Problem Set 05 · Non-Linear Regression

Instructions:

1. Each problem in this problem set has a set of deliverables for you to submit. You are responsible for following the appropriate guidelines and instructions below. Create appropriately-named files as instructed.

2. Save all files to your Purdue career account in a folder specific to PS05.

3. Compress all deliverables into one zip folder named **PS05_yourlogin.zip**. Submit the zip file to the Blackboard drop box for PS05 before the due date. *REMEMBER*:
    - Only include deliverables. Do not include the problem document, blank templates, etc.
    - Only compress files into a .zip folder. No other compression format will be accepted.

Deliverables List

Item	Type	Deliverable
Problem 1: Wabash River Streamflow	Individual	PS05_wabash_streamflow_excel_*yourlogin*.xlsx
Problem 2: Headphone Volume Control	Individual	PS05_volume_control_*yourlogin1*_*yourlogin2*.m PS05_volume_control_ *yourlogin1*_*yourlogin2*_report.pdf All data files that are loaded into your m-file

Formatting Reminder

Always format your text, plots, and numerical outputs in a professional manner.

- Numerical values must have a reasonable number of decimal places and include units when necessary.
- Displayed text should be descriptive and professional. Use complete sentences.

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Problem 1: Excel – Wabash River Streamflow

Individual Analysis

Learning Objectives

Non-Linear Regression	13.02 Identify function types from graphs of bivariate data, specifically linear, power, exponential, and logarithmic
	13.03 Confirm function identification using a combination of linear and log transformations of the independent and dependent data variables
	13.05 Create plots with linear and/or log axis scales (Excel)
	13.07 Linearize and plot data appropriately
	13.08 Linearize a power, exponential, and logarithmic functions
	13.09 Determine the linear and general forms of the equations for linear, power, exponential, and logarithmic functions
	13.11 Use the function to make predictions only when appropriate

Problem Setup

The Wabash River Enhancement Corporation (WREC) is creating a strategic plan to develop the Wabash riverfront and needs to understand how the river's flow rate changes as the water level increases. This information will help engineers and designers find safe, durable solutions to enhance both Lafayette and West Lafayette river areas.

The nearest United States Geological Survey (USGS) streamgage to Lafayette is located at the Brown Street Bridge, which is gage for the whole Greater Lafayette area. A gage reading of 11 ft indicates minor flood stage - a water level that mainly affects low-lying agricultural land. Moderate flood stage is at 18 ft, which starts to affect usage of North River Road. A major flood would begin at 26 ft.

Continuous measurement of river streamflow isn't feasible. So, the USGS measures river height and uses that, along with information about a river's shape, size, slope, and channel roughness, to model streamflow. You have been provided with several months of USGS daily river height measurements and estimated streamflow rate values generated from the USGS model, in a data file named **Data_Wabash_River.csv**. Your task is to create your own model of the relationship between river height and streamflow for this area of the Wabash River, which will allow you to predict streamflow rates given river height.

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Problem Steps

1. Open the Excel template file and fill out the appropriate header information. Save the Excel workbook as instructed in the Deliverables list. Use this workbook to complete all of your computational work for this problem.
    a. Complete your work in the appropriate section of the sheets. You can add extra columns to a section as needed, but do not change the order of the sections.
2. Create four plots to visualize how river height affects streamflow. Plot the data using appropriate linear and/or log scaling. Organize your plots on the ***Streamflow Regression*** sheet. Be sure to label the plots for technical presentation, paying particular attention to the labels on the x- and y-axes.
    a. Plot 1: linear scale on the x- and y-axes
    b. Plot 2: log scale on the x-axis, linear scale on the y-axis
    c. Plot 3: linear scale on the x-axis, log scale on the y-axis
    d. Plot 4: log scale on the x- and y-axes
3. Use the plots to diagnose the type of function that best represents the relationship between the data. On the ***Analysis Questions*** sheet of your Excel workbook answer the following
    Q1: Based on your plots of the data using the four different axis scaling options, which type of function do you think best represents the data? Provide a reason for your selection by making reference to the plots and the axes' scaling.
4. In the Linearization section of ***Streamflow Regression*** sheet, linearize the data and plot it on linear x- and y-axes scales. Be sure to label the plots for technical presentation, paying particular attention to the labels on the x- and y-axes. This will be Plot 5.
5. Use Excel to add a regression line to the data on Plot 5. Show the trendline equation and r-squared value on the plot. Use clear, appropriate variable names in place of x and y in the equation.
6. On the ***Analysis Questions*** sheet of your Excel workbook answer the following:
    Q2: Determine the model (i.e., general form of the equation) from the function you diagnosed in Q1. Show work as necessary. Manage the decimal precision of the coefficients.
    Q3: As appropriate, use your model to predict the streamflow of the Wabash for the following river heights:
        2 ft (Low river height)
        6 ft (normal river height)
        12 ft (Minor flooding)
        18 ft (Moderate flooding)
        26 ft (Major flooding)
    Use the ***Model Calcs*** worksheet to perform your streamflow prediction calculations.

