# Metanet User's Guide and Tutorial

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Metanet is a toolbox of Scilab for graphs and networks computations. It comes as new Scilab functions together with a graphical window for displaying and modifying graphs.

You can use the Metanet toolbox in Scilab without using the graphical window window at all, *i.e.* without seeing the graphs or the networks you are working with.

## 1 Representation of graphs

The graphs handled by Metanet are directed or undirected multigraphs (loops are allowed). A *graph* is a set of arcs and nodes.

A graph must have at least one arc. We call *arc* a directed link between two nodes. For instance the arc $(i, j)$ goes from *tail* node $i$ to *head* node $j$. We call *edge* the corresponding undirected link. A minimal way to represent a graph is to give the number of nodes, the list of the tail nodes and the list of the head nodes. Each node has a number and each arc has a number. The numbers of nodes are consecutive and the number of arcs are consecutive. In Scilab, these lists are represented by row vectors. So, if we call `tail` and `head` these row vectors, the arc number $i$ goes from node number `tail(i)` to node number `head(i)`. Moreover, it is necessary to give the number of nodes, because isolated nodes (without any arc) can exist. The size of the vectors `tail` and `head` is the number of edges of the graph. This is the standard representation of graphs in Metanet as it is described in the graph list (see 1.1). There are functions to compute other representations better suited for some algorithms (see 1.2).

The distinction between edges and arcs is meaningful when we deal with undirected graphs. This distinction is not needed when we only use the standard functions of Metanet. There is no distinction between an *arc* and a *directed edge*. We will often use indistinctly these two terms.

A new object, the graph list data structure, is defined in Scilab to handle graph. It is described below.

### 1.1 The graph list data structure

Metanet uses the graph list data structure to represent graphs. With this type of description (see 1.2), we can have directed or undirected multigraphs and multiple loops are allowed. The graph list data structure is a typed list. As usual, the first element of this object is itself a list which defines its type, `'graph'`, and all the access functions to the other elements. The graph list has 33 elements (not counting the first one defining the type). Only the first five elements must have a value in the list, all the others can be given the empty vector `[]` as a value, and then a default is used. These five required elements are:

**name** name of the graph (a string)

**directed** flag equal to 1 if the graph is directed or equal to 0 if the graph is undirected

**node_number** number of nodes

**tail** row vector of the tail node numbers

**head** row vector of the head node numbers

A graph must at least have one arc, so `tail` and `head` cannot be empty.

For instance, you can define a graph list (see 2.1) by

```
g=make_graph('min',1,1,[1],[1]);
```

which is the simplest graph you can create (it is directed, has one node and one loop arc on this node).

Each element of the list can be accessed by using its name. For instance, if `g` is a graph list and you want to get the `node_number` element, you only have to type:
`g('node_number')`
and if you want to change this value to 10, you only have to type:
`g('node_number')=10`

The `check_graph` function checks a graph list to see if there are inconsistencies in its elements. Checking is not only syntactic (number of elements of the list, compatible sizes of the vectors), but also semantic in the sense that `check_graph` checks that `node_number`, `tail` and `head` elements of the list can really represent a graph. This checking is automatically made when calling functions with a graph list as an argument.

You will find below the description of all the elements of a graph list. Each element is described by one or more lines. The first lines give the name of the element and its definition, with its Scilab type if needed. The last line gives the default for elements that can have one. The name of the element is used to access the elements of the list.

**name** Name of the graph; a string with a maximum of 80 characters (*REQUIRED*).

**directed** Flag giving the type of the graph; it is equal to 1 if the graph is directed or equal to 0 is the graph is undirected (*REQUIRED*).

**node_number** Number of nodes (*REQUIRED*).

**tail** Row vector of the tail node numbers (*REQUIRED*).

**head** Row vector of the head node numbers (*REQUIRED*).

**node_name** Row vector of the node names; they *MUST* be different.

Default is the node numbers as node names.

**node_type** Row vector of the node types; the type is an integer from 0 to 2:

0: plain node

1: sink node

2: source node

This element is mainly used to draw the nodes in the Metanet window. A plain node is drawn as a circle. A sink or source node is a node where extraneous flow goes out the node or goes into the node; it is drawn differently (a circle with an outgoing or ingoing arrow).

