Individualized Assignments and Assessment through Automated Grading

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Outline

- Engineering Computation Lab Course Overview
- Motivation and Learning Approach
- Assessment Methods and MapleTA
- Automated Grading and Individualized Questions
- Case Study – Least Squares

Course Goal and Themes

- For engineering students to become proficient with an industrial grade tool including symbolics, numerics, visualization and scripting that they can use for engineering computation
- Design, Exploration, and Simulation
- Required of all freshmen engineering students (~950/year)

Course Objectives

- Technical
  - Using an interactive CAS for mathematical computations
  - Setting up and using mathematical models
- Programming
    - Assignment, looping, conditionals, functions
    - Data Structures
- Software engineering
  - Developing scripts
  - Testing
  - Troubleshooting
  - Learning from documentation
  - Communicating technical material

Course Organization

- 1 credit hour per term, 3 terms (30 weeks)
- Separate from calculus (math content lags behind one term)
- Meet 2 hours in weeks 2,4,6,8 in lab
- Automated quizzes (Maple TA, web based) in weeks 3,5,7,9 (on-line, any time)
- Exam in week 10 (Maple TA, proctored – 36%)
- Staff: 1 or 2 senior instructors, 4 or 5 instructors, 15+ undergrad assistants

Lab Format

- Prelab readings and preparatory quiz
- Brief introduction to key concepts and themes
  - Powerpoint presentation
- Mixture of tutorials (examples) and problems
  - Teach by example and through problem solving
  - Work in small groups
  - Monitored by instructor and lab assistants
  - Lab verification
  - Follow up quiz
    - Online (with Maple, feedback, and 5 day time limit)

Core Functionality

- Basic expressions
  - variables, symbols, numbers,+-*/^, functions, eval, evalf
- Math solvers
  - solve, fsolve, diff, int, optimization, sum
- Visualization
  - plot, pointplot, display, animate
- programming
  - if, for, while, proc...end, ->, unapply, lists, sequences
- Use it repeatedly in Labs

Computation Lab I Overview '11

- Tutorial Introduction to Maple
  - Worksheet interface, expressions, evaluation
- Equation Solving and Plotting
  - Numeric vs. symbolic
- Curve Fitting – Least Squares method
  - Lists
- Introduction to Programming
  - Working with scripts

Computation Lab II Overview '11

- Additional Programming features
  - if, looping statements
- Simulations utilizing time staged models
- Visualization of solutions using advanced plotting techniques (eg. Parameterized plots), animations

Computation Lab III Overview '11

- Differentiation and Integration
- Optimization of functions
- Spline curve fitting
- Graphical user interfaces
- Programming – use of procedures

Motivation for learning Approach

- Recent literature* re-iterates the value of our key strategies:
  - Value of a quiz based learning experience
    - “interleaving of worked example solutions and problem-solving exercises”
    - “use quizzing to promote learning, re-expose students to information”
    - “use pre-questions to introduce a new topic”
  - Value of an extended learning experience (3 semesters instead of a single term)
    - “space learning over time”

*H. Pashler, P. Bain, B. Bottge, A. Graesser, K. Koedinger, M. McDaniel and J. Metcalfe, Organizing instruction and study to improve student learning: A practice guide (NCER 2004-2007).

Roles of the Assessment Process

- 1 - Determine how effectively course objectives are being met
  - Current objectives focus on “use of an interactive technical computation system to perform calculations necessary for typical undergraduate Engineering problem solving at the 1st year level”
  - Areas encompassed by objectives include:
    - Programming skills
    - Software development concepts
    - Communication – documentation and presentation of solutions
    - Computational modeling techniques

Roles of the Assessment Process

- 2 - Assess effectiveness of applied learning strategies – quiz based approach over extended time frame
  - Introduction – via text readings and preliminary quiz and initial lab exercises
  - Teaching and mastering – via detailed lab problems and comprehensive post lab quizzes
  - Re-enforcement – via follow up quiz examples and (perhaps) small group projects

