Data Analysis using Excel (weeks 2 and 3)

- Data Analysis
- Histogram
- Descriptive Statistics
- Correlation
- Fitting Equations to Data
- Solving Equations
- Matrix Calculations
- Finding Optimum Solutions
- Financial functions
- Look-up functions
- What-if analysis
- Testing/Debugging/Auditing Spreadsheets
Data Analysis

- Data analysis techniques allow professionals like engineers, social scientists and economists to extract meaningful information from a (typically) vast amount of data.
- Excel is widely available, and provides useful functions/features for data analysis.
- Some of these functions/features include:
  - Histogram
  - Descriptive Statistics
  - Correlation
  - Regression Analysis
  - Iterative Solutions: Solving Equations
  - Iterative Solutions: Optimization Problems
  - Some Advanced Functions/Features
  - Matrix Calculations
  - Using Charts
- See Topics 3, 4, 5 and 6 in the textbook.
Analysis Toolpak in Excel

- Analysis Toolpak is an add-in package for Excel. You need to activate it using Excel Options/Add-Ins (via the File menu in Excel 2010, or the Office button in 2007).
- Make sure that both the Analysis ToolPak and Solver Add-in are in the “Active Application” list, otherwise click Manage Add-ins.
- For more info see “Enable or disable add-ins” in “Excel Help”.
- The Analysis Toolpak provides tools to help users to quickly and easily carry out reasonably complex data analysis tasks.
- It provides support for many popular statistical and engineering data analysis tasks.

Note: Excel's statistics algorithms are not sufficiently robust for use by professional statisticians (but they're OK for normal purposes)
Histogram

- A **histogram** is a graphical representation of a **frequency distribution**.
- A process of creating a histogram requires a user to provide "**bin**" values. Data values are aggregated/separated into classes based on these bin values. In a histogram, each bar represents one bin, and the height of the bar represents the frequency of that bin.

**Demonstration**......

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Bin

frequency

Cumulative %

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Descriptive Statistics

- Excel provides many **predefined statistical functions** to calculate useful information like: mean, max, min, median, standard deviation, etc.

- Often a user wants to calculate most commonly used statistical functions (like the functions described above) for a given data set in order to get some **description** of the data set.

- Excel provides a tool called “**Descriptive Statistics**” that calculates such commonly used statistical functions for a given data set and produces a useful report.

- Alternatively, a user can apply each function individually and calculate the required information. Obviously this may prove very time consuming and tedious!
Descriptive Statistics

- Demonstration …..

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<tr>
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Correlation

- **Correlation** is a statistical measure referring to the strength of linear relationship between two or more variables.

- It can vary from -1 (perfect negative correlation) through 0 (no correlation) to +1 (perfect positive correlation).

- Excel provides a tool called “Correlation” that can calculate correlations between two or more variables.

- Alternatively, a user can plot a chart for two or more variables and try to visually identify possible correlations between variables.
Fun examples of correlation

New England Journal of Medicine

http://pubs.acs.org/doi/abs/10.1021/ci700332k
Correlation

- Demonstration …….
Fitting Equations to Data

- The method of least squares tries to fit a curve (including a straight line) through an aggregate of data. It tries to find a simple relationship among variables and express the relationship as an equation.
- The “best-fit” curve is the one that minimises the sum of the squares of the residuals (differences between data and the predicted value).
- Two approaches in Excel:
  - Using “Trendlines” on charts (preferred for casual use)
  - Using the “Regression” tool (gives more stats)
- If we do not need a lot of information about the regression, we can use Trendlines on charts. They provide the basic equation and $R^2$ value, and show the regression line superimposed on the data values.
- The $R^2$ value (varies from 0 to 1) indicates how well the model fits the data. $R^2 = 1$ indicates that the regression line (curve) is a perfect fit to the data.
- See Topic 4 in the textbook.
- Demonstration…..
Fitting Equations to Data

Equation:

\[ y = 0.5571e^{0.4057x} \]

\[ R^2 = 0.9949 \]

Trendline:

Excel Graph with Trendline Options.
Fitting Equations to Data

- Calibrating an old device:

  - **Expected Relationship:**
    \[ Y = 1.2X^2 + 5 \]

  - We can derive the actual relationship from the trendline as below:

  \[
  y = 1.3712x^2 + 0.5339x + 4.5291 \\
  R^2 = 0.9984
  \]
Fitting Equations to Data

- The Analysis Toolpak offers the tool called “Regression” to compute regression analysis.

