</u>



## **Flipped Classroom in Practice**

#### Mid-term project Part I - Locking in the Timoshenko beam discretizations

Finite element discretizations of shear-deformable elements, such as beams and plates, suffer for numerical transverse-shear locking. Numerical transverse-shear locking tr

Revise the attached recording and then study how to identify the presence of transverse-shear locking for the Timoshenko beam problem using the Live Script main\_Chapter4\_TransverseShearLocking\_TimoshenkoBeam.mlx und folder 4\_TransverseShearLocking/4\_TransverseShearLocking\_TimoshenkoBeam/ of interactive Courseware on Finite Element Methods.

A Verfügbar ab 19. Mai 2024, 08:00 (sonst verborgen)



# Flipped classroom using digital platforms

- Provision of the chapter's interactive teaching materials
- Access to the chapter's recorded lecture
- Access to self-graded assignments
- Access to the recorded Q&A (practical) session



# Flipped Classroom in Practice

* Apostolatos, Andreas, Sebastian Gross, and Kai-Uwe Bletzinger.	'Teaching the Finite Element Method with Notebooks and Autograded Exercises.'	2022 IEEE German Education Conference (GeCon), IEEE, 2022.
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### Student Survey on the Effectiveness of Flipped Classroom



#### 📣 MathWorks<sup>.</sup>

### Student survey on the effectiveness of the interactive teaching materials





#### Student survey on the hybrid format of the lecture





### Student Survey on the Preferred Programming Language





#### Student Survey on the Key Components of the Course



Fig. 2022



### Student Survey on the Key Components of the Course





### Student Survey on the Key Components of the Course

actually having to think through all the iFEM things (4%)



Lecture pdf-handouts (11%)



# Effectiveness of Computational Environments, Weekly Assignments, and MATLAB





### Auto-grading using MATLAB Grader

#### MATLAB Grader

Overview LMS Integration Assessment Content Documentation & Support ~



Create interactive course assignments Automatically grade student work and provide feedback Run your assignments in any learning environment



#### **Conventional Assessment Process**



- Manual grading of solutions
- Provision of *individual feedback*
- Students need to wait for the feedback
- Lack of resources/teaching assistants to provide timely feedback to students
- Can't easily obtain mid-week progress



### Autograding Methods – MATLAB Grader



- Automated provision of feedback
- Real-time statistics
- Cloud-hosted solution no software
   installation or maintenance is needed
- Enables Summative and Formative assessment
- **Rescoring** all solutions with no effort



#### The Learner-View of MATLAB Grader

#### MATLAB Grader

#### ⊟ CONTENTS

MATLAB Grader for Teaching, 14.06.2023 > Set up and use a linear regression model >

#### Set up and use a linear regression model for the prediction of the gas consumption 0 solutions submitted (max: Unlimited)

Given are four MATLAB variables, namely, the weight gewicht, the horsepower pferdestaerke, the acceleration beschleunigung, and the miles per gallone meilenProGallone for a set of cars. The goal is to set up a linear regression model 1m leveraging these data that predicts the gas consumption. A linear regression model has the following mathematical form:

#### $\hat{y} = \beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n$

where variables  $x_1, \ldots, x_n$  are the predictors und where variable  $\hat{y}$  is the response. In case of two predictors and one response, one can represent the multiple linear regression through a surface, see the following figure:



Fig. Assignment Description

Script 🥹	C Reset	MATLAB Documentation
<pre>1 % Load the data 2 myData = load('carsmall', 'Weight', 'Horsepower', 'Acceleration', 'MPG 3 weight = myData.Weight; 4 horsepower = myData.Horsepower; 5 acceleration = myData.Acceleration; 6 milesPerGallon = myData.MPG;</pre>	;');	
7 8 % 1. Conversion of the miles per gallon to kilometers per liter 9 kilometerPerLiter = 0.2*milesPerGallon 10		
<pre>11 % 2. Setting up a MATLAB table 12 % predictorsAndReponse = 13</pre>		
<pre>% % 3. Setting up a linear regression model % lm = % 16</pre>		
<pre>17 % 4. Predict the gas consumption in kilometer per liter for this new s 18 % plot the diagram horsepower2 (X-Achse) vs the newly computed gas 19 [lm2, weight2, horsepower2, acceleration2] = 20 computeMyMultipleLinearRegression(weight, horsepower, acceleration 21 % kilometerPerLiter2 = 22 % plot</pre>	set of variables a consumption (Y-a) n, milesPerGallon	and (is) );
		► Run Script