Default is 0 (plain node).

**node_x** Row vector of the x coordinates of the nodes.

Default is computed when showing the graph in the Metanet window (see 3).

**node_y** Row vector of the y coordinates of the nodes.

Default is computed when showing the graph in the Metanet window (see 3).

**node_color** Row vector of the node colors; the color is an integer from 0 to 16:

0: black
1: navyblue
2: blue
3: skyblue
4: aquamarine
5: forestgreen
6: green
7: lightcyan
8: cyan
9: orange
10: red
11: magenta
12: violet
13: yellow
14: gold
15: beige
16: white

Default is 0 (black).

**node_diam** Row vector of the sizes of the node diameters in pixels (a node is drawn as a circle).

Default is the value of element `default_node_diam`.

**node_border** Row vector of the sizes of the node borders in pixels.

Default is the value of element `default_node_border`.

**node_font_size** Row vector of the sizes of the font used to draw the name or the label of the node; you can choose 8, 10, 12, 14, 18 or 24.

Default is the value of element `default_font_size`.

**node_demand** Row vector of the node demands.

The demands of the nodes are used in functions `min_lcost_cflow`, `min_lcost_flow1`, `min_lcost_flow2`, `min_qcost_flow` and `supernode`.

Default is 0.

**edge_name** Row vector of the edge names; edge names need not be different.

Default is the edge numbers as edge names.

**edge_color** Row vector of the edge colors; the color is an integer from 0 to 16 (see `node_color`).

Default is 0 (black).

**edge_width** Row vector of the sizes of the edge widths in pixels.

Default is the value of element `default_edge_width`.

**edge_hi_width** Row vector of the sizes of the highlighted edge widths in pixels.

Default is the value of element `default_edge_hi_width`.

**edge_font_size** Row vector of the sizes of the font used to draw the name or the label of the edge; you can choose 8, 10, 12, 14, 18 or 24.

Default is the value of element `default_font_size`.

**edge_length** Row vector of the edge lengths.

The lengths of the edges are used in functions `graph_center`, `graph_diameter`, `salesman` and `shortest_path`.

Default is 0.

**edge_cost** Row vector of the edge costs.

The costs of the edges are used in functions `min_lcost_cflow`, `min_lcost_flow1` and `min_lcost_flow2`.

Default is 0.

**edge_min_cap** Row vector of the edge minimum capacities.

The minimum capacities of the edges are used in functions `max_flow`, `min_lcost_cflow`, `min_lcost_flow1`, `min_lcost_flow2` and `min_qcost_flow`.

Default is 0.

**edge_max_cap** Row vector of the edge maximum capacities.

The maximum capacities of the edges are used in functions `max_cap_path`, `max_flow`, `min_lcost_cflow`, `min_lcost_flow1`, `min_lcost_flow2` and `min_qcost_flow`.

Default is 0.

**edge_q_weight** Row vector of the edge quadratic weights. It corresponds to $w(u)$ in the value of the cost on edge $u$ with flow $\varphi(u)$: $\frac{1}{2}w(u)(\varphi(u) - w_0(u))^2$.

The quadratic weights of the edges are used in function `min_qcost_flow`.

Default is 0.

**edge_q_orig** Row vector of the edge quadratic origins. It corresponds to $w_0(u)$ in the value of the cost on edge $u$ with flow $\varphi(u)$: $\frac{1}{2}w(u)(\varphi(u) - w_0(u))^2$.

The quadratic origins of the edges are used in function `min_qcost_flow`.

Default is 0.

**edge_weight** Row vector of the edge weights.

The weights of the edges are used in function `min_weight_tree`.

Default is 0.

**default_node_diam** Default size in pixels of the node diameters of the graph.

Default is 20.

**default_node_border** Default size in pixels of the node borders of the graph.

Default is 2.

**default_edge_width** Default size in pixels of the edge widths of the graph.

Default is 1.

**default_edge_hi_width** Default size in pixels of the highlighted edge widths of the graph.

Default is 3.

