Project Plovdiv 3.3 user manual

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1 General

Project Plovdiv is a network epidemiology simulator and can be used to teach basic graph theory. It is primarily aimed at students and demonstrates some of the basic concepts of graph theory and epidemiology. You can manually create a contact network or load one from a standard format. Nodes in the graph (individuals) can be set in one of three state- susceptible to the infection, infected or vaccinated. You can now run a simulation with a single keystroke!

1.1 History and attributions

Plovdiv started in 2009 and is based on two separate pieces of software. The first one was developed under the York Transit Bursary Scheme under the supervision of Dr Daniel Franks, and the second at the University of Sussex under Dr Istvan Kiss. It is not intended for detailed modelling or efficient calculations but rather as a supplementary course resource. Our main goals throughout the development process were simplicity and ease of use as well as mathematical correctness.

Plovdiv is hosted on Github and is distributed under a three-clause BSD license. Please submit bug reports and feature requests to the our issue tracker[1]. We welcome contributions from the community.

1.2 Requirements

Plovdiv is written in Java 7 and built with Maven. To run it, you need a recent version of Java 7, preferrably by Sun. OpenJDK may work, but has not been tested.

2 User interface

The overall appearance of the application is shown in Figure 1. The window is divided into three main areas, annotated with A, B and C respectively. Area A holds controls for the mouse mode. Area B holds a number of information

[1] `https://github.com/mbatchkarov/Plovdiv/issues`

panels. Area C is a rendering of the currently loaded graph. Each of these is discussed separately below.

2.1 Graph rendering (Area B)

Plovdiv features several rendering modes, shown in Figure 2. Vertices can be rendered as simple coloured circles or as icons. For instance, when presenting a model of a computer network you can render all vertices as computers and mobiles. Alternatively, icons can be rendered as humans in the context of social networks. To change the icon of a single node, right-click it and select **Change icon**. To change the icons of all nodes, right-click the background and select **Node Icons**> **Icon Type**> **Human/Computer**. When **Computer** is chosen, the exact icon (mobile phone, desktop computer, access point) is determined based on the degree of the vertex. To switch from icons to circles, right-click the background and select **Node icons**> **Enable/Disable icons**.

The colour of a vertex encodes it epidemiologic state. Yellow stands for susceptible, red stands for infected and green for resistant/immune. Selected nodes (Section 2.2) are blue. Edges are not colour coded. Their colour can be changed by right-clicking the background and selecting **Change colors**> **Edges**.

To change the background image, right-click it and select **Background image**. Plovdiv ships with a map of the world and a map of the United Kingdom, but you can choose an image from file. The background image can also be disabled by selecting **Background image**> **None**. When no background image is used, you might want to change the colour of the background by right-clicking it and selecting **Change colors**> **Background**.

2.2 Mouse modes (Area A)

The mouse is can be used to control how the graph is visualised. You use the mouse to zoom and pan, to create and delete vertices and edges, etc. The mouse operates in four different modes, each of which is used for a different kind of action:

1. Selection mode allows the user to select vertices and move vertices.

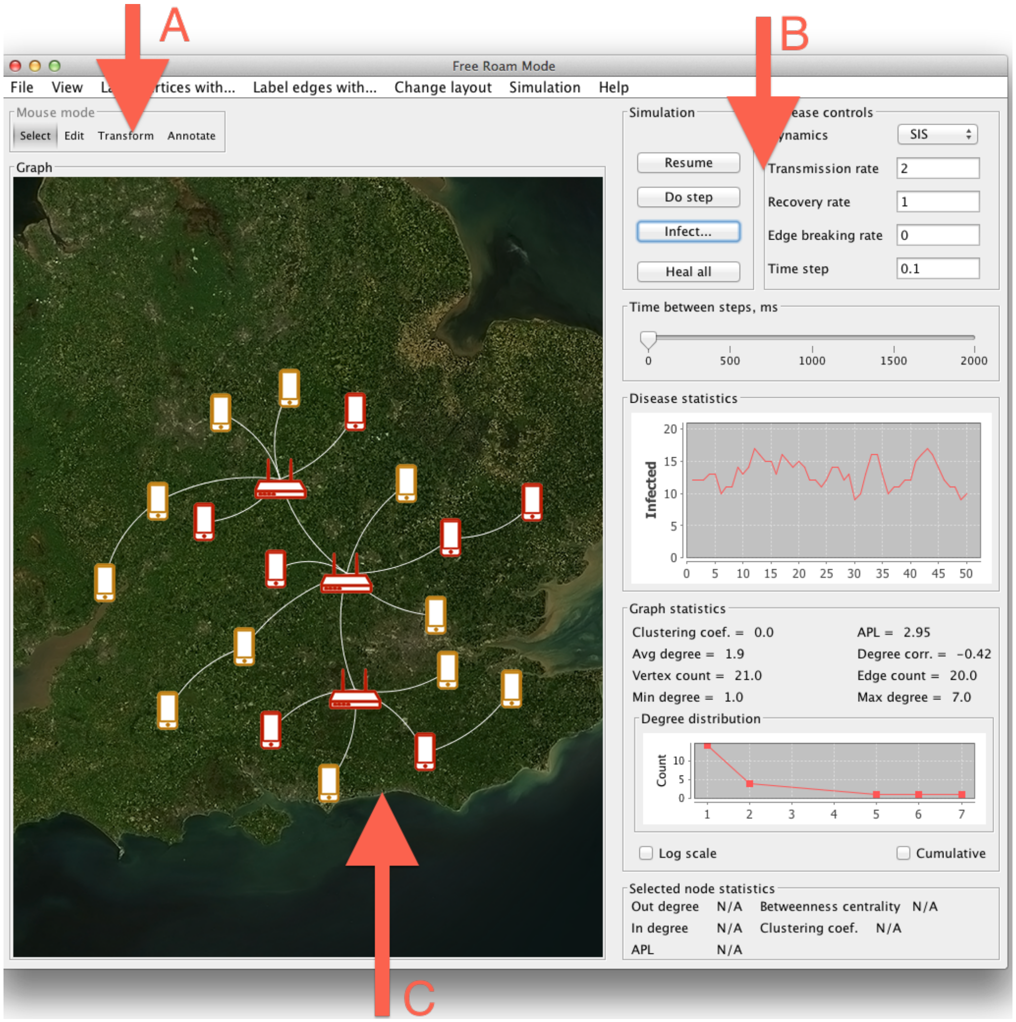
    (a) Left-clicking a vertex will select it

    (b) Left-clicking and dragging moves a vertex

    (c) Left-clicking the background will deselect all vertices

    (d) Ctrl+left click over a vertex will select it and move it the the centre of the screen

    (e) Shift+left click will select multiple vertices Click and drag will draw a selection rectangle- when the mouse button is released, all vertices inside the rectangle are selected. Selection by dragging is also supported.