 Is the gas consumption correctly converted in kilometers per liter?
 0% (20%)

 Variable kilometerPerLiter has an incorrect value.
 0% (20%)

The conversion factor for the conversion of the miles per gallon to kilometers per liter is 0.425144

Fig. Code-Editor and automated feedback



#### The Instructor-View of MATLAB Grader – Reference Solution

MATLAB Grader	MATLAB Grader
Problem Type <sup>*</sup> 🥹	Problem type 🔹 😥
Script O Function	Script OFunction
Code	Code
Reference Solution 2 Learner Template 2	Reference Solution (?) Learner Template (?)
<pre>1 % Load the data myData = load('carsmall', 'Weight', 'Horsepower', 'Acceleration', 'MPG'); weight = myData.Weight; horsepower = myData.Morsepower; s acceleration = myData.Acceleration; milesPerGallon = myData.ACCEleration; % 1. Conversion of the miles per gallon to kilometers per liter 9 conversionFactor = 0.425144; 10 kilometerPerLiter = milesPerGallon*conversionFactor; 11 12 % 2. Setting up a MATLAB table 13 predictorsAndReponse = table(weight, horsepower, acceleration, 14 kilometerPerLiter, VariableNames={'weight', 'horsepower', 'acceleration', 'kilometerPerLiter'}); 15 16 % 3. Setting up a linear regression model 11 m = fitlm(predictorsAndReponse, 'ResponseVar', 'kilometerPerLiter'); 19 24 . Predict the gas consumption in kilometer per liter for this new set of variables and 25 w plot the diagram horsepower2 (X-Achse) vs the newly computed gas consumption (Y-axis) 11 [Im2, weight2, horsepower2, acceleration2] = 26 computeMyMultipleLinearRegression(weight, horsepower, acceleration, milesPerGallon); 21 kilometerPerLiter2 = predict(Im2, [weight2, horsepower2, acceleration2]); 24 hReference = plot(horsepower2, kilometerPerLiter2); 25 26 % Save the figure data in a separate variable, because the figure-object is overwritten by the learner solution 27 XDataReference = hReference.YData; 28 YDataReference = hReference.YData; 4 4 4 4 4 4 4 4 4 4 4 4 4</pre>	<pre>% Load the data % Load the data % Load the data % Load the data % Lorsepower = myData.Weight', 'Horsepower', 'Acceleration', 'MPG'); % weight = myData.Keight; % acceleration = myData.Acceleration; % acceleration = myData.Acceleration; % acceleration = myData.Acceleration; % % 1. Conversion of the miles per gallon to kilometers per liter % kilometerPerLiter = % % 2. Setting up a MATLAB table % predictorsAndReponse = % % 3. Setting up a linear regression model % % 1. Predict the gas consumption in kilometer per liter for this new set of variables and % % 10 the diagram horsepower2 (X-Achse) vs the newly computed gas consumption (Y-axis) % Line, weight2, horsepower2, acceleration2] = % computeMyMultipleLinearRegression(weight, horsepower, acceleration, milesPerGallon); % kilometerPerLiter = % plot</pre>