Roles of the Assessment Process

- 3. Identify opportunities for future course improvement, including:
  - Optimal utilization of limited (time and man power) resources
  - Enhanced effectiveness of quiz examples to teach key concepts
  - Opportunities to provide remedial guidance to targeted students in danger of failing
  - Improved delivery of course activities

Course Tools for Information and Analysis of Instruction and Learning

- Computation Lab uses “off the shelf” information gathering
  - MapleTA
  - bbVista – Drexel’s learning management system
  - AEFIS Course Evaluation system - Drexel University’s system to conduct and report student evaluations for academic courses
- We analyze the information gathered from these sources using standard tools such as Excel.

MapleTA Overview

- Web-based quiz system with Maple backend
  - Enables class and roster management along with provisions to create, conduct and report / store results for individual quizzes
  - Instantaneous feedback, hints, multiple attempts
- Allows for the following types of question creation
  - Multiple choice, matching, true/false
  - Computed solutions to word problems
  - Free form answers checked against patterns and via Maple computation
    - Mathematical formulas
    - Maple code/programs

MapleTA Overview

- Can “individualize” tests at the student level
  - Different parameter values for the same problem
  - Different questions for the same concept
- Provides a wide range of statistics for quizzes

Example – MapleTA Quiz Problem

Maple T.A.

Grade | Refresh | Close

Description: *Potato Problem - Hot Potato 3 (2010)*

Jump To: Question | Information Fields

Question:

Computing the time to bake potatoes.

From Problem 38, chapter 1 review, Anton, Calculus 8th edition.

An oven is preheated and then remains at a constant temperature. A potato is placed in the oven to bake. Food scientists have measured the rise of temperature of a baking potato. They have found that the temperature T (in degrees Fahrenheit) of the potato can be described by the relation given by the equation

$$T = 448 - 379\ 0.97^{t}$$

where t is the amount of time (in minutes) after the potato is put in the oven.

In Maple "1 dimensional (keyboard entry)" syntax this formula is written as

T = 448-379*.97^t

The potato will be considered done when its temperature is anywhere between 260 and 280 degrees Fahrenheit.

Example – MapleTA Quiz Problem

(a) Enter two numbers that are the start and end times of "doneness". Enter an number with decimal point. Your answer will be graded as correct if you are within .1% of the answer computed by Maple.

Doneness begins at t = ________ minutes after the potato is put into the oven.

Doneness ends at t = ________ minutes after the potato is put into the oven.

(b) How long does it take for the difference between the potato's starting temperature and the oven's temperature to be cut in half? Enter an approximate value (with decimal point) correct to within .1% of the correct time (as calculated by Maple).

It takes approximately ________ minutes for the potato's temperature to get half way from its starting temperature to the oven's temperature.

Hints Edit

Hint 1: You can copy and paste the "1d" version of the equation from the web page into Maple, and it should accept it just as if you've typed it in from the keyboard.

Hint 2: For all parts of this question, Maple TA is programmed to accept any answer that is within .1% of what it calculates as the correct answer.

Hint 3: The solve operation on the equation you set up here will have a decimal point answer ... because there is a decimal point in the equation itself.

Hint 4: To do several similar calculations in a row, you can copy and paste the sequence of actions to repeat them. Edit the copies so that they do something slightly different. Then select the whole area with the mouse and use the Edit->Execution->Selection menu item at the top of the Maple window and Maple will do all the operations at once. This can save typing. However, typing in the variations of the equation to solve for (a) and (b) and solving them individually will also work.