...ynamics SIS

Transmission rate 2

Recovery rate 1

Edge breaking rate 0

Time step 0.1

Clustering coef. = 0.0

Avg degree = 1.9

Vertex count = 21.0

Min degree = 1.0

APL = 2.95

Degree corr. = −0.42

Edge count = 20.0

Max degree = 7.0

□ Log scale

□ Cumulative

Out degree N/A

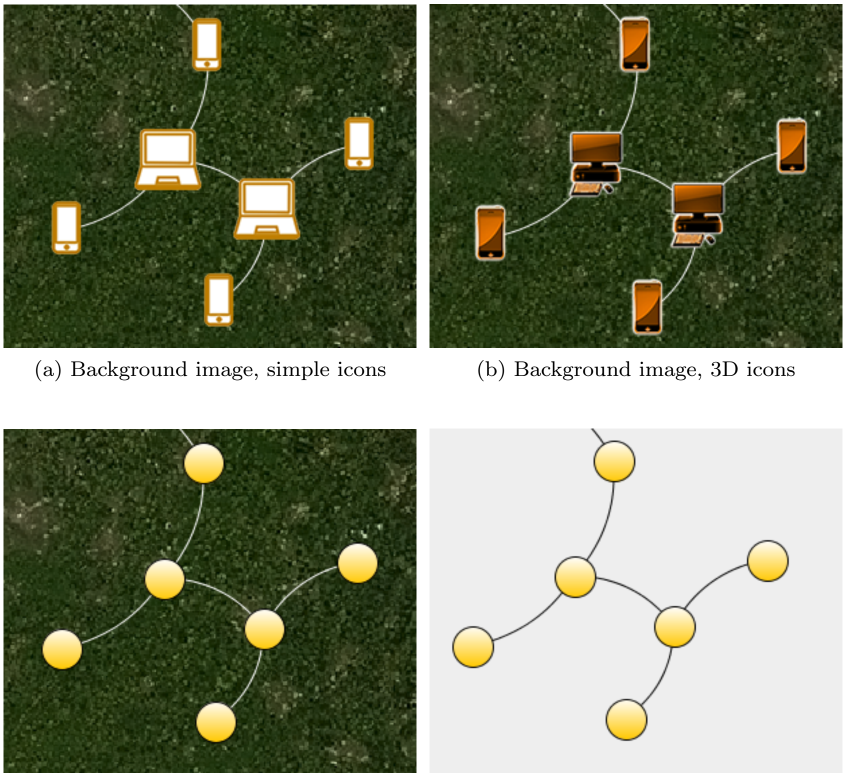
In degree N/A

APL N/A

Betweenness centrality N/A

Clustering coef. N/A

Figure 1: Overall appearance



(a) Background image, simple icons

(b) Background image, 3D icons

(c) Background image, no icons

(d) No background image, no icons

Figure 2: The same graph with different rendering styles

2. Editing mode: allows the user to create vertices and edges.
    (a) Left clicking anywhere on the screen will create a new vertex at that location
    (b) Dragging a line from a vertex to another will connect them with an undirected edge, unless they are already connected or you are trying to connect a vertex to itself
    (c) Holding Shift while dragging will create a directed edge
3. Transforming mode changes the way the graph is laid out.
    (a) Dragging will move the portion of the graph that is displayed on screen
    (b) Ctrl+drag will skew the graph
    (c) Shift+drag will rotate the graph
4. Annotation mode: this mode allows the user to draw annotations on the screen, for example for teaching or demonstration purposes. In this mode an additional tool bar will appear at the bottom of the screen, allowing control over the way the annotations are created
    (a) Dragging will create a new annotation with the selected shape, colour and position relative to the other elements in the graph
    (b) Shift+left click over an annotation will delete it
    (c) Right click anywhere on the screen will let the user enter some text, which will be drawn on the scree. Please note: clicking the right mouse button in annotation mode overrides the default behaviour of the right mouse button (see below)

The additional panel that appears when the mouse is in Annotation mode has four adjustable parameters:

1. Shape of the annotation (rectangle by default)
2. Colour of the annotation
3. Fill. If this button is not toggled, an annotation will appear as a coloured frame. If it is toggled, the annotation area will be filled with the chosen colour. See Figure 3.
4. Z-order (lower or upper). When lower is selected, the annotation appear behind the graph. When upper is selected, the annotation appear in front of the graph. See Figure 4.