**default_font_size** Default size of the font used to draw the names or the labels of nodes and edges.

Default is 12.

**node_label** Row vector of the node labels.

Node labels are used to draw a string in a node. It can be any string. An empty label can be given as a blank string `' '`.

**edge_label** Row vector of the edge labels.

Edge labels are used to draw a string on an edge. It can be any string. An empty label can be given as a blank string `' '`.

## 1.2 Various representations of graphs

### 1.2.1 Names and numbers

First of all, we need to distinguish between the name of a node or the name of an edge and their internal numbers. The name can be any string. Its is saved in the graph file (see 2.2). The internal number is generated automatically when loading a graph. The nodes and the edges have consecutive internal numbers starting from 1. When using the Scilab functions working on graphs, *all the computations are made with internal numbers*.

It is very important to give different names to the nodes because the nodes are distinguished by their names when they are loaded. This distinction is not important for edges.

Often, the names are taken as the internal numbers. This is the default when no names are given. In this case, the distinction between a name and a number is not meaningful. Only the type of the variable is not the same: the name is a string and the number is an integer.

In the following when we talk about the number of a node or the number of an edge, we mean the internal number.

### 1.2.2 Tail head

We have seen that the standard representation of a graph used by Metanet is by the means of two row vectors `tail` and `head`: arc number $i$ goes from node number `tail(i)` to node number `head(i)`. The size of these vectors is the same and is the number of arcs of the graph.

Moreover the number of nodes must be given. It is greater than or equal to the maximum integer number in `tail` and `head`. If node numbers do not belong to `tail` and `head` then there are isolated nodes.

If the graph is undirected, it is the same, but `tail(i)` and `head(i)` can be exchanged.

This representation is very general and gives directed or undirected multigraphs with possible loops and isolated nodes.

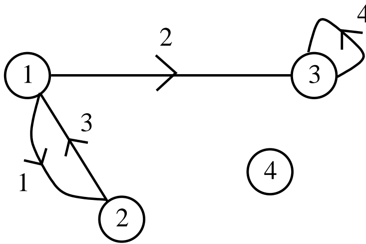



Figure 1: Small directed graph

The standard function to create graphs is `make_graph` (see 2.1). For instance, we can create a small directed graph with a loop and an isolated node (see figure 1) by using:
node number = 4, tail = [1,1,2,3], head = [2,3,1,3],
or in Scilab:

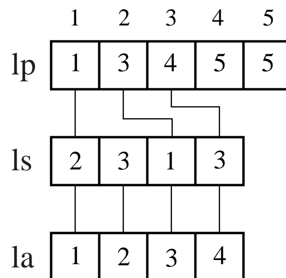
```
g=make_graph('foo',1,4,[1 1 2 3],[2 3 1 3]);
```

### 1.2.3 Adjacency lists

Another interesting representation often used by algorithms is the *adjacency lists* representation. It uses three row vectors, `lp`, `ls` and `la`. If $n$ is the number of nodes and $m$ is the number of arcs of the graph:
`lp` is the pointer array (size = $n+1$)
`ls` is the node array (size = $m$)
`la` is the arc array (size = $m$).
If the graph is undirected, each edge corresponds to two arcs.

With this type of representation, it is easy to know the successors of a node. Node number `i` has `lp(i+1)-lp(i)` successors nodes with numbers from `ls(lp(i))` to `ls(lp(i+1)-1)`, the corresponding arcs are have numbers from `la(lp(i))` to `la(lp(i+1)-1)`.

The adjacency lists representation of the graph of figure 1 is given below:




The function used to compute the adjacency list representation of a graph is `adj_lists`.

### 1.2.4 Node-arc matrix

For a directed graph, if $n$ is the number of nodes and $m$ is the number of arcs of the graph, the node-arc matrix $A$ is a $n \times m$ matrix:
if $A(i,j) = +1$, then node $i$ is the tail of arc $j$
if $A(i,j) = -1$, then node $i$ is the head of arc $i$.
If the graph is undirected and $m$ is the number of edges, the node-arc matrix $A$ is also a $n \times m$ matrix and:
if $A(i,j) = 1$, then node $i$ is an end of edge $j$.