MapleTA Question Parameterization

Algorithm Edit

```
$ovenTemp = range(350,450)
$startTemp = range(68,85)
$delta = $ovenTemp-$startTemp
$coef = range(80,98)/100
$doneLow = 260
$doneHigh = 280
$formula = maple("$ovenTemp-$delta*$coef^t")
$lowTime = maple("fsolve($doneLow = $formula,t)")
$highTime = maple("fsolve($doneHigh = $formula,t)")
$midTemp = $delta/2+$startTemp
$midTime = maple("fsolve($midTemp = $formula,t)")
$qml = maple("MathML[ExportPresentation](T = $ovenTemp-$delta*$coef^t)")
$eq = maple("T = $ovenTemp-$delta*$coef^t")
```

MapleTA Question Selection

Question Name: Parameter ver2

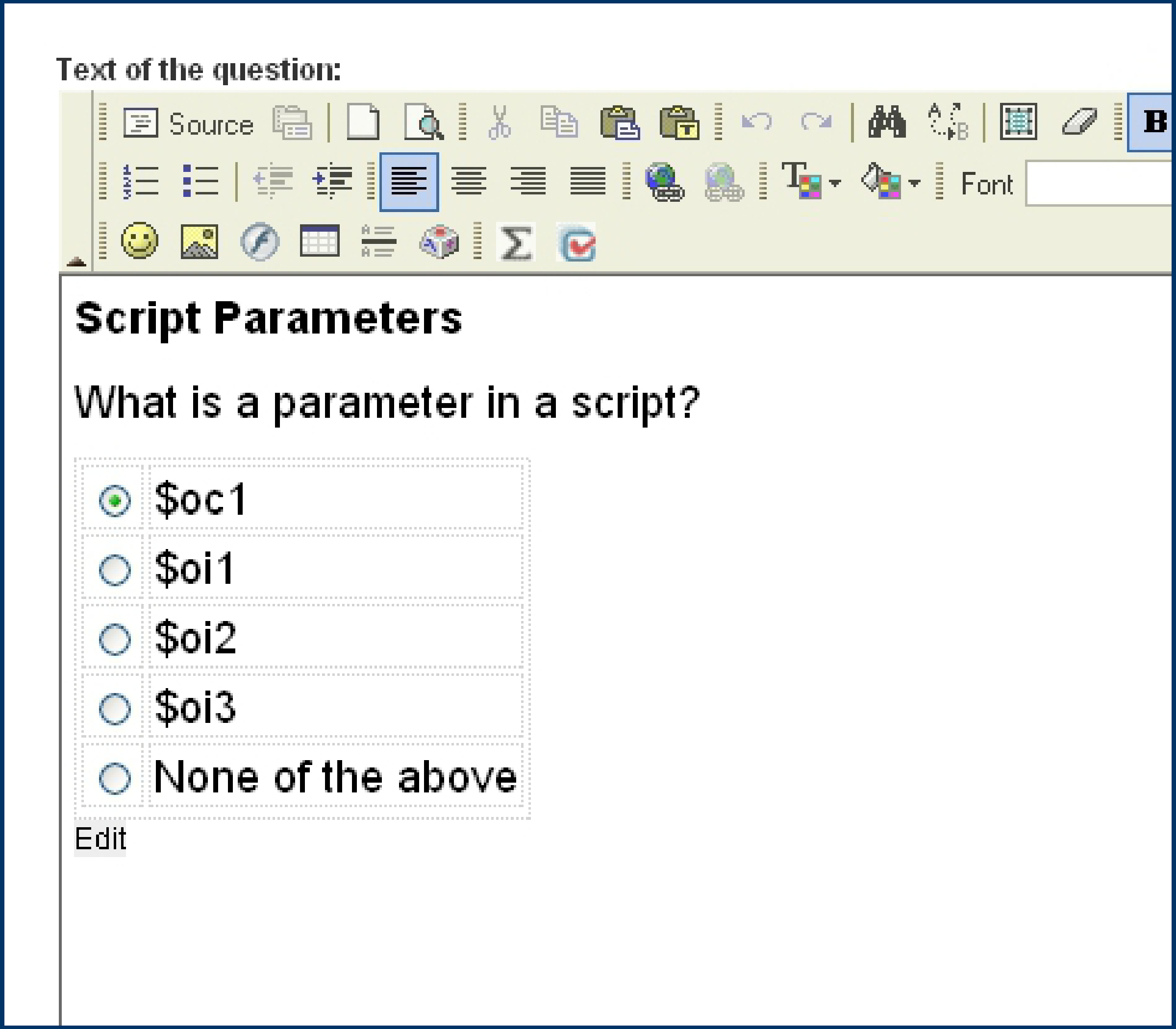
Script Parameters

What is a parameter in a script?