The following actions work in all mouse modes:

1. Scrolling the mouse wheel up will zoom out and scrolling down will zoom in

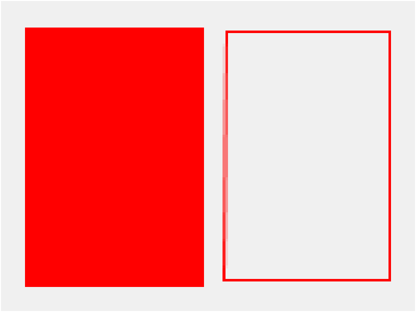


Figure 3: Annotations with and without fill

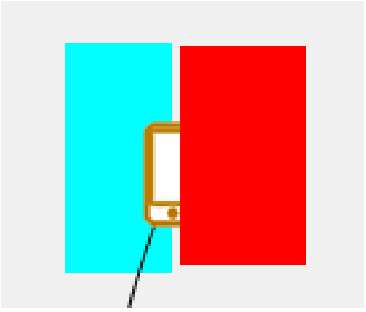


Figure 4: Annotations in lower (blue) and upper (red) position

2. Right clicking a currently deselected vertex will allow you to remove it or modify its characteristics, such as infection status, icon type, etc.

3. Right clicking a selected vertex will pop up a context-sensitive menu, which allows you to create edges as well as to modify the vertex characteristics

2.3 Information panel (Area B)

A close-up of the information panel normally located on the right hand side of the application window is shown in Figure 5. This consists of six parts, labelled A to F in the figure. Each of these is described separately below.

2.3.1 A: Simulation controls

This toolbar control the simulation of disease transmission. When the application starts, a simulation is initialised with default settings, and is paused. The **Do step** (keyboard shortcut **S**) button will perform a single step of the simulation. The **Resume (R)** button will resume[2] the simulation and will then change to **Pause**. The **Pause** button can be used to temporarily pause the simulation— it can be resumed by clicking **Resume**. The **Heal all (H)** resets the simulation to its initial state and heals all individuals (sets them to susceptible state).

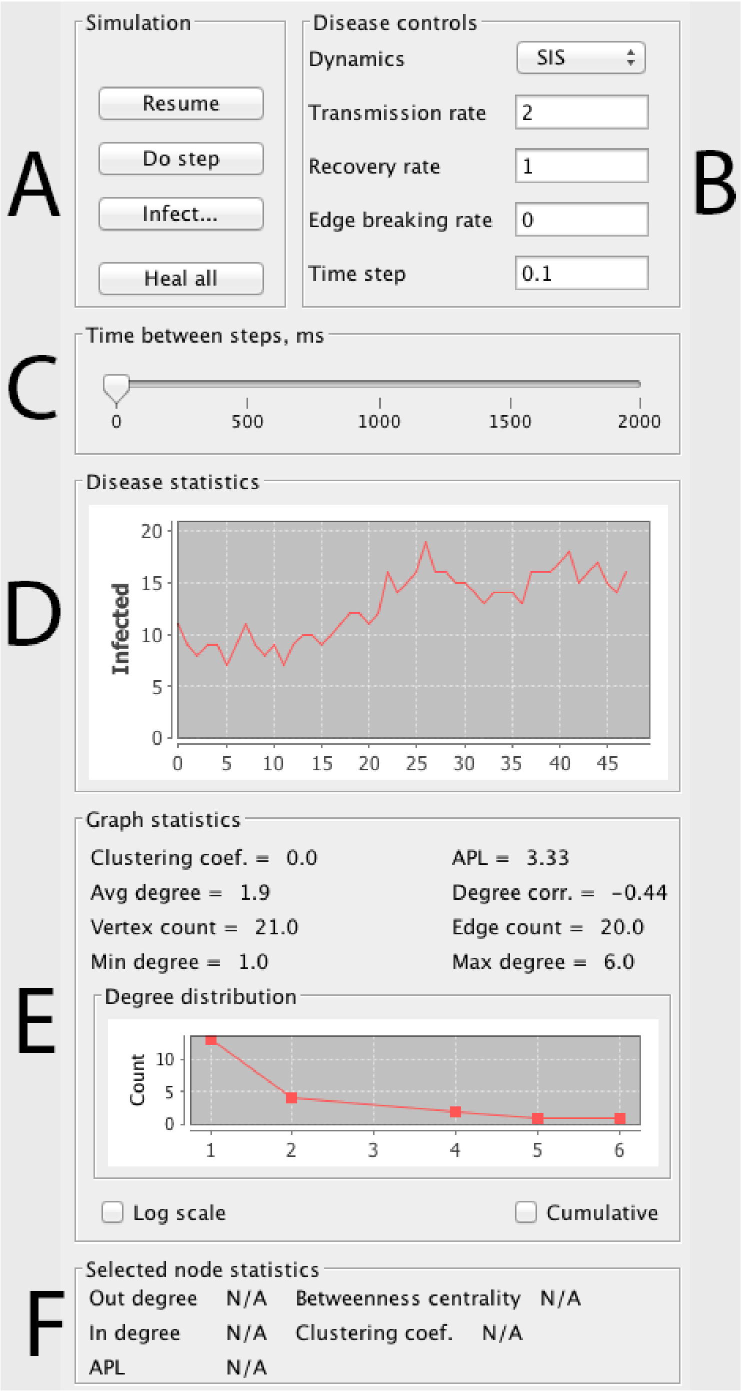
The **Infect (I)** button brings up the Infect window (Figure 6), which is used to randomly infect a number of vertices. You can either specify a proportion of the vertices that should be infected by using the top slider, or enter a number in the bottom input field.