With this type of representation, it is impossible to have loops.
This matrix is represented in Scilab as a sparse matrix.
For instance, the node-arc matrix corresponding to figure 1, with loop arc number 4 deleted is :

$$\begin{pmatrix} 1 & 1 & -1 \\ -1 & 0 & 1 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

If the same graph is undirected, the matrix is:

$$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

The functions used to compute the node-arc matrix of a graph, and to come back to a graph from the node-arc matrix are `graph_2_mat` and `mat_2_graph`.

### 1.2.5 Node-node matrix

The $n \times n$ node-node matrix of the graph is the matrix $A$ where $A(i, j) = 1$ if there is one arc from node $i$ to node $j$. Only 1 to 1 graphs (no more than one arc from one node to another) can be represented, but loops are allowed. This matrix is also known as the "adjacency matrix".

The same functions used to compute the node-arc matrix (see above) of a graph are used to compute the node-node matrix: `graph_2_mat` and `mat_2_graph`. To specify that we are working with the node-node matrix, the flag `'nodenode'` must be given as the last argument of these functions.

For instance, you can find below the node-node matrix of the graph corresponding to Figure 1:

$$\begin{pmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

and the node-node matrix for the same undirected graph:

$$\begin{pmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

### 1.2.6 Chained lists

Another representation used by some algorithms is given by the *chained lists*. This representation uses four vectors, `fe`, `che`, `fn` and `chn` which are described below:
`e1=fe(i))` is the number of the first edge starting from node `i`
`e2=che(e1)` is the number of the second edge starting from node `i`
`e3=che(e2)` is the number of the third edge starting from node `i`
and so on until the value is 0
`fn(i)` is the number of the first node reached from node i
`chn(i)` is the number of the node reached by edge `che(i)`.

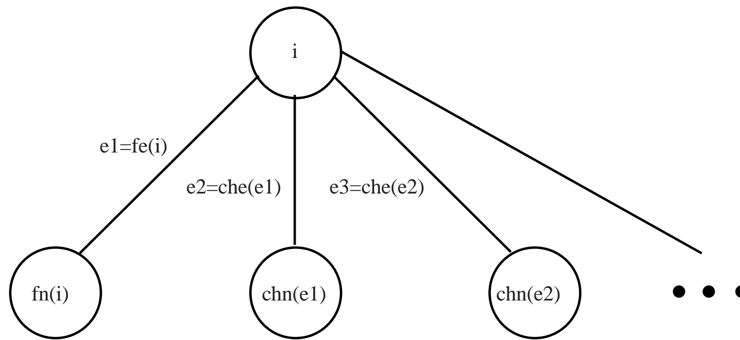



Figure 2: Chained lists representation of graphs

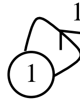



Figure 3: Smallest directed graph

All this can be more clearly seen on figure 2.

You can use the chain_struct function to obtain the chained lists representation of a graph from the adjacency lists representation (see 1.2.3).

# 2 Managing graphs

We have seen (see 1.1) that a graph in Scilab is represented by a graph list. This list contains everything needed to define the graph, arcs, nodes, coordinates, colors, attributes, width of the arcs, etc.

To create, load and save graphs in Scilab, you can use only Scilab functions, handling graph lists, or you can use the Metanet window. We describe here the first way. For the second way, see 3.

## 2.1 Creating graphs

The standard function for making a graph list is make_graph. The first argument is the name of the graph, the second argument is a flag which can be 1 (directed graph) or 0 (undirected graph), the third argument is the number of nodes of the graph, and the last two arguments are the tail and head vectors of the graph.

We have already seen that the graph named “foo” in figure 1 can be created by the command:

```
g=make_graph('foo',1,4,[1 1 2 3],[2 3 1 3]);
```

The simplest graph we can create in Metanet is:

```
g=make_graph('min',1,1,[1],[1]);
```

It is directed, has one node and one loop arc on this node and can be seen in figure 3.