- ○ Typed characters such as parentheses or square brackets that bound pieces of an expression
- ○ Variables that you assign at the beginning of a script
- ○ Equations used in the description of a problem
- ○ The things that don't change between different versions of a problem
- ○ None of the above

```
$correct=maple(" [ `Something that changes between different versions of a problem ` ,`Variables that you assign at the beginning of a script` ] " ) ;
$chooseCorrect=range (1, 2) ;
$oC=$chooseCorrect; $oc1=maple("printf(convert($correc t[$oC], string) )");
........
```

MapleTA Question Selection



Example – MapleTA Quiz Statistics

Question	Description	Success rate	p-Value	d-Value	Count	Correct	Partial	Incorrect
(1)	Sensor2	0.845	0.744	0.67	801	596	133	72
(2)	Fibonacci with Loops	0.864	0.816	0.48	801	654	66	81
(3)	Temperatures 1	0.792	0.76	0.627	801	609	51	141
(4)	Blammo Find Velocity 2	0.752	0.752	0.65	801	602	0	199

Success Rate = points awarded/total points
p-Value = percentage of correct answers
d-Value = discrimination measure

Benefits of a Large Sample Size

- Each Computation Lab class consists of between 800 to 1000 students, divided into sections of 32 students.
- The raw data and subsequent refined information is the composite of a significant number of observations.

Case Study

Using the Least Squares Curve Fitting Concept To Demonstrate Drexel's Computation Lab Learning and Assessment Approach

Computation Lab Learning Approach

- Current Computation Lab teaching model
  - Introduce the concept
  - Formally teach / master the key principles
  - Test effectiveness of the learning experience
  - Re-enforce the imparted knowledge
- Note that all phases of this approach employ quizzes to facilitate the learning process

Cycle of Activities (2 week)

- Pre-lab activities
  - Read text materials
  - Take pre-lab quiz – how thoroughly have materials been reviewed (MapleTA)
- Lab period
  - Lecture – formal introduction of key concepts
  - Introductory exercises – practice basic principles using technical tools (Maple)
  - Lab examples – solve engineering / math based problems utilizing concepts (Maple)

Cycle of Activities (cont)

- Post lab activities
  - Take post lab quiz
    - Additional opportunities to practice concepts
    - Opportunity to display mastery of topics
- Beyond the 2 week lab cycle
  - Proficiency exam (end of term)
    - Test mastery and retention of key concepts taught
  - Future quizzes
    - Re-enforce important principles learned in prior labs
  - Special projects
    - Additional opportunity to re-enforce key concepts in future labs

Case Study - Least Squares

- Overview of the Least Squares Algorithm
  - Produces a “best fit” linear expression in the form
    - Dependent variable = a + b * Independent variable

    for a list of ordered pairs [independent, dependent]
  - Curve fitting is taught in Computation lab at Drexel
    - CS121 – Least Squares (Ideal Gas Law)
    - CS123 – Spline curve fit
  - Curve fitting is utilized in Drexel's freshman engineering design lab sequence
    - Exponential curve fit to model capacitor charge and heating profiles
    - Linear curve fit to correlate actual versus measured distances for robot light sensors

Case Study - Least Squares

- Teaching the Least Squares (LS) algorithm in Computation Lab encompasses the following 4 learning objectives:
  - O1. Math basis for LS analysis – nature of the computation and significance of the resulting expression
  - O2. Mechanics for using the LS algorithm in Maple
    - Loading Maple's "CurveFitting" package
    - Executing the LS algorithm to produce the linear curve fit expression
    - Evaluating the resulting expression and solving for the dependent and independent variables
  - O3. Application to practical problems
  - O4. Using Maple's "Help" feature to learn about LS curve fitting