Image reference:
http://www.wabashriver.net/

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Problem 2: Headphone Volume Control

Paired Programming

Learning Objectives

Scripts	04.00 Create and execute a script
Variables	02.00 Assign and manage variables
Arrays	03.00 Manipulate arrays (vectors or matrices)
Text Display	05.00 Manage text output
Import Data	06.00 Import numeric data stored in .csv and .txt files
Plotting	07.00 Create and evaluate x-y plots suitable for technical presentation
Linear Regression	12.16 Compare data sets based on their best fit linear models and r-squared values
Non-Linear Regression	13.02 Identify function types from graphs of bivariate data, specifically linear, power, exponential, and logarithmic
	13.03 Confirm function identification using a combination of linear and log transformations of the independent and dependent data variables
	13.06 Create plots with linear and/or log axis scales (MATLAB)
	13.07 Linearize and plot data appropriately
	13.08 Linearize power, exponential, and logarithmic functions
	13.09 Determine the linear and general forms of the equations for linear, power, exponential, and logarithmic functions
	13.11 Use the function to make predictions only when appropriate

Problem Setup

Designing control systems for electronic devices requires an engineer to understand the relationships between power and device output, such as heat, light, or sound. Many of these relationships are not linear; however, an engineer may want a control system, like a volume knob or a dimmer switch, to produce a linear response that meets the expectations of users.

You and your teammate work for headphone company, which is designing two new prototypes that need volume control systems. The company has collected experimental data in their testing lab for the two prototype designs (Design OEP4 and Design IEP3) and has sent it to you in a file named **Data_volume_power.csv**. They need you to determine the relationship between power and volume for each design.

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Problem Steps

1. Open **PS05_volume_control_template.m** and complete the header. Save it using the name indicated in the Deliverables list. Use programming standards to place code in the appropriate sections within the template.

    a. Create a figure with 2x2 subplots (i.e. 2 rows and 2 columns) that contain plots of the data on linear, semilogx, semilogy, loglog scales. Each subplot must display the data for both headphone designs. Format the subplots for technical presentation, paying particular attention to the labels on the x- and y-axes.

    Depending on your version of MATLAB, you may have the `suptitle` built-in function. This command allows you to put one overarching title on the figure window, thus permitting you to use short, scale-specific titles on each subplot.

    Hint: You can also control the font size of all subplot elements by using the FontSize property on the current axis (`gca`) within the set command. For example, the command to use 8-point font on one subplot is

    ```
    set(gca,'FontSize',8)
    ```

    b. Use the subplots to diagnose the type of function that best represents the form of relationship. In the `ANALYSIS` section, answer the following:

    Q1: What type of function best represents the relationship between the data? Justify your answer by making reference to the plots and the axes' scaling.

    c. In the `LINEARIZATION` section,

        i. Linearize the data using the technique that is most appropriate for the function type you diagnosed above.

        ii. For both designs, find the linearized form of the equations using least squares regression.

        iii. Print the linearized form of the equations to the Command Window. Use clear, appropriate variable names in place of x and y in the equation.

        iv. Plot the linearized data and the trend lines for both designs on a single plot in a second figure window. Be sure to label the plot for technical presentation, paying particular attention to the labels on the x- and y-axes

    d. In the `HEADPHONE DESIGN MODELS` section,

        i. Determine the general form of the best-fit equations for each of the headphones designs.

        ii. Clearly display these equations in the MATLAB Command Window. Use clear, appropriate variable names in place of x and y in the equation.

        iii. Plot, on a single plot, the original data with the best-fit curve for each of the headphone designs.

2. In the `ANALYSIS` section of your code, answer the following questions:

    Q2: The lead engineer wants to know the predicted decibel level each headphone produces when given 25 mW, 40 mW, and 50 mW of power. Write a short email with your results and an explanation of any limitations of the model that the lead engineer needs to know.

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Q3: Headphone sensitivity is a measure of how the volume level changes as the power level changes. The headphone with the largest volume gain for the same power gain is the most sensitive. The company knows that both headphone designs meet their sensitivity requirement; however, they prefer a headphone design that is less sensitive, if possible. Use your models to compare the sensitivity of the headphones. Identify which headphone design has the greater sensitivity. Justify your response.

3. Publish your code to a PDF file and save it using the name format given in the deliverables list for this problem.

Image Reference: http://www.shure.com/americas/products/headphones/srh1440-professional-open-back-headphones

http://cdn.shure.com/specification_sheet/upload/152/Spec_Sheet_SRH1440.pdf