PHYS3071/7073 - Due Friday, 9th of May, 2014 by 11am

Assignment 8 —- Climate Change

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1 Analysing climate change

Your goal is to write a program which fits the variation in global mean temperature over the last 130 years using a linear least squares method. The data file that you are going to use is taken from the US National Climatic Data Centre and gives global mean temperature anomalies for the surface of the Earth. It is called `monthly_climate.dat` and is available for download on Blackboard. The temperature anomaly is defined as the deviation from the average global temperature of the 20^{th} century.

The climate data file is organised into lines of data that give the year (first column), the month (second column), the temperature anomaly (third) and the mean error of the temperature (forth).

2 Theory

If data points have individual errors e_i, as in this case, the expression for the sum E, which measures the deviation of the fit from the data is given by:

$$E = \sum_i \frac{(y_i - (a \cdot x_i + b))^2}{e_i^2} \tag{1}$$

Again, to minimize E, the partial derivatives of a and b have to be zero,

$$\frac{\partial E}{\partial a} = \frac{\partial E}{\partial b} = 0.$$

This leads to the following two expressions for a and b:

$$\begin{aligned} a &= \frac{\sum_i \frac{1}{e_i^2} \sum_i \frac{x_i y_i}{e_i^2} - \sum_i \frac{x_i}{e_i^2} \sum_i \frac{y_i}{e_i^2}}{\sum_i \frac{1}{e_i^2} \sum_i \frac{x_i^2}{e_i^2} - \left(\sum_i \frac{x_i}{e_i^2}\right)^2}, \\ b &= \frac{\sum_i \frac{y_i}{e_i^2} - a \sum_i \frac{x_i}{e_i^2}}{\sum_i \frac{1}{e_i^2}}. \end{aligned} \tag{2}$$

The parameter E/n gives again an indication for the goodness of the fit. If it is significantly larger than 1, the fit is not acceptable, i.e. a linear model does not fit the data.

3 Problem 1

Modify the C program that you wrote for worksheet 14/15 and use it to make a linear least square fit to the climate data. Your program should ask the user for the name of the climate file and the range of years over which the climate data should be fitted. The fitting should be done in a function which accepts the climate data together with the years over which the fit should be made and calculates a, b and E/n and passes these values back to the calling routine.

4 Problem 2

Use your C program to answer the following questions:

1. How large are the constants a, b if the whole data range is fitted? How large is the average deviation E/n between data and fit? Is a linear temperature change over the whole range an acceptable fit to the data?

2. How do a, b change if only the last 60 years of climate data are taken into account? Is the linear model acceptable for this range?

3. Based on your fit over the whole range, by how much will global temperatures be larger than the mean temperature of the 20th century in the years 2050 and 2100?

Write your answers to the questions into a text file called `as08-answers-studentname-studentid.txt`. In additon, use gnuplot and produce a plot called `as08-problem2-studentname-studentid.ps` which shows the temperature data, as well as fits based on the full data set and based only on the last 60 years of measurements. Remember that in `gnuplot` you can draw lines with the `set arrow` command.

5 Problem 3 (Advanced)

Modify your program such that it also prints the five times when the global temperature were highest in the past to the screen and add these times to the answer file. Also modify your program such that arrays are declared as pointers and their space is allocated by malloc. Array elements should be addressed in "pointer format", i.e, `*(x+i)=...` instead of "array format" `x[i]=...` throughout the program. Also global variables are not allowed, you need to pass all variables to the function that fits the data when you call this function. So in a nutshell: Practise what was taught in the lecture on Monday about pointers.

The full set of files you will have when you are done should be:

- `as08-studentname-studentid.c`
- `as08-problem2-studentname-studentid.ps`
- `as08-answers-studentname-studentid.txt`

To submit your assignment, upload the above files to your directory, eg. s1234567/as08/. Name the new directory `as08`. Upload the C programs and the text file with your answers as COURSENUMBER AS08 SURNAME STUDENTID (case doesnt matter) at the top. Your postscript figure should have the same information in its title, i.e. use `set title <COURSENUMBER> AS08 <SURNAME> <STUDENTID>`.

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Grading Sheet – Assignment 8: Climate Change

A: /30% **Function**: Does the program run and produce the correct output?

B: /10% **Usability**: Is the program easy to use? Are the input requirements and output formatting easy to understand?

C: /10% **Readability**: Is the program easy to read and comprehend? Is it well-commented? If the code is sufficiently complex, has it been broken up into manageable subroutines, each of which is well-documented?

D: /10% **Efficiency**: Does the program run efficiently? Is the coding clunky or unnecessarily complicated?

E: /10% **Analysis**: Were correct answers given to the questions asked in the assignment, and was the process used to obtain them reasonable and clearly explained?

F: /10% **Presentation (Plots)**: Do the plots clearly convey the results? Does each plot have an appropriate title? Are the axes and the plot items clearly labeled?

G: /20% **Advanced part**: Half of the grading for the advanced part follows the rules outlined under points A to E. The other half is awarded if the program makes ample usage of pointers.

Total Points: /100