The following graph shown in figure 4 is the same as the first graph we have created, but it is undirected:

```
g=make_graph('ufoo',0,4,[1 1 2 3],[2 3 1 3]);
```

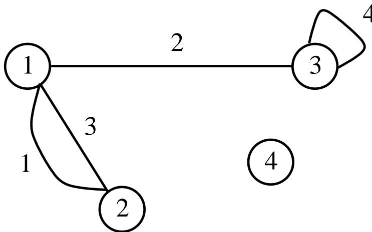



Figure 4: Small undirected graph

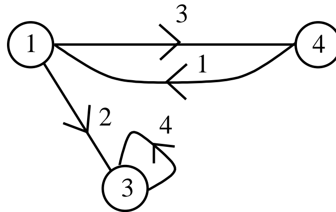



Figure 5: Directed graph

You can also give 0 as the third argument of `make_graph` (number of nodes). This means that `make_graph` will compute itself from its last arguments, the tail and head vectors, the number of nodes of the graph. So, this graph has no isolated node and the nodes names are taken from the numbers in tail and head vectors. For instance, if you enter

```
g=make_graph('foo1',1,0,[1 1 4 3],[4 3 1 3]);
```

the graph (shown in figure 5) has three nodes with names 1, 3 and 4, no isolated node and four edges. Note the difference with the graph of figure 1.

The other elements of the graph list (see 1.1) can be entered by using the names of the elements. For instance, to give graph "foo" coordinates for the nodes, you can enter:

```
g=make_graph('foo',1,4,[1 1 2 3],[2 3 1 3]);
g('node_x')=[42 108 176 162];
g('node_y')=[36 134  36  93];
```

Another simple example: if you want to transform the directed graph `g` into an undirected graph, you only have to do:

```
g('directed')=0;
```

There is a wizard way to create a graph list "by hands" without using the `make_graph` function. This can be useful when writing your own Scilab functions. You can use the Scilab function `glist` which must have as many arguments as the elements of the graph list (see 1.1). This way can lead to errors, because the list is somehow long. You can use the `check_graph` function to check if the graph list is correct.

### 2.2 Loading and saving graphs

Graphs are saved in ASCII files, called *graph files*. A graph file has the extension `.graph`. The structure of a graph file is given below:

```
GRAPH TYPE (0 = UNDIRECTED, 1 = DIRECTED), DEFAULTS (NODE DIAMETER, NODE BORDER,
   first line continuing ARC WIDTH, HILITED ARC WIDTH, FONTSIZE):
<one line with above values>
NUMBER OF ARCS:
<one line with the number of arcs>
NUMBER OF NODES:
<one line with the number of nodes>
****************************************
DESCRIPTION OF ARCS:
ARC NAME, TAIL NODE NAME, HEAD NODE NAME, COLOR, WIDTH, HIWIDTH, FONTSIZE
COST, MIN CAP, CAP, MAX CAP, LENGTH, Q WEIGHT, Q ORIGIN, WEIGHT
<one blank line>
<two lines for each arc>
****************************************
DESCRIPTION OF NODES:
NODE NAME, POSSIBLE TYPE (1 = SINK, 2 = SOURCE)
X, Y, COLOR, DIAMETER, BORDER, FONTSIZE
DEMAND
<one blank line>
<three lines for each node>
```

For an undirected graph, `ARC` is replaced by `EDGE`. Moreover, the values of `NODE DIAMETER`, `NODE BORDER`, `ARC WIDTH`, `HILITED ARC WIDTH` and `FONTSIZE` for the graph, `COLOR`, `WIDTH`, `HIWIDTH` and `FONTSIZE` for the arcs, and `POSSIBLE TYPE`, `COLOR`, `DIAMETER`, `BORDER` and `FONTSIZE` for the nodes can be omitted or equal to 0, then the default is used (see 1.1).

It is possible to create by hands a graph file and to load it into Scilab, but it is a very cumbersome job. Programs are given to generate graphs (see 4).

To load a graph into Scilab, use the `load_graph` function. Its argument is the absolute or relative pathname of the graph file; if the `.graph` extension is missing, it is assumed. `load_graph` returns the corresponding graph list.

