JPollution Instructor's Manual

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October 10, 2005

1 Introduction

JPollution is a pair of Java programs with which you can create topographic maps of land contaminated by pollution from various sources, and simulate sampling runs to measure the pollution. The idea is not to teach specifics of pollution propagation (the pollution distribution models were selected for computational ease, not accuracy), but different sampling strategies and their advantages and disadvantages.

1.1 Getting JPollution

The programs making up the JPollution package are written in Java. You will require a Java Runtime Environment (JRE, also called a Java Virtual Machine, or JVM) to run the programs. See section 1.1.2 for details.

    The package and documentation are both available for download for free from the project website, www.ibises.org.uk/JPollution. Choose the appropriate download for your Java version (section 1.1.2) and download the zip file. This will include the two .jar files that are the programs, two .pdf files[1] of documentation, and a licence document and copyright notice.

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[1]Portable Document Format (PDF) is a format developed by Adobe Inc. Free readers are available for download from their website, www.adobe.com.

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1.1.2 Installing Java

JPollution is written in Java. The advantage to this is that it will work on any operating system (Windows, Unix, Mac OSX, etc.) for which Java has been written. The disadvantage is that you must install a Java Runtime Environment (JRE, sometimes called a Java Virtual Machine, or JVM) before you can run the programs.

You may already have a JRE installed. The easiest way to test is to download JVersion from the project website, www.ibises.org.uk/JPollution, and double click on the icon of the downloaded file. If it runs, a window will appear, containing the words "Java version: " and a number. If so, note down the number, and proceed to the next section.

If the program does not run, you either have no JRE installed or it is set up incorrectly. You will need Administrator access to your machine to install a JRE; you may need to contact your System Administrator.

Several vendors supply JREs. The official version is available for download without charge from Sun Microsystem's website, java.sun.com. Download and install the version appropriate for your platform. You do not need either documentation or the Software Development Kit (SDK), although you may also download these. Follow the instructions on the website to install the JRE.

1.1.3 Installing JPollution

You need a Java Runtime Environment to be able to run the JPollution programs. See section 1.1.2 for instructions on how to install a JRE, or how to determine the version of the JRE you have installed.

JPollution requires no installation. Simply download the appropriate zip file and unzip it to a folder. The zip file contains the following:

1. PollutionCreator.jar – the program for creating polluted maps

2. PollutionSampler.jar – the program for sampling the maps

3. InstructorManual.pdf – this manual

4. StudentManual.pdf – a one-page introduction to PollutionSampler, intended for use by students

5. gpl.txt – the GNU General Public Licence, under which this package is distributed

If you have a Java Runtime Environment installed, you should be able to run the two programs immediately. Under Windows and Mac OSX, just double click on their icons. If you are running from a command line, change to the directory in which the .jar files reside, and use 'java -jar PollutionCreator.jar' to run. If the programs won't run, you may not have a JRE installed. See the previous section.

1.2 Bugs

It is very rare for a program to be entirely free of errors, or bugs. JPollution probably has some — you can help remove them by reporting any you encounter.

1.2.1 Known bugs

There are no known bugs in JPollution.

1.2.2 Reporting bugs

Please report bugs to pollution@ibises.org.uk. Any bug report is better than nothing, but the more information it contains the better. The better the report, the more likely the bug is to get fixed. Information that is helpful in diagnosing bugs is:

- Your operating system

- Your Java Runtime Environment version and manufacturer

- Which version of JPollution you are using (see the 'About' option in the 'Help' menu)

It is also useful if you can provide a copy of the map you were using or editing when the problem occurs. If you can determine a sequence of actions that causes the bug to manifest, this is also useful.

1.2.3   Feature requests

If JPollution doesn't do something you'd like it to, please email a suggestion to pollution@ibises.org.uk. I don't guarantee that I'll implement your idea, but I can't if you don't ask for it.

2   Running PollutionCreator

When you want to create an exercise for your students, you first need to create a map. PollutionCreator is the program that does this. Under Windows and Mac OSX, as well as many UNIX graphical environments you can simply double click the PollutionCreator.jar icon. From a command line, change to the directory containing the .jar file and type 'java -jar PollutionCreator.jar'. A window titled "Pollution Creator" should appear after a few seconds.

2.1   Creating a map

The PollutionCreator window is divided into two regions, the Control Panel on the left and the Map Display on the right.