- The ‘Regression” tool provides many statistical values, many of which will only be meaningful once you’ve done future studies in statistics and regression analysis (second year in most engineering programs).

- Quick demonstration ....
Fitting Equations to Data

Functions in Excel:

• **FORECAST**  Returns a value along a linear trend
• **GROWTH**  Returns values along an exponential trend
• **TREND**  Returns values along a linear trend
• etc .. etc .. etc
• Again using the interactive tools with a chart is probably better in the short term.
What is company X?

THE $25,000,000,000* EIGENVECTOR
THE LINEAR ALGEBRA BEHIND X

• The message behind the headline is:
  – The founders of company X came up with a brilliant equation
  – The solution of the equation turned company X into a $25B
    business in 2004. (About $230B in March 2013.)

• A lot of complicated equations can be solved automatically and routinely by computers nowadays
  – Know what computational tools are available
    • Excel may not be robust for all purposes, there are other tools. More in Week 12.
  – Make your own tools only if necessary

• Difficulty is in coming out with useful and insightful equations that can transform the world
Solving Equations in One Variable

• Finding the roots of an equation can sometimes, but not always be done analytically, but if not we need other approaches.

• **Graphical Solutions:**
  - One of the ways to find a possible root(s) of a given equation is to assign different values to a variable (say \(x\)), calculate the corresponding function values (say \(f(x)\)), and plot a graph for \(f(x)\) vs \(x\). Now try to see where the chart line intersects with the \(x\)-axis!
  - This approach is **useful** when we can **guess a finite interval(s)** within which to search for possible root values.

• See **Topic 6** in the textbook.
Solving Single Equations

\[ f(x) = 4x^3 + 12x^2 - 64x + 16 \]
Solving Single Equations

- Using **Goal Seek** (Tools - Goal Seek)
  - **Goal Seek** will try to find input values of an equation when the results are known. It starts with a provided initial guess for an input value, and uses iterative refinement to find a solution.
  - If an initial guess is not close enough, **Goal Seek** may not be able to find a solution.
  - **Goal Seek** tries a fixed number of iterations (attempts at getting closer to the goal) and stops after that, even if the equation is not solved.
  - "**Solver**" tool is more powerful than "**Goal Seek**" tool.
  - **Demonstration** .....
Solving Single Equations

- Using **Goal Seek**

\[ f(x) = 3x^3 + 2x^2 + 4 \]

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<th>f(x)</th>
</tr>
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<tbody>
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<td>2</td>
<td>36</td>
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\[ f(x) = 3x^3 + 2x^2 + 4 \]

<table>
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<th>X</th>
<th>f(x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.37347</td>
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Optimisation problem

- Becky’s dream is to study Engineering at UNSW because it is perfect in every way …

<table>
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<th>ATAR score ((x_1, x_2, x_3, x_4, x_5))</th>
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<tbody>
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<td>(x_1) hours/week on English</td>
<td></td>
</tr>
<tr>
<td>(x_2) hours/week on Maths</td>
<td></td>
</tr>
<tr>
<td>(x_3) hours/week on Physics</td>
<td></td>
</tr>
<tr>
<td>(x_4) hours/week on Hockey</td>
<td></td>
</tr>
<tr>
<td>(x_5) hours/week on Cello</td>
<td></td>
</tr>
</tbody>
</table>

\[
x_3 \geq 5 \\
x_4 + x_5 \leq 5
\]

\(\leftarrow\) Objective

To maximise in this example, but for some other problems, it may be more appropriate to minimise

\[
x_1, x_2, x_3, x_4, x_5
\]

Decision variables

Constraints
Finding Optimum Solutions

• Excel’s **Solver** (Tools - Solver) tool allows users to solve constrained nonlinear optimization problems.

• First make sure that Solver is installed. If not, select Tools - Add-Ins and install it.

• Often we want to maximize or minimize a value of a variable or a function. Such a function is called an **objective function**. For example, we may want to maximize our profit OR say minimize cost.

• In case we cannot find the best solution, often we are also interested in “**optimal**” solutions.

