DEPARTMENT OF MATHEMATICS
MATHS 761 Ordinary Differential Equations and Dynamical Systems

Using the software package XPP in the computer laboratory

In this course we make use of the software package XPP (also known as XPPAUT). XPPAUT stands for 'X-Windows Phase Plane plus AUTO'. With XPP you can do phase plane analysis, continue solutions when varying parameters, and many other things. This package is maintained by Prof. Bard Ermentrout at the University of Pittsburgh. Information about the software, useful tutorials, and the software itself is available at

`http://www.math.pitt.edu/~bard/xpp/xpp.html`

The software is free and you can install it on your home computer if you want. XPP is available in the Mathematics Department Basement Computer Laboratory and the Basement Tutorial Laboratory. All Maths students have an account in these labs.

Make sure you know your NetAccount login and password **before you come to the first laboratory session**. If you are unsure, try out your account **before** the first laboratory session.

The laboratory sessions for Maths 761 will be held room 303S.G87 (GPL) which is accessed from GCL (the ground floor computer laboratory). XPP can also be accessed from BCL and BTL. General information about the Computer Laboratories and a map showing you how to find the labs can be obtained from:
`https://www.sit.auckland.ac.nz/Student_Computer_Lab_Management`

Getting started with XPP

1. Login using your usual NetAccount login and password.

2. Before starting XPP, create a folder for the work you will do with XPP. Double-clicking on the Users Home Directory Icon; click on 'Organize', then 'New Folder'. Change the folder name to xpp.

3. Next create a file containing the differential equations you want to investigate with XPP. To do this start a text editor. You can use any editor you like; one that is easy to use is TextPad: click on the Start Icon and then select the TextPad line. When you have a text editor running, type in the following:

   ```
   # quadratic two-dimensional ODE
   dx/dt=x^2-a
   dy/dt=-y
   par a=1
   init x=0,y=1
   done
   ```

   Save this file with the filename quadratic.ode in the xpp folder in My Documents that you created above. To do this, select 'Save As' from the File menu in the

TextPad window, click on 'Desktop' on the left, then 'Users Home Directory', and 'xpp'. Type `quadratic.ode` in the 'File name' box, select 'All files' in the 'Save as type' box, and click on Save.

In the file quadratic.ode which you have just created, the first line is a comment (the #). The next two lines specify the ODEs,

$$\begin{aligned} \frac{dx}{dt} &= x^2 - a \\ \frac{dy}{dt} &= -y \end{aligned}$$

The line starting with 'par' specifies the values of the parameters; in this case setting $a = 1$. The 'init' line specifies the initial values of x and y. It is important that you do not type any spaces on either side of the '=' signs. The last line **must** say 'done'.

At this point you can exit from the text editor or you can leave the editor window open in case you want to edit the file quadratic.ode again before the end of the session.

4. Before starting XPP you also need to start an X-Win32 session. Go to the Start menu, select 'Programs', 'Utilities', 'X-Win32 9.2' and then 'X-Win 32'. You will get a window called 'X-Win 32 - Welcome' which asks 'What would you like to do?' You should just ignore this window (but do not close it). You only need to start X-Win32 once.

5. Now start XPP. Go to the Start menu, select 'Programs', then 'Maths & Stats' then 'xpp'. If you get a window asking 'Confirm Host Connection', click 'Yes'.

   If everything is working correctly a small window with 'Select an ODE file' at the top will appear. If the window does not appear, try Steps 4 and 5 again. If this still fails, ask for help from your lecturer or a lab demonstrator.

6. You now need to tell XPP which equations to use. In the XPP window that appeared in the last step, click on the line `xpp`. This opens the xpp directory you made in Step 2. Then click on `quadratic.ode`. Click OK. You should now see a new window with the title 'XPP Ver 5.98 >>quadratic.ode'. If you can see this, you are successfully running XPP. If you cannot see this, ask for help.

Running XPP

When you try to tasks listed below, you will notice that the XPP interface is somewhat quirky, but you will get used to that. Some hints:

- In menus you can press the capital letter of the menu item instead of using the mouse.
- Right clicking in a graphics window lets XPP show you the coordinates of the mouse cursor within the window.

- The general escape key is 'Esc' and if this key does not work during numerical calculations you can try the slash key ('/').
- The Tab key does not do what you expect.
- Input box editing is limited to Backspace, Delete, Home, End, Left and Right.