2.1.1   Points

The core of creating a map is putting points into the Map Display. To put a point on to the map, click somewhere on the Map Display and one will appear. A point can represent a hill (shown as a yellow cross), a visible source of pollution (a light blue box) or a hidden source of pollution (a dark blue box). You can decide which type of point to create using the "New point type" drop-down box in the Control Panel.

A point can be selected once it has been created, just by clicking on it. A purple circle appears around the selected point. Data describing the selected point appears in the Control Panel. The selected point can be deleted by clicking the "Delete selected" button in the Control Panel while a point is selected. A point can be moved by dragging it around the Map Display.

When a point is selected, data describing it appears in the Control Panel. This data can be edited to change the properties of the point. The point type can be changed using the "Current point type" drop-down box. Its position can be altered using the "x" and "y" text boxes. The origin of coordinates is in the top left of the screen, and the length of a side is shown in the "Scale" text box. The other point settings do different things depending on the point type.

- **Hill**: The boxes below the "y" control are "Hill height" and "Hill radius", and the "Air strength", "Air inner radius" and "Air outer radius" boxes are greyed out and inoperative. A hill point is the center of a circular Lorentzian-profiled hill (see section 2.4), whose height in metres is set using the "Hill height" box. The "Hill radius" box sets the radius at which the hill height is half its maximum value. If either of the height or radius settings are zero, the hill does not contribute to the terrain. The displayed

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terrain is the sum of all the hill points. The displayed contour lines are at ten-metre intervals.

- **Source**: The boxes below the "y" control are "Ground strength" and "Ground radius", and the "Air strength", "Air inner radius" and "Air outer radius" boxes are active. If the source is a **Visible source** it will appear on the map in PollutionSampler; if it is a **Hidden source** it does not appear on the map. The pollution contour lines (which appear at ten parts-per-million intervals) will not appear in either case. Pollution sources can produce two types of pollution

  - **Ground water pollution**: A pollution source of this type is at the center of a circular Lorentzian-profiled pollution field (see section 2.4). The strength of the pollution (in parts-per-million) at the source is set using the "Ground strength" box. The radius in kilometres at which the pollution drops to half its maximum value is set using the "Ground radius" box.

  - **Airborne pollution**: Airborne pollution is usually produced by a chimney. Its strength is, therefore, zero at the source, rises to a maximum at a certain radius, and decays away again. The strength of the pollution at the maximum, in parts-per-million, is controlled using the "Air strength" box. The radius of the maximum and the decay radius are controlled by the "Air inner radius" and "Air outer radius" boxes. The relationships are slightly complex; please see section 2.4 for details. The distribution also depends on the wind speed and direction (section 2.1.2).

2.1.2 Map settings

The Control Panel has some controls that affect the whole map and the sampling runs. The uppermost box in the Control Panel is labelled "Pollution at cursor", and displays the pollution in parts-per-million that a user of PollutionSampler would see if they sampled the pollution where the mouse pointer currently is. It is more accurate than the contour lines (see section 2.4 for details).

The second box is labelled "Map title". You can enter a title here, and it will appear in the title bar of both PollutionCreator and PollutionSampler when the map is loaded.

The third and fourth boxes are titled "Wind speed" and "Wind direction" respectively. They control the speed and direction of the prevailing wind on the map, which affects the distribution of airborne pollution. The speed is specified in kilometres per hour, and the direction as a bearing in degrees. North is aligned vertically upwards on the map, and the wind blows towards the bearing specified.

The fifth box is titled "Scale", and is used to specify the lengths of the sides of the map in kilometres.

The sixth box is titled "Samples allowed". When the map is loaded in PollutionSampler, the user will only be allowed to sample the pollution a certain number of times. That number is specified using this control.

Below the "Samples allowed" box is a tick-box titled "Results visible on click". If this box is selected, the pollution strength is visible in PollutionSampler as soon as a sample is

taken. If it is not set, the results are only visible once all samples have been taken. This allows you to simulate the condition in which samples can be analysed in the field, or in which samples must be returned to the lab for analysis.

2.2 Saving, loading and exporting maps

Once you have created a map, you can save it using the "Save map" option in the "File" menu. The map is then ready to load in PollutionSampler, or it can be loaded for further editing by using the "Load map" option in the "File" menu.