All actions described above are also available in the **Simulation** dropdown menu. An additional action, called **Run 100 simulations** (keyboard shortcut **D**) is also available in the dropdown menu. This action runs 100 simulations until convergence, where all individuals are either susceptible or resistant. It requires that there are some infected vertices to begin with and the the simulation dynamics is SIR. At the end the action displays a scatter plot (Figure 7), where the **x** axis corresponds to vertex ID and the **y** axis to how many times (out of 100) that vertex was infected. Points in the window are clickable to improve legibility. Additionally, you may want to label vertices with their ID by clicking **Label vertices with ... > ID**.

2.3.2 B: Infection parameters

This panel controls various parameters of the infection, such as its type (SI, SIS, SIR), transmissions rate, recovery rate (where applicable), etc. Input validation is performed on the fly and the text will change to red if invalid data is entered (e.g. string instead of a number). You need to press **Apply** for your changes to be saved. Additionally, extra options are available upon clicking **More...**. A

[2] We think of *running* as the default state of the simulation, and pausing it as a temporary action. A simulation always starts when Plovdiv starts.



Disease controls

Dynamics SIS

Transmission rate 2

Recovery rate 1

Edge breaking rate 0

Time step 0.1

Graph statistics

Clustering coef. = 0.0

APL = 3.33

Avg degree = 1.9

Degree corr. = −0.44

Vertex count = 21.0

Edge count = 20.0

Min degree = 1.0

Max degree = 6.0

□ Log scale

□ Cumulative

Selected node statistics

Out degree N/A

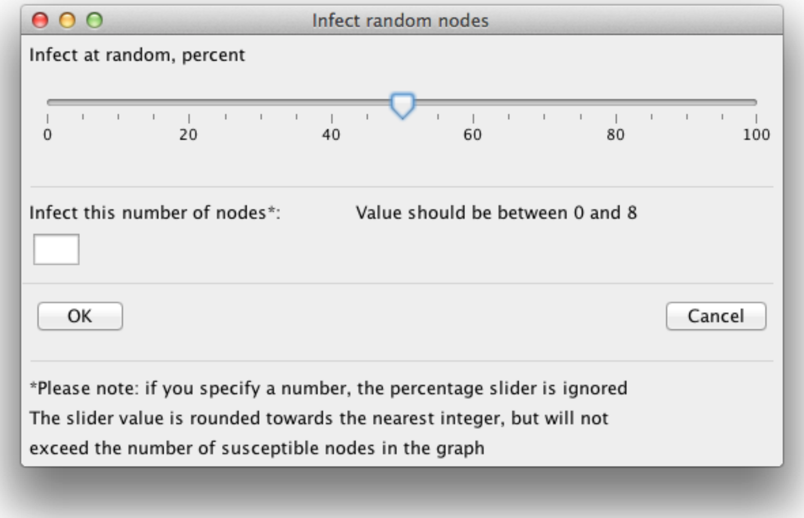
Betweenness centrality N/A

In degree N/A

Clustering coef. N/A

APL N/A

Figure 5: The information panel and its components



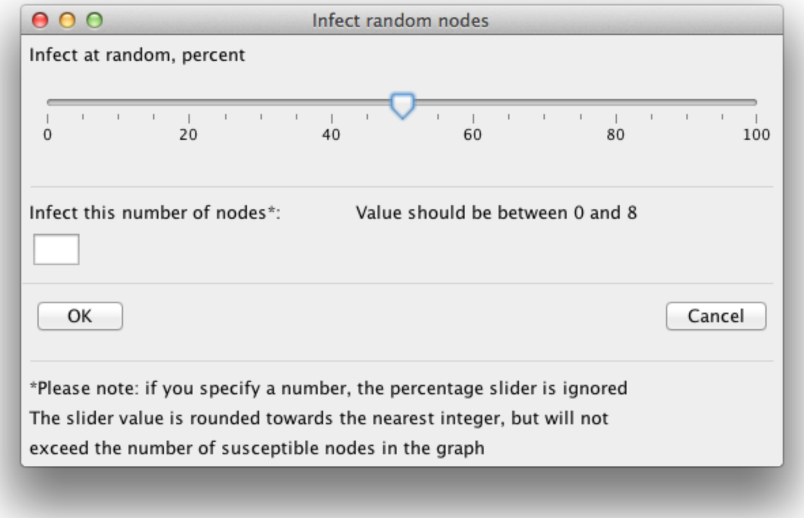
Infect at random, percent

Infect this number of nodes*:

Value should be between 0 and 8

*Please note: if you specify a number, the percentage slider is ignored
The slider value is rounded towards the nearest integer, but will not
exceed the number of susceptible nodes in the graph

Figure 6: The Infect dialog



Infect at random, percent

Infect this number of nodes*:

Value should be between 0 and 8

*Please note: if you specify a number, the percentage slider is ignored
The slider value is rounded towards the nearest integer, but will not
exceed the number of susceptible nodes in the graph

Figure 7: The Times infected information window

window will pop up that allows you to specify the rate of creation, deletion and rewiring of edges based on the state of the endpoints of that edge (susceptible, infected, resistant). For example, to simulate the real-world scenario where susceptible individuals stop contacting infected ones, enter a positive number if the cell corresponding to **SI** and **Edge deletion**. This means that edges between S (susceptible) and I (infected) vertices will be deleted at the specified rate.

Note: all numbers in this section refer to **rates**. A rate is a the k parameter the function $f(k) = exp(-k\Delta t)$, where Δt is the time step of the simulation. $f(k)$ is the probability of an event occurring.

2.3.3 C: Simulation speed

When the simulation is running, this slider controls how much time should pass before the next simulation step. Use the left and right arrow keys to adjust this value. If the simulation is pause, you can trigger a step manually by pressing **S** or clicking **Do step.**

2.3.4 D: Infection statistics

Displays a graph of the number of infected vertices over the past 100 time steps. This updates dynamically as the simulation runs. The values on the **x** axis may seem low. This is because it shows the "real time" that has elapse. For instance, a single time unit would have elapsed after running 10 time steps at a $\Delta t = 0.1$. Note a time step does not correspond to any real-world unit of time.

2.3.5 E: Graph statistics

Displays statistics for the whole graph. These include average clustering coefficient, average, min and max degree, average weighted path length, etc. There is also a chart of the degree distribution of the graph, which can be switched to cumulative degree distribution.

2.3.6 F: Selected node statistics[3]

This tool bar displays information about the selected node, such as in and out degree, betweenness centrality, clustering coefficient and average path length. If you select a number of vertices other than one, all fields will read **N/A**.