Case Study - Least Squares

- How the Computation Lab cycle facilitates teaching and realizing the LS learning objectives
  - Pre-lab readings
    - O1 – discussion of LS math basis and purpose
    - O2 – examples demonstrating LS mechanics
    - O3 – practical examples
    - O4 – introduction to Maple's "Help" feature
  - Pre-lab quiz
    - O1, 2 and 4 – questions to re-iterate the readings
    - O2 – simple example – given a table of data (independent vs. dependent variables), execute the LS algorithm (Maple) and enter the result into the quiz (MapleTA)

Case Study - Least Squares

- How the Computation Lab cycle facilitates teaching and realizing the LS learning objectives
  - In class lab – lecture portion
    - O2 – hands on exercises to practice the Maple mechanics for a simple table of data
    - O4 – have students invoke and peruse Maple's “Help” feature for LS documentation
  - In class lab – lab problems
    - O2 – generate the LS expression for a practical example
    - O3 – evaluate the expression, solving for dependent and independent variables
    - O4 – students use the “Help” feature as necessary

Case Study - Least Squares

- How the Computation Lab cycle facilitates teaching and realizing the LS learning objectives
  - Post Lab quiz
    - O2 – re-enforce the LS mechanics to solve problems similar to those encountered in lab
    - O3 – evaluate the LS expression, solving for variables for typical queries associated with practical examples
    - O4 – students use the “Help” feature as necessary
  - Downstream re-enforcement
    - O2 – proficiency exam to demonstrate mastery of concept at end of term
    - O2, 3 – inclusion of LS concept in future labs and/or projects (eg. comparison of LS versus Spline fit results)
    - O2, 3 – future quiz problems to support retention of concept

Maple T.A. - - Mozilla Firefox

https://mapleta.cs.drexel.edu:8443/mapleta/contentmanager/DisplayQuestion.do?actionID=display&annotate=enter&

MapleT.A.

Grade | Refresh | Close

Description: *least squares 1 (2010)*

Jump To: Question | Information Fields | Annotations

Question:

The public health authorities of the country of Veliki Sira have measured life expectancies in their country over the past several decades:

Year of Birth	1930	1940	1950	1960	1970	1980	1990	2000
Life Expectancy	61.80	65.10	70.80	72.70	75.00	77.20	79.10	79.80

The data can be summarized as two lists:

years := [1930, 1940, 1950, 1960, 1970, 1980, 1990, 2000]
lifeExpectancies := [61.80, 65.10, 70.80, 72.70, 75.00, 77.20, 79.10, 79.80]

(a) Enter the coefficients for the formula produced by least squares data fitting for the line a + b*t that describes the life expectancies *L* as a function of time *t* . The number for each coefficient should be expressed as a number that has at least two decimal places to the right of the decimal point.

L(t) = ____ + ____ * t

Done | mapleta.cs.drexel.edu:8443

https://mapleta.cs.drexel.edu:8443/mapleta/contentmanager/DisplayQuestion.do?actionID=display&questionId

(b) What does this formula predict is the life expectancy for the year 2007? Enter a number that has at least two places to the right of the decimal point.

(c) When does this formula predict that the life expectancy in Veliki Sira will reach 87? Enter a whole number corresponding to the year when the life expectancy reaches this target. Round down to the nearest year.

(d) When does this formula predict that the life expectancy will reach 91? Enter a whole number corresponding to the year when the life expectancy reaches this target. Round down to the nearest year.

(e) What does this formula predict the life expectancy will be in the year 2015?

Information Fields:

quiz	quiz 3

Done

mapleta.cs.drexel.edu:8443

Maple T.A. - - Mozilla Firefox

https://mapleta.cs.drexel.edu:8443/mapleta/contentmanager/DisplayQuestion.do?actionID=display&qu

Question:

Building a script to fit a line to data, and answering questions about the situation that the line models.