You may also want to provide printed copies of the maps for your students. This is most easily done using the "Export as BMP (no pollution)" option in the "File" menu. This produces a copy of the map in bitmap format, including any visible sources and terrain contour lines but not pollution contour lines, invisible sources or hilltop markers. Bitmap is a standard format that can be displayed and printed by most image viewing and editing programs, and imported into most word processors. If you want a version of the map including the pollution contour lines then use the "Export as BMP (pollution)" option.

2.3 Worked example

This section takes you through the steps to create a map with pollution ready for use in a sampling exercise. This map is used in the "Suggested exercise" (section 4), and can be downloaded from the project website, www.ibises.org.uk/JPollution.

Start PollutionCreator (see section 2). The Map Display should be blank.

2.3.1 Creating topography

The first step is to create some hills. These (currently) have no effect on the pollution distribution, but provide some character to the area.

1. Make sure that the "New point type" box is set to 'Hill'.

2. Click on the Map Display near the upper right corner. A yellow cross with a purple circle will appear where you click, numbers will appear in the "x" and "y" boxes, and zeros will appear in the "Hill height" and "Hill radius" boxes.

3. Click in the "x" box, delete the numbers and enter the value '0.85' and press the Enter key. The point will move to the upper left corner.

4. Press the Tab key and the cursor should jump to the "y" box (this won't work if you have an old JRE or if you've clicked somewhere else since you pressed Enter. If it doesn't work, click in the "y" box instead). Delete the numbers and enter the value '3.92' and press the Enter key. The point will move to the lower left corner.

5. Press Tab again (or click) to select the "Hill height" box. Delete the number and enter the value '75'.

6. Select the "Hill radius" box, delete the number, and enter the value '0.5'. Seven green contour lines, roughly circular, will appear around the yellow cross.

7. Click on the map once more. The purple circle disappears from around the first point, and appears around the new one.

8. Move the mouse pointer so that it is within the purple circle, and drag (press and hold the left mouse button while moving the mouse) the point until the "x" and "y" values read approximately '0.7' and '3' respectively. Edit the numbers to make them read exactly '0.7' and '3'. Set the "Hill height" and "Hill radius" to '65' and '0.5' respectively.

9. Create a third point and set "x", "y", "Hill height" and "Hill radius" to '1.7', '4', '50' and '0.25', respectively. The result should be an egg shaped hill, with three peaks in an L shape.

2.3.2 Creating pollution

The most important part of the map creation is creating the pollution sources. There are two types of sources; visible and hidden. We will create one of each.

1. Click on the map, and a yellow cross appears, centred in a purple circle. Change the "Current point type" to 'Visible source', and the yellow cross changes to a light blue square. "Hill height" and "Hill radius" become "Ground strength" and "Ground radius". The three other boxes, "Air strength", "Air inner radius", and "Air outer radius" become active with value zero.

2. Move the square (using the mouse or by editing "x" and "y") to (4.6,4.6). Change "Air strength" to '20', "Air inner radius" to '1' and "Air outer radius" to '1.25'. Red contour lines will appear when the third number is typed.

3. Move the mouse around in the Map Display. As the mouse moves, numbers appear in the "Pollution at cursor" box at the top of the Control Panel. Notice that the pollution strength is very low at the source, rises to a maximum of about twenty parts per million just outside the first contour line, then decays away again.

4. Set the "New point type" to 'Hidden source'. Click on the map, and a dark blue square will appear, surrounded by a purple circle.

5. Set "x", "y", "Ground strength", and "Ground radius" to '0.72', '1.8', '50', and '0.1' respectively. More red contour lines will appear as the last number is entered. Note that the contour lines are brighter for higher values.

2.3.3 Setting the map parameters

The map has certain properties that can be set.

1. The distribution of airborne pollution is affected by the prevailing winds in the area. Set the "Wind speed" box to '0.45'. Notice that the contour lines around the visible source (which is set to produce airborne pollution) move, while those around the hidden source (which only leaches ground water) do not.

2. Set the "Wind direction" box to '315'. Notice the change in the pollution contour lines when the entry changes.

3. "Scale" is set to '5.0' by default. This can be changed, but is fine as it is.

2.3.4 Creating a village

To add a sense of reality to the map, visible sources with zero strengths and radii can be added to appear like a village. Add six visible sources with no pollution set at these coordinates:

x	y	x	y	x	y
2.9	4.7	2.9	4.8	2.9	4.9
3.0	4.7	3.0	4.8	3.0	4.9

2.3.5 Sampling settings

The last thing to set is the limits on the sampling the students will perform. They will have a limited number of samples, representing a limited time or limited budget. In this case, they will be able to see the results immediately.