#### The Instructor-View of MATLAB Grader – Tests

MATLAB Grader	dreas Apostolatos 🗸	
E CONTENTS Courses & Content   LMS Integration   Documentation & Support +	∨ T	est 1: Is the gas consumption correctly converted in kilometers per liter?
Test 1: Is the gas consumption correctly converted in kilometers per liter?	1	
	(20%)	
1	1 % Get r	reference solution for x.
Test Type	2 % The r	reference values for the variables contained herein are defined in the reference soluti
Variable Equals Reference Solution y 👔	3	
	4 % Compa	are with learner solution.
ariable Name You Want To Compare" 🥥	5 In = gci	, = h Children(1) Children:
kilometerPerLiter	7 if isa	(hLine, 'matlab.graphics.chart.primitive.Line')
	8 if	numel(h) == 1
eedback on Incorrect (in addition to default feedback) 🥥	F€ 9	
■ 🗠 Normal - B I U M 🗄 🗄 🗵 % ‰ 💀 📾 🖉 🖉 Σ	10	% Check the y-values of the data in the figure for the first plot
TEXT CODE INSERT	11	if isprop(hLine(1), 'YData')
he conversion factor for the conversion of the miles per gallon to kilometers per liter is 0.425144		YData = hLine(1).YData;
	13	absessvariableequal( ibaca , ibacakererence);
	<b>T</b> 15	error("Variable 'hLine(1)' contains no Data along the Y-Achse")
	16	end
rielesi 🧭	17	
verance: This test allows for a small difference (+/- 0.1% relative, +/- 0.0001 absolute) between the learner solution and reference solution; for example, to account	for different 18	% Check the x-values of the data for the first plot
plementations of an algorithm. Learn more	19	<pre>if isprop(hLine(1), 'XData')</pre>
	Convert Test To Cod	XData = hLine(1).XData;
		assessVariableEqual('XData', XDataReference);
Test 2: Is the table with the predictors correctly set up?	1 22	error("Variable 'bling(1)' contains no Data along the X_Achse")
	(20%) 24	end
	25 el:	Se
est Type	26	error("The figure contains %i lines, but it should only contain one line", numel(hLin
MATLAB Code	27 end	d
	28 else	
ATLAB Code* 📀	29 err	ror("Variable "hLine" is not a kein LinePlot-object")
1 % Get the reference solution with the variable 'predictorsAndReponse'	30   end	
2 xxeterence = reterenceVariables.predictorsAndReponse; 3		
<pre>4 % Does variable 'praediktoren' exist and does it represent a MATLAB table? s if ~exist('predictorsAndReponse', 'var')</pre>		
<pre>6 error("Set up a variable with the name 'predictorsAndReponse' containing" + 7 "variables 'weight' 'borgenomer' 'arceleration' " +</pre>		
a "and kilometerPeriiter")		Create tests with custom MATLAR code



#### The Instructor-View of MATLAB Grader - Statistics

MATLAB Grader			Andreas Apostolatos 👻
CONTENTS Clos	e Courses & Content LMS Integration	Documentation & Support 👻	
Advanced Finite Element Methods	Advanced Finite Element Method:	s > Locking in the Reissner-Mindli	n Plate Discretizations >
> Basis functions and geometry description	four-noded quadrilatera	al Finite Elements for the	Edit Actions -
> Timoshenko beam theory	discretization of a Reise uniform distributed load	sner-Mindlin plate under 1 - Shear force	
<ul> <li>Finite Element discretization of a Reissn Mindlin plate using four-noded bilinear elements</li> </ul>	er-		
<ul> <li>Locking in the Timoshenko beam discretizations</li> </ul>	Learner Analytics Class Overview Learner Solution	15	
<ul> <li>Locking in the Reissner-Mindlin Plate Discretizations</li> </ul>	Status Summary	Salvad	
Identifying the locking behavior when using four-noded quadrilateral Finite Elements for the discretization of a Reissner-Mindlin plate under uniform distributed load - Shear force distribution	27 Learners are in the course.	10 Learners have solved the pro	Average Submissions ? Required to Pass Each Test
Identifying the locking behavior when using four-noded quadrilateral Finite Elements for the discretization of a Reissner-Mindlin plate under uniform distributed load - Slenderness study	26% - 37	16 10% 13 10% 9 10%	6 5 4 3,4 3,4 3,4 4
Identifying the locking behavior when using four-noded quadrilateral Finite Elements for the discretization of a Reissner-Mindlin plate under uniform distributed load - Convergence study	37%	4 20% 2 10%	3- 2- 1-
Using higher-order basis functions to alleviate locking for the Reissner- Mindlin plate formulation	Solved: 37% (10)	0 10 20 30 40 % Learners	0 - Test 1 Test 3 Test 5 Tests
ADD PROBLEM	Submitted, not solved:		details.
<ul> <li>Variational Formulation of Finite Element</li> </ul>	ts		
> Alternative Finite Element Formulations		Not Solved:	utions but hoven't vet colled the