For instance, to load the graph `foo`, which is in the current directory, and put the corresponding graph list in the Scilab variable `g`, do:
`g=load_graph('foo');` or `g=load_graph('foo.graph');`.
To load the graph `mesh100` given in the Scilab distribution, do:
`g=load_graph(SCI+'/demos/metanet/mesh100.graph');`

To save a graph, use the `save_graph` function. Its first argument is the graph list, and its second argument is the name or the pathname of the graph file; if the `.graph` extension is missing, it is assumed. If the path is the name of a directory, the name of the graph is used as the name of the file.

For instance, the following command saves the graph `g` into the graph file `foo.graph`:
`save_graph(g,'foo.graph');`

## 2.3 Plotting graphs

The fastest way to see a graph is to plot it in a Scilab graphical window. We can use the `plot_graph` function to do this. Note that no interaction is possible with the displayed graph. If you want to graphically modify the graph, use Metanet windows (see 3).

# 3 Metanet windows

Metanet windows can be used to see the graphs and the networks. It is a powerful tool to create and modify graphs. You can have as many Metanet windows as you want at the same time. Each Metanet window is an Unix process: the communications between Scilab and the Metanet windows is made by using the communication toolbox called GeCI. *NOTE* that at the present time, Metanet windows only work under Unix environment with X Window.

By default, the size of Metanet windows is 1000 pixels by 1000 pixels. If you want to see big graphs, you have to change this values by using X Window ressources. Put the new values in the ressources `Metanet.drawWidth` and `Metanet.drawHeight` in a standard ressource file (for instance `.Xdefaults` in your home directory). For instance, if you want Metanet windows with a size of 2000 by 3000 pixels, puts the following lines in the ressource file:

```
Metanet.drawWidth: 2000
Metanet.drawHeight: 3000
```

An important point is that there is no link between the graph displayed in the Metanet window and the graphs loaded into Scilab. So, when you have created or modified a graph in the Metanet window, you have to save it as a graph file (see 2.2) and load it again in Scilab. Conversely, when you have modified a graph in Scilab, you have to display it again in the Metanet window by using the `save_graph` function (see 3.2). The philosophy is that computations are only made in Scilab and the Metanet window is only used to display, create or modify graphs. So, you can use Metanet toolbox without using Metanet windows.

Another way to see a graph is to plot it in a Scilab graphical window (see 2.3), but there is no possibility to modify the displayed graph.

## 3.1 Using the Metanet window

To open a Metanet window, use the `metanet` or `show_graph` Scilab functions (see 3.2).

The Metanet window comes with three modes. When no graph is loaded, you are in the *Begin mode*. When a graph is loaded, you are in the *Study mode*. When you are creating a new graph or modifying a graph, you are in the *Modify mode*.

### 3.1.1 Begin mode

In this mode, you can load a graph or create a new one. You will find below the description of the items of the menus.

**Files**

**New** Create a new graph. Prompt for the name of the graph and for its type (directed or not directed). Then you enter Modify Mode.

**Load** Load a graph. Show the list of graphs in the default directory. You have to choose one.

**Directory** Change the default directory.

**Quit** Quit Metanet.

### 3.1.2 Study mode

In this mode, you can load a graph, create a new one or work with an already loaded graph.

With the left button of the mouse, you can highlight an arc or a node.

You will find below the description of the items of the menus.

**Files**

**New** Create a new graph. Prompt for the name of the graph and for its type (directed or not directed). Then you enter Modify Mode.

**Load** Load a graph. Show the list of graphs in the default directory. You have to choose one.

**Directory** Change the default directory.

**Save As** Save the loaded graph with a new name in the default directory.

**Quit** Quit Metanet.

**Graph**

**Characteristics** If there is an highlighted arc or node, print its characteristics, otherwise print the characteristics of the graph.

**Find Arc** Prompt for an arc name and highlight it. The viewport of the window is moved to display the arc if needed.

**Find Node** Prompt for a node name and highlight it. The viewport of the window is moved to display the arc if needed.

**Graphics** Change the scale. The default is 1.

**Modify Graph** Enter Modify mode.

**Use internal numbers as names** Use the consecutive internal numbers of arcs and nodes as names. This is useful when doing computations with Scilab.