1. Set the "Samples allowed" box to 25.

2. Click on the "Results visible on click" tick box, and a mark should appear it to show that it is set.

The last touch is to set the "Map title" box to something descriptive of the exercise. Set it to 'Fakeham, Cd, 25 visible'. Note that the title appears in the window title bar as you type. Finally, save the map (use the "Save" option in the "File" menu) as "cd_vis.map". This file can be loaded for further changes using the "Load" option in the "File" menu, or loaded in PollutionSampler (see section 3).

2.4 Technical details

This section goes into detail describing the mathematics of the pollution distribution and the contour lines. It is presented for interest, and is not necessary reading.

Both the hills and the ground water pollution obey Lorentzian distributions. Thus the height a distance r away from a hill with height h_0 and radius r_0 is given by:

$$h(r) = \frac{h_0}{1 + (r/r_0)^2} \tag{1}$$

Similarly, the equation for the pollution a distance r away from a ground source of strength p_0 and radius r_0 is:

$$p(r) = \frac{p_0}{1 + (r/r_0)^2} \tag{2}$$

Airborne pollution is calculated in a different way. In the absence of wind, the pollution from an airborne source of strength p_0 with inner radius r_0 and outer radius R_0 is given by:

$$\frac{2r_0}{R_0} \frac{p_0 r}{r_0^2 + (r/R_0)^2} \tag{3}$$

This function is zero at the origin and tends to zero as r tends to infinity. It has a maximum value of p_0 when $r = r_0 R_0$.

Wind affects the distribution of airborne pollution. If the prevailing wind is set to blow on bearing θ with a windspeed of w then the pollution strength at the point (x, y) due to an airborne pollution source of strength p_0 located at (x_c, y_c) is given by:

$$p'(x, y) = \frac{2r_0}{R_0} \frac{p_0 r'(w, x, y, \theta)}{r_0^2 + (r'(w, x, y, \theta)/R_0)^2} \tag{4}$$

where

$$r'(w, x, y, \theta) = (x - x_c + rw \sin \theta)^2 + (y - y_c - rw \cos \theta)^2 \tag{5}$$

in which $r = \sqrt{(x - x_c)^2 + (y - y_c)^2}$.

The height at any point on the map is the sum of the contributions at that point from each hill point. Similarly, the pollution at any point is the sum of the contributions from airborne and ground water leached pollution from each pollution source. Approximate contour lines are shown in the Map Display. It is computationally expensive to calculate a height for every point on the screen, so JPollution uses a linear approximation. The map is divided up into squares, each one twenty pixels on a side. Each square is then divided into two right angled triangles. The pollution at each corner of each triangle is calculated, and a flat plane is fitted. The contour lines that are drawn are the contour lines of this plane. This is why the contour lines can appear and disappear as a point is moved around — a tight (small radius) hill or pollution source might not be sampled by the contour line approximation.

Both the "Pollution at cursor" indicator and the sampling used by PollutionSampler use the actual pollution at the point, not this linear approximation. Use the contour lines only as a guide.

3   Running PollutionSampler

This section is summarised for students as the Student's Manual. It is recomended that you distribute that to students in preference to this section.

You should have created a map (see section 2), or acquired one from somewhere. The map files are small, and can be distributed by email or on a disk.

To start PollutionSampler under Windows and Mac OSX, as well as many UNIX graphical environments you can simply double click the PollutionCreator.jar icon. From a command line, change to the directory containing the .jar file and type 'java -jar PollutionCreator.jar'. A window titled "Pollution Sampler" should appear after a few seconds.

3.1 Overview

The interface to PollutionSampler is similar to the interface to PollutionCreator. The large black area on the left is the Map Display, and the remainder of the window is the Data Panel. The area at the top of the Data Panel is the Map Data Panel, which displays information about the loaded map. Below that is a button marked "Take sample", and below that is the Sample Data Panel.

3.2 Loading a map

A map can be loaded using the "Load map" option in the "File" menu. When a map is loaded, the topographic contour lines and any visible sources appear in the Map Panel. Hidden sources, hilltops, and the contour lines of pollution are not visible. The map settings appear in the Map Data Panel.

- **Title**: The first line is the map title, which also appears in the title bar of the window.

- **Results visible**: This entry will read 'Yes' if the pollution at a sample is visible immediately, and 'No' if the sample values will only be visible after all samples have been taken.