Fig. Classroom-Statistics in MATLAB Grader

MATLAB Grader
Advanced Finite Element Methods > Locking in the Reissner-Mindlin Plate Discretizations > Identifying the locking behavior when using four-noded quadrilateral Finite Elements for the discretization of a Reissner-Mindlin plate under uniform distributed load - Shear force distribution
Learner Analytics
Class Overview Learner Solutions
Map View     List View       Date Created (Newest - Oldest)       Search by last name, code or ٤
Solution 16: 5 of 6 tests passed (95%) Test Results
Submitted on 21 Nov 2022 by         ID:         Size: 737         ID:         ID: </td
<pre>1 %% Load the precomputed data 2 load data_Locking_ReissnerMindlinPlate_shearForces.mat 3 4 %% 1, Generate a mesh with elements along the x- and y-Cartesian directions 5 [msh_Q1, nodesX, nodesY] = generateBilinearQuadrilateralMeshOnRectangularPlate(X0, X0+XLx, Y0, Y0+YLy, 5,5); 6 7 %% 2. Predict the plate's deformation using the Reissner-Mindlin plate theory 8 freeDOFs_Q1 = (19:33); 9 for i = 2:5 10 freeDOFs_Q1 = [freeDOFs_Q1, 3*(1+6*i)-2:3*(5+6*i)]; 11 end 12 u_Q1 = solve_ReissnerMindlinPlate_over_BilinearFourNodedMesh(msh_Q1,freeDOFs_Q1,propStr); 13 14 %% 3. Generate a sequence of 20 equidistant points spanning the length of the plate along the x- physical directior 15 coordPts = zeros(20,2); 16 coordPts(:,1) = linspace(X0,X0+XLx,20); 17 coordPts(:,2) = Y0+YLy/2; 18 </pre>
19 %% 4. Loop over all the sampling points in coordPts and compute the shear force qx

Fig. Individual-Statistics in MATLAB Grader



## Sample Problems from MathWorks

MATLAB Grader			Andreas Apostolatos 👻
	ses and Collections   LMS-Integration   Documen	tation and Support 👻	
Add Problem			
Sample Problems from MathWor	ks 🕝		
Getting Started with MATLAB Grader 13 Problems	Created By: MathWorks 10 Problems	Statistics Created By: MathWorks 15 Problems	Electric Circuits Created By: MathWorks 16 Problems
<ul> <li>Digital Signal Processing</li> <li>Created By: MathWorks</li> <li>10 Problems</li> </ul>	System Dynamics and Control Created By: MathWorks 10 Problems	Dynamics Created By: MathWorks 10 Problems	Introduction to Programming Created By: Eric Davishahl 111 Problems
Created By: MathWorks 10 Problems	Numerical Methods Created By: MathWorks 10 Problems	Symbolic Math Toolbox Created By: MathWorks 10 Problems	

\*Reach out to a MathWorks representative (<u>aapostol@mathworks.com</u>) to grant you access



#### **Collaboration with other Instructors**

MATLAB Grader				
CONTENTS Close	Courses & Content LMS Integration Documentation & Support -			
	>			
Reorder Content	Collaborate with	Instructors		
				Enroll ≫
	Enroll Instructors		•	0
	Enter comma separated e	email addresses to enroll instructors to coll	aborate with you on your collection.	
ADD GROUP				
Collaborate with Instructors				
			Cancel	Enroll
	Instructors (4)			
	Select None ~			
	Name ?	Enrolled As?	Accessing As (if different)?	

- Use Collections to share
   exercises with other instructors
- Adjust dynamically the access to the shared exercises
- Use Collections as pools of exercises to add to different courses

📣 MathWorks

#### Moodle-Integrated Version of MATLAB Grader





Fig. LMS-integrated Version von MATLAB Grader *Fig.* Transfer of the Grades in the LMS-Grade Book



#### **MATLAB Grader in Practice**



#### Summary

- MATLAB Live Editor enables the standardization of teaching materials
- MATLAB Grader enables, among other:
  - Flipped Classroom among other modern teaching approaches
  - Automatic grading of MATLAB code
  - Preparation of *digital*, *informative*, and *reusable* assignments
    - Immediate feedback
    - Real-time statistics
    - Formative and Summative Assessment
    - Assignment sharing with other instructors
  - Integration into standard LMS platforms (Moodle, Canvas, ILIAS, etc.)
    - Simple assignment distribution
    - *Transfer of grades* into the LMS gradebook