You are measuring the properties of a collection of distance sensors. Because of imperfections and limitations in the technology, the distance a sensor reports may differ significantly from the actual distance. You have performed experiments on each sensor in the collection.

For each sensor, you have taken a series of readings where you measure a distance from a target, place the sensor there, and record what its reading is. You have recorded the results as a list of ordered pairs (a list of lists). The first number in each pair is the actual distance a, the second number is the sensor's reading of the distance b.

For each series of readings, you wish to compute with Maple the "trend line": the formula of the general form $c1 + c2\, a$ where c1 and c2 are calculated to be the least squares fit of the data. You will use the formula to help you understand some properties of the sensor.

For example, for experimental measurements [[2.000, 4.473], [7.000, 7.845], [11.000, 11.344], [20.000, 17.756], [27.000, 23.241], [31.000, 25.554], [39.000, 32.652]], we would have the following result for the trend line:

Done | mapleta.cs.drexel.edu:8443

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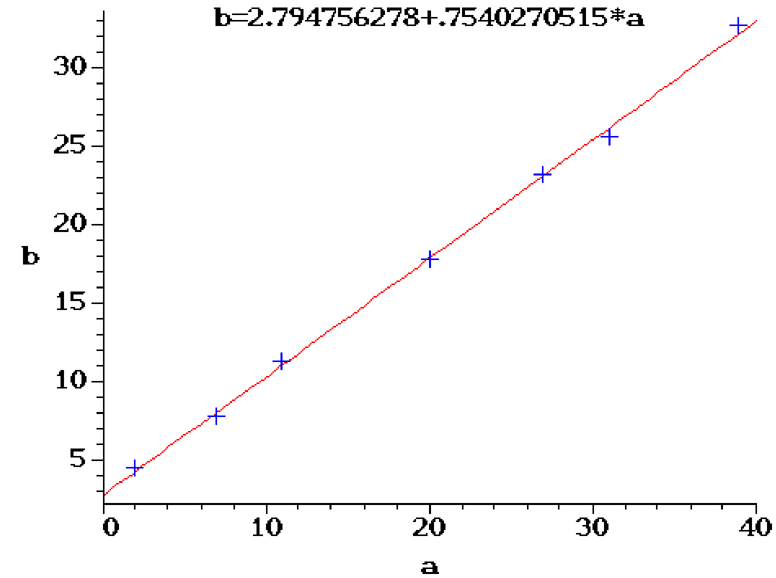

The first sensor in your collection had these readings: [[9.000, 7.670], [11.000, 8.722], [12.000, 9.413], [22.000, 15.516], [34.000, 22.246], [35.000, 22.591], [36.000, 23.507], [39.000, 25.062]] .

(a)

Fill in the blanks to create a Maple expression that creates the least squares fitted trend line for the data with independent variable a.

CurveFitting[______](______ , a);

Done | mapleta.cs.drexel.edu:8443

Case Study - Least Squares

- How we can measure the effectiveness of meeting the objectives for the LS concept
  - Measuring initial learning experience
    - Pre-lab quiz results – no current data on LS problem
    - Lab verification score – nearly 100% success rate for 3 person teams
  - Measuring retention between 1st encounter and end of term
    - Fall, 2010 – post-lab quiz (874 students) – 87.0%
    - Fall, 2010 – end of term proficiency exam (551 students) – 81.2%
  - Measuring longer term retention
    - Fall term, 2010 – post-lab quiz (874 students) – 87.0%
    - Winter, 2010 – review problem in post-lab quiz (802 students) - 86.3%

Future Direction - What's Next

- More diagnostic tools and better remediation
  - On the fly question selection based on previous results
- Better management of quiz questions
  - Searchable with meta data (multiple versions)
  - Catalogue questions based on learning objectives
- Maple TA improvements
  - Better programming support (esp. for novices)
  - Continued development (bug fixes) of Maple TA
    - Improved scalability, verification, fault tolerance
- Coordination with other Engr/Math/Sci courses