• In Solver, we provide the following:
  – Optimization function
  – Set of input variables (that could be changed)
  – Set of constraints to be satisfied

• See **Topic 6** in the textbook.
## Finding Optimum Solutions

### Demonstration....

This example is from the book: *Microsoft Office System Inside Out, 2003 Edition* by Michael J. Young and Michael Halvorson.
Finding Optimum Solutions

- Options for Solver:

  - Defaults are OK for simple problems but can reduce tolerance.
  - Problem-dependent options allow for convergence issues.
  - Select if convergence is very slow.
  - Adjust if Solver fails to obtain a solution (see Help).
Solving Optimization Problems

• Find the values of $x$ and $y$ that maximize
  \[ f(x,y) = \sin(x) \times \cos(y) \]

Fig 9.50 on page 221 of the textbook
Solving Optimization Problems II

• Given experimental data for a system described by a mathematical model with several parameters, Solver may be able to identify the parameter set that best fits the data.

• Example *: viscosity of a non-Newtonian fluid is described by the Carreau-Yasuda equation:

\[
\eta = \eta_\infty + (\eta_0 - \eta_\infty) \left(1 + (\gamma \lambda)^a\right)^{\frac{n-1}{a}}
\]

where \( \gamma \) (shear rate, units of \( \text{s}^{-1} \)) is the independent variable and \( \eta \) (viscosity, units are poise, equal to \( 0.1 \text{Pa s} \)) is the dependent variable. There are five adjustable parameters as shown

* This example is by Prof Faith Morrison, Chem Eng at Michigan Technological Uni
www.chem.mtu.edu/~fmorriso/cm4650/Using_Solver_in_Excel.doc
Viscosity example, continued

• Data: measured shear rates and viscosities.
• Set up the 5 parameters in named cells
• Calculate: viscosity predicted by the model for each $\gamma$
• Calculate: the square of the differences for each point
• Set up a cell to hold the sum of the squares (to be minimised)
• Start Solver, identify target cell, minimise, constraints (all non-negative), adjust options to improve results (see workbook)
Matrix Operations

- Excel provides all the standard matrix operations like: add, multiply, inverse, transpose, determinant, etc.

- Excel uses the term **arrays** to refer to a collection of values that should be kept together.

- In Excel, both **vector** and **matrix** are considered as arrays.

- We can provide a **name to an array**, using Insert/Name/Define. This may make your spreadsheet easier to read/understand. However, note that we do not have to name arrays in order to use matrix functions.

- Need to use **Ctrl-Shift-Enter** to enter arrays

- Basic Matrix Operations: add, scalar multiplication,
  - *Demonstration* ....
Matrix Operations

- **Matrix (Linear Algebra) Functions**
  - **MMULT**\((M_1, M_2)\)
    Returns the matrix product of two matrices \(M_1\) and \(M_2\).
  - **MINVERSE**\((M_1)\)
    Returns the inverse matrix for matrix \(M_1\).
  - **TRANSPOSE**\((M)\)
    Transposes matrix \(M\)
  - **MDETERM**\((M)\)
    Returns the determinant of matrix \(M\)

- See [Topic 3](#) in the textbook.
- Also see [Microsoft Excel Help](#) for more on the above Matrix operations
- *Demonstration*...
Solving Simultaneous Equations

- Using Matrix operations:

\[
\begin{align*}
\text{Using Matrix operations:} & \\
&M V = b \\
&M^{-1} V = b \\
&M^{-1} = \text{MINVERSE}(M) \\
&M V = \text{MMULT}(M^{-1}, b) \\
\end{align*}
\]
Solving Equations in Excel Using Solver

• In Solver we can specify
  – constraints on the independent variables.
    For example, \( X \geq 0 \)
  – convergence criteria
  – Etc …

• **Simultaneous Equations**
  – Solver could be used to solve linear as well as nonlinear simultaneous equations.
  – One way to do this is to force the following function \( Y \) to zero:

\[
Y = f_1^2 + f_2^2 + \ldots + f_n^2
\]

where \( f_1, f_2, \ldots, f_n \) represent the equations
Excel offers a wide range of financial functions. For example:

- **PMT**(\(i, n, P\))  
  Returns the periodic (e.g. monthly) payment for an \(n\)-payment loan of \(P\) dollars at interest rate \(i\).

- **FV**(\(i, n, A\))  
  Returns the future value of a series of \(n\) payments of \(A\) dollars each at interest rate \(i\).

- **PV**(\(i, n, A\))  
  Returns the present value of a series of \(n\) payments of \(A\) dollars each at interest rate \(i\).

- Etc .. Etc ….