Tasks for Laboratory 1

If you have started XPP correctly as outlined above, you will see a window on your screen entitled 'XPP Ver 5.9 >> quadratic.ode' in which you can see an empty X vs T graph. Make sure you can see this window before going on from here.
In the remainder of the first laboratory session, work through as many of the tasks below as possible so that you become familiar with XPP. Make sure you know how to do everything on the list before you come to the second Laboratory session.

1. Before numerically solving the differential equation, set up the main window. For the system of equations above, it is helpful to look at the phase plane with $-2 < x < 2,\ -2 < y < 2$. To change from the default $x - t$ window to an $x - y$ window, select (V)iewaxes, then 2D. In the 2D View window that appears, change the x-axis variable to X (from T) and change the $x$min and $x$max values to -2 and 2. Change the settings for the y-axis similarly. Press OK. The main window should now show y versus x.

2. Next try to integrate the equation. You can do that by pressing (I)nitialconds, and then (G)o. Now a curve will appear corresponding to the solution starting from the initial condition specified in 'quadratic.ode', i.e., from $x = 0$, $y = 1$. You can specify other conditions as well, without modifying 'quadratic.ode'. For instance to start the solution at $x = 0.5$, $y = 0.25$ select (I)nitialconds, and then (N)ew. Now type the new value of x in the input bar at the top of the window, and press Enter. Next type the new value of y and press enter. You will see an additional curve being drawn.

   If you want to plot solutions from initial conditions selected with the mouse, press (I)nitialconds, and then m(I)ce. Then click on the desired points in the $x - y$ window. When you have seen enough solutions, press Escape.

3. See if you can work out how to plot solutions with time running backwards.

4. You can also change the parameter a: select (P)arameters, type 'a' and Enter, change the value of a from 1 to 2, then Enter. Press Enter once more to exit from the parameter interface. Now the next time you do (I)nitialconds it will use this new parameter value.

5. You may also want to play a bit with the zooming capabilities of XPP: select (W)indow/zoom, then select ZoomIn. Select an area by pointing somewhere, and dragging the mouse to the other corner of the area. Now this area is shown close-up. Try zooming and and out. You can also rest the window dimensions from the Viewaxes menu as outlined in Step 1 above. Before going on you may wish to clear the window by selecting (E)rase from the main menu.

6. Now set the parameter 'a' back to 1. We are interested in the equilibrium solutions of the ODE. It is easy to calculate that they are at $x = -1, y = 0$ and $x = 1, y = 0$ but XPP can do that for us as well: select (S)ing pts, then (M)ouse, click on a point somewhere in the $x - y$ window, and click 'No' for 'Print Eigenvalues'. XPP will find one of the equilibria and report its position and stability in a new window. (If you get a question 'Draw invariant sets?' click No). For instance if XPP finds the equilibrium at $(-1, 0)$ it will report $r- = 2$ in the equilibria window, meaning that there are two real negative eigenvalues. (In this window c stands for complex, with positive or negative real parts and im for purely imaginary.)

   Repeat the process above to find the position and stability of the other equilibrium point.

   The 'AUT' part of XPPAUT stands for AUTO, which is software you can use to continue solutions as parameters are varied. In this case you could use 'File' and 'AUTO' to continue the equilibrium solution in a. But we will leave this for another time.

7. Draw a phase portrait for the system above and print it.

   Note about plotting and printing phase portraits: XPP does not automatically save orbits for plotting. If you draw a curve that you want to include in your final phase portrait, select `Graphic stuff` from the options menu, then `(F)reeze`, then `(F)reeze` again. This will save the last curve that was drawn. Next time you freeze a curve it will be added to the set of curves already frozen.

   To save a picture, send the picture to a postscript file: select (G)raphic stuff, then (P)ostscript, then OK to select the default postscript parameters (black and white or colour, landscape or portrait, etc), type in a filename in the Print window that appears (for example, the default is quadratic.ode.ps), and click OK. There should now be a new file in your xpp directory, with the filename ending with '.ps'. To open the file, open GSView by going to the Start menu, 'Programs', 'Utilities', 'Ghostgum', 'GSview4.9'. Select 'File', 'Open' in the GSView window and select your .ps file.

8. If there is time, play around with XPP to see what else it can do. For instance, try to change the stepsize for the numerical method used to integrate the equations. Which numerical method is used?

9. To quit XPP select (F)ile, (Q)uit, and (YES).

10. Before you leave log off the computer. To do so just left click on 'Start' and then select 'Log Off'.