3 Using the menu options

3.1 The File menu

Contains the following commands:

[3] Note in later version of Plovdiv this panel has been moved to the top of the main window and only appears when a vertex is selected. To do that, put the mouse into Select mode and left-click a vertex.

New Creates a new graph with no vertices and no edges. Keyboard shortcut is **CTRL+N** (or **CMD+N** on OS X)

Save Saves the graph to a file. This creates two or three files, one with a .graph extension, one with a .layout and one with a .backgroun. The first one contains a description of the graph in Pajek plain text format. Information about the state of each vertex (infected, susceptible of resistant) is also encoded in this file. This is editable in any text editor. The second file is binary (not editable) and describes where each vertex of the graph should be positioned on screen. The third file is a standard jpeg image (with a non-standard file extension) that holds the background image. The three files should be thought of as one for all intents an purposes. The second and third file **need to have the same name** as the first file and a different extensions. Renaming them will lead to Plovdiv not detecting them when the .graph wile is loaded. The layout and background files are optional though- if they are missing, Plovdiv will work fine. If they are present, you will be asked if you want to use them. Keyboard shortcut is **CTRL+S.**

Load Loads a .graph file that has been previously saved. If a .layout file is present, it will be loaded and all vertices will be restored to their previous position. Otherwise an the graph will be laid out using one of the built-in algorithms. Make sure to always load the graph file, even when a layout or a background files are available. Keyboard shortcut is **CTRL+O.**

Generate Generates a new graph. Keyboard shortcut is **CTRL+G.** The program currently employs the following algorithms:

1. Rectangular lattice: a lattice in which each vertex has four local connections. The **Node density** parameter controls how densely the nodes are laid out on screen. You probably do not want to change that.

2. Hexagonal lattice: a lattice with six local connections per vertex

3. Scale-free generator: Starts with a single vertex an creates the specified number of vertices, attaching them to existing ones based on the principle of preferential attachment.

4. Small world generator- starts with a circular lattice of the specified size, connecting each vertex it its k closest neighbours on each side. Then traverses all edges, and rewires some of them with probability p.

5. Random, with a pre-defined number of vertices and edges. Edges are chosen uniformly from the pool of all possible edges.

6. Erdos- Renyi- generates a random graph by creating a predefined number of edges and the adding each possible edge with a probability of **Edge probability**.

Note on performance: depending on your machine's specification, working with large graphs may be very slow. For demonstration purposes it is recommended that you do not generate a graph with more than **100** vertices.

An example of each kind of graph Plovdiv can generate is shown in Figure 8. Please refer to one of the standard textbooks on graph theory for a detailed description of the generation algorithm used to these graph.

3.2 The View menu

This menu currently contain a sto save the what is currently on the screen to a jpg file (**View> Save to .jpg**). To hide the side bar on the right hand side, click **View> Hide sidebar.** The keyboard shortcut for this is **F1**.

3.3 The Label edges/vertices menu

By default edges and vertices are not labelled. Vertex features include degree, local clustering coefficient, betweenness centrality, distance from the currently selected vertex. Edge features include weight and centrality.

