**Introduction to Nonlinear Dynamics**

# Modelling Industrial Dynamics: A Study on *IBM*

This is a set of guidelines for you to follow when analysing the data pertaining to the growth of *IBM*. You may also implement your own ideas. The purpose of this exercise is to give you practical experience in working with real economic data. For this task you need a basic understanding of what we have done so far in the class. The following items give a description of the contents of the other files in the folder, along with some suggestions for the mathematical modelling.

- **The data files:** There are two of them. One is named `growth_ibm.dat`, and it contains data in three columns. The first column gives the revenue (measured in millions of dollars) that *IBM* has generated every year. The second column gives the human resource that *IBM* has been employing world-wide from year to year. The third column gives the year count itself starting from the year 1914 (this is the first year for which the revenue record exists). The last year up to which you have been given the data is the 93rd year (which makes it the year 2006).

  The next data file is named `prof_ibm.dat`. This data file has two columns. The first column is again the year count, and the second column gives the net profit (in millions of dollars) that *IBM* has made every year. Regarding this point, note that in the early 1990s, the company suffered major financial reverses.

- **Reading material:** There is an article in a .pdf-formatted file named `rev_ibm.pdf` (and its preprint version is also available as `IBM_modelling.pdf`). Read the first two sections of any one of these documents. It will help you with the mathematical modelling, especially in tuning the numerical values of the various fixed parameters of the model equations.

- **The mathematical modelling:**

  1. In the article(s) provided, an equation of the form $\dot{x} = \lambda x(1 - \eta x^{\alpha})$ is used to fit the data for the case of $\alpha = 1$. This makes for the simple case of the logistic equation, which seems to fit the data (especially the revenue data) well on long time scales.
  2. You could carry out some improvisations in the graph plotting as well. While the article shows a log-log plot of the revenue and the human resource versus time, you could do a simple linear-log testing of the aforementioned data against time. Carry out an elementary manipulation on the data like $\ln(x^{-\alpha} - \eta)$ and plot it against time, $t$, to see if you get a straight line. Since $\alpha = 1$, the slope of this linear-log plot could be used to test the value of $\lambda$. The software tools you may use for the data-fitting exercise are standard ones like *Matlab* or *GNUPlot*. The way forward is to overlap the data curve with a well-chosen fiduciary analytical function. You might use the function given in the paper itself.
  3. The data could be analysed in another way. For instance, the data are given in the format $x$ (which could be either the revenue or the human resource content of *IBM*) versus time, $t$. You could render the data (coding in *Fortran* or *C* could be useful here) in the form $\mathrm{d}x/\mathrm{d}t$ versus $x$. This will set up your data in the autonomous form, $\mathrm{d}x/\mathrm{d}t = \dot{x} = f(x)$, which you can plot and see if the plot matches the parabolic behaviour of the logistic equation.
  4. From the plot, as well as from a direct application of the algebraic techniques, you could find out the carrying capacity in *IBM*'s annual revenue generation and human resource content. After knowing this it will be easy for you to estimate the time scale of the onset of nonlinearity-driven saturation in *IBM*'s growth. You could test this time scale independently on the profit graph of *IBM*.