- **See pages 90-91 in the textbook.** Also see Microsoft Excel Help for more on the above and other Financial functions.
Lookup Functions

• **VLOOKUP** (lookup_value, table_array, column_index_num, range_lookup)

  Searches for a value in the leftmost column of a table, and then returns a value in the same row from a column (whose index number you provide) in the table.

• See also **HLookUp**

• *Demonstration* ....

• See pages 84-86 in the textbook, and also **Microsoft Excel Help** for more on the above and other lookup functions
More on what-if analysis

- **Goal Seek**: we discussed this already
- **Solver**: we discussed this already
- **Data tables**:
  - A data table is a range of cells that shows how changing certain values in your formulas affects the results of the formulas.
  - Data tables provide a shortcut for calculating multiple versions in one operation and a way to view and compare the results of all of the different variations together on your worksheet.
  - See **Microsoft Excel Help** for more details on how to create and use data tables.
More on what-if analysis

- **Scenario:**
  - A scenario contains a set of values that Microsoft Excel saves and can substitute automatically in your worksheet.
  - You can use scenarios to forecast the outcome of a worksheet model.
  - You can create and save different groups of values on a worksheet and then switch to any of these new scenarios to view different results.
  - See Microsoft Excel Help for more details on how to create and use scenarios.
  - Data tab – What-If Analysis – Scenario Manager
Testing/Debugging/Auditing Spreadsheets

- In spreadsheets, computational steps are often scattered across a wide range of cells and even across many spreadsheets.

- It is very easy to make mistakes while developing a solution in Excel. Therefore, it is essential to thoroughly test your solutions.

$24-million spreadsheet “clerical error”

June 03, 2003 TORONTO (Reuters) - TransAlta Corp. said on Tuesday it will take a $24 million charge to earnings after a bidding snafu landed it more U.S. power transmission hedging contracts than it bargained for, at higher prices than it wanted to pay.

 [...] the company's computer spreadsheet contained mismatched bids for the contracts, it said. "It was literally a cut-and-paste error in an Excel spreadsheet that we did not detect when we did our final sorting and ranking bids prior to submission," TransAlta chief executive Steve Snyder said in a conference call. "I am clearly disappointed over this event. The important thing is to learn from it, which we've done."
Testing/Debugging/Auditing Spreadsheets

• From “How do you know your spreadsheet is right?: Principles, Techniques and Practice of Spreadsheet Style” by Philip L. Bewig, July 28, 2005 (available at http://www.eusprig.org/hdykysir.pdf):
  – A **missing minus** sign caused Fidelity’s Magellan Fund to overstate projected earnings by **$2.6 billion (yes, billion)** and miss a promised dividend.
  – Falsely-linked spreadsheets permitted **fraud totaling $700 million** at the Allied Irish Bank.
  – **Voting** officials reported spreadsheet **irregularities** in New Mexico and South Africa.

• More examples (again a few years old) from the same source *European Spreadsheet Risks Interest Group* (yes, the organisation does exist):  http://www.eusprig.org/stories.htm

• Survey of error rates in spreadsheets:
  http://panko.shidler.hawaii.edu/ssr/Mypapers/whatknow.htm
Testing/Debugging/Auditing Spreadsheets

- So……. **Test, Test, Test,** …….. your solutions ……!!

- Test your solution for **obvious mistakes**, like:
  - invalid or missing data in a cell
  - formula is replaced a constant in a cell
  - incorrect cell references in a formula (due to incorrect usage of relative/mixed/absolute addressing while copy and past actions)
  - Etc .. Etc ..
Testing/Debugging/Auditing Spreadsheets

- Test your solutions for **different input values**. In particular, use borderline cases and abnormal input values.

- IMPORTANT: use an **alternative method** (say by hand or using a different approach) to compute few answers, and make sure that your solutions are correct.

- Try to keep **input**, **processing** and **output** regions of your spreadsheet **separate**.

- Be creative!… use IF statements, Conditional Formatting, Statistical functions, etc to **locate errors**.

- Test, Test, Test… !!
Excel Provides some **debugging tools**:

- **Debugging by Using Cell Selection**
  - Select **Home/Editing/Find and Select/Go To Special**
  - You can now locate cells with blanks, formulas, constants, etc.
  - You can locate cells that are “**different**” in a given range
  - You can also locate **Precedents** and **Dependents** of a given cell
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- Debugging by Using Tracing
  - Select Formula/Trace Precedence and Formula/Trace Dependents