3.4 Layouts: The Change Layout menu

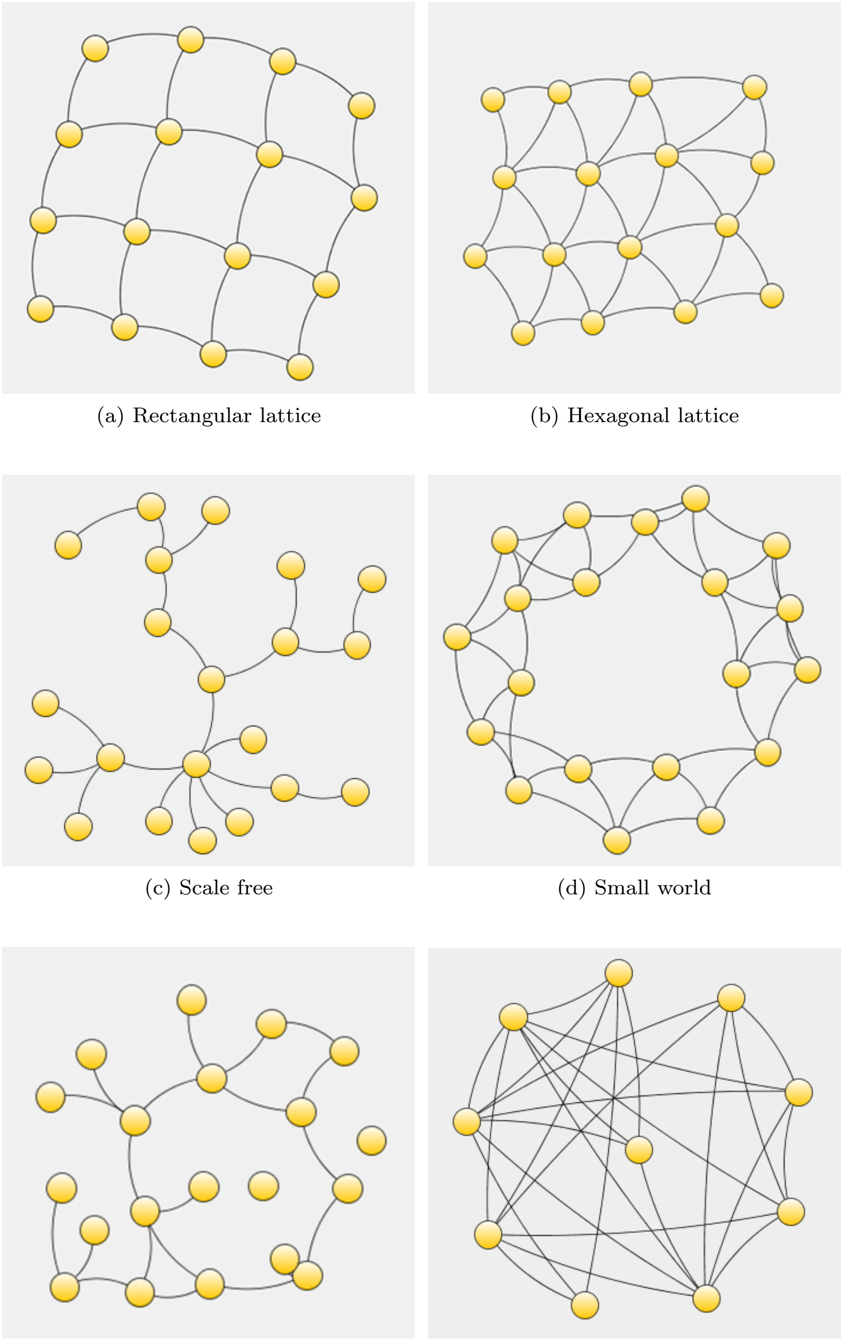
If the graph looks cluttered or unordered, try changing the layout. Different algorithms will produce different results, and sometimes dynamic algorithms, when applied on the same graph more than once, can produce significantly different results. Some algorithms will work better than others on certain types of graphs. This is still an open research area, so there is no optimal layout- try which one looks best for you. Lattice graphs (both hexagonal and rectangular) come with a special grid layout when generated by Plovdiv, but you cannot use this layout for other kinds of graphs.

3.5 The Simulation menu

This menu provides another way of accessing the buttons in the Simulation panel (A in Figure 5).

3.6 The Help menu

The Help menu contains a copy of the mouse modes documentation (Section 2.2) as well as information about the version of the software you are running.



(a) Rectangular lattice

(b) Hexagonal lattice

(c) Scale free

(d) Small world

(e) Random

(f) Erdos-Renyi

Figure 8: Example generated graphs