- **Scale**: The length of each side of the map in kilometres.

- **Wind speed**: The speed of the prevailing wind in kilometres per hour.

- **Wind direction**: The compass bearing towards which the wind blows. North is upwards.

- **Samples**: The number of samples taken, and the number allowed to be taken,

3.3 Taking samples

There are two steps to taking a sample. The first is to choose a site for the sample, and the second is to take the sample. If at least one sample has not been taken, then clicking on the Map Panel will cause a purple cross to appear at that point. No sample is taken. Click somewhere else on the map and the purple cross will move to the point at which the mouse was clicked.

To take a sample, click the "Take sample" button. If you have selected a point on the map, then the purple cross turns yellow and a sample of the pollution at that point will be taken. The number of the sample, the x and y positions (measured from the origin in the top left corner of the Map Panel), and possibly the pollution strength at that location will be added to the Sample Data Panel.

If the results should not be immediately visible, the pollution entry will be "--". When the last sample is taken, all of the dashes will be replaced with the pollution values. The program does not simulate the process of lab analysis of samples.

3.4 Saving the data

When all of the samples have been taken, it becomes possible to save the data. Use the "Save" option in the "File" menu to choose the filename to save the data. Data is saved in plain text in a file, with one entry per line. Each entry is the x coordinate, the y coordinate, and the pollution strength, each separated by a tab character. Most spreadsheets can open this type of file and understand it as a simple table.

4 Suggested exercise

This is a simple exercise, probably best performed in groups of two or three. It is not really intended for use, but more as an illustration of an application of JPollution.

4.1 Set up

For this exercise, you need the map whose creation is described in section 2.3. If you did not create it, you can either do so now, or download it from the project website, www.ibises.org.uk/JPollution. Save the map as 'cd_vis.map'.

1. Start PollutionCreator and load the map. De-select the "Results visible" box and save the changed map as 'cd_not_vis.map'. Export a copy of the map as a bitmap using the "Export as BMP (no pollution)" option in the "File" menu, and one copy using "Export as BMP (pollution)".

2. Make sure that a JRE is installed on all the computers that the students are going to use (see section 1.1.2).

3. Make sure that a version of PollutionSampler appropriate for the JRE version is installed in a place where the students can run it. A shared drive will work; alternatively, they could download it from a website and run it from their user area.

4. Put the maps in a place where the students can access them (perhaps a website or a shared drive).

5. Print a copy of the bitmap and the exercise and provide photocopies for each student (and some extras...).

6. Photocopy the map onto acetate, one per group of students.

7. Print one copy of the map with the pollution marked onto acetate.

The students will be asked to use PollutionSampler to estimate the cadmium distribution around the map, then present their results. Some will detect the small but strong zone of pollution around the hidden source, some will not. After they have presented, explain that the hidden source is a forgotten spoil heap (the smelter had to smelt something — there was a mine there...). Lead into a discussion of the strengths and weaknesses of different sampling methods.

4.2   The exercise

The village of Fakeham lies to the east of a small range of hills. The small village served a smelter to the east of the town. Although the smelter is now disused, when it was operating its main chimney used to produce smoke laden with cadmium. Cadmium is a heavy metal that lingers in soil, and builds up in human tissue, where it has adverse effects.

In recent years, interest has risen in using the land to the north of Fakeham for agriculture. However, there is some concern that there might be residual cadmium contamination. Your company has been hired to assess the risk associated with this possible contamination.

(i) What are the legal levels of cadmium in soil that is to be used in agriculture?

In this exercise, you will be comparing several sampling strategies. The strategies you will be investigating are:

- Directed sampling

- Grid sampling

- Random grid sampling

The instructor will assign a sampling strategy to your group. If you are assigned to directed sampling then load the map 'cd_vis.map'; otherwise load the map 'cd_not_vis.map'. See the attached "Students' Guide" for details of how to do this, and how to take samples. Note that, due to time and budget constraints, you only have 25 samples with which to estimate the pollution distribution.

Use the sampling strategy you have been assigned to take samples. Each group should be issued with one acetate copy of the map of the area around Fakeham.

(ii) Draw approximate contour lines of the cadmium distribution on this map, using the pens provided.

(iii) Mark the areas on the map where agriculture would be legal.

(iv) Is the village of Fakeham a safe place to live?

Your group will be asked to present your results in a five minute presentation at the end of the session.