**Display arc names** Display arc names on the arcs.

**Display node names** Display node names on the nodes.

**Redraw** Refresh the screen and redraw the graph.

### 3.1.3 Modify mode

In this mode, you can modify and save the graph.

With the left button of the mouse, you can highlight an arc or a node.

With the right button of the mouse, you can modify the graph:

- if you click where there is no arc or node, a new node is created;

- if you click on a node and another node is highlighted, a new arc is created between the two nodes;
- if you click on a node and drag the mouse, the node is moved.

You will find below the description of the items of the menus.

**Files**

**Directory** Change the default directory.

**Save** Save the modified graph in the default directory. All the arcs and nodes must have names.

**Save As** Save the modified graph with a new name in the default directory. All the arcs and nodes must have names.

**Quit** Exit Modify Mode. If the graph has been modified, it must be saved first.

**Graph**

**Characteristics** If there is an highlighted arc or node, print its characteristics, otherwise print the characteristics of the graph.

**Find Arc** Prompt for an arc name and highlight it. The viewport of the window is moved to display the arc if needed.

**Find Node** Prompt for a node name and highlight it. The viewport of the window is moved to display the arc if needed.

**Graphics** Change the scale. The default is 1.

**Use internal numbers as names** Use the consecutive internal numbers of arcs and nodes as names. This is useful when doing computations with Scilab.

**Display arc names** Display arc names on the arcs.

**Display node names** Display node names on the nodes.

**Modify**

**Attributes** Display the attributes of the highlighted arc or node. Then, they can be changed.

**Delete** Delete the highlighted arc or node. *NOTE:* there is no undelete.

**Name** Name the highlighted arc or node.

**Color** Give a color to the highlighted arc or node.

**Create Loop** Create a loop arc on the highlighted node.

**Create Sink** Transform the highlighted node into a sink.

**Create Source** Transform the highlighted node into a source.

**Remove Sink/Source** Transform the highlighted source or sink node into a plain node. It has no effect if the highlighted node is neither a source nor a sink.

**Automatic Name** Give the consecutive internal arc and node numbers as the names of arcs and nodes. This can be useful for a new graph. *NOTE* that if some arcs and nodes already have names, they are replaced by the corresponding internal numbers.

**Default Values** Change some default values:

- the default size of the font
- the default diameter of the nodes

- the default width of the border of the nodes
- the default width of the arcs
- the default width of the highlighted arcs

**Redraw** Refresh the screen and redraw the graph.

## 3.2 Using the Metanet window from Scilab

The standard way of using the Metanet window is from Scilab. Indeed, the Metanet window is opened only when needed as a new process.

Many Metanet windows can be opened at the same time. Each Metanet window has a number (integer starting from 1). One of these windows is the *current Metanet window*.

The `metanet` function opens a new Metanet window and returns its number. A path can be given as an optional argument: it is the directory where graph files are searched; by default, graph files are searched in the working directory. The `metanet` function is mainly used when we want to create a new graph.

We describe below the Scilab functions used in conjunction with the Metanet window.

### 3.2.1 Showing a graph

The first thing we would like to do is to see the graph we are working with: use the `show_graph` function.

`show_graph(g)` displays the graph `g` in the current Metanet window. If there is no current Metanet window, a new Metanet window is created and it becomes the current Metanet window. If there is already a graph displayed in the current Metanet window, the new graph is displayed instead. The number of the current Metanet window, where the graph is displayed, is returned by `show_graph`.

Two optional arguments can be given to `show_graph(g)` after the graph list. If an optional argument is equal to the string `'new'`, a new Metanet window is created. If an optional argument is a positive number, it is the value of the scale factor when drawing the graph (see 3.1).

For instance `show_graph(g,'new',2)` displays the graph `g` in a new Metanet window with the scale factor equal to 2.

### 3.2.2 Showing arcs and nodes

Another very useful thing to do is to distinguish a set of nodes and/or a set of arcs in the displayed graph. This is done by highlighting nodes and/or arcs: use the `show_arcs` and `show_nodes` functions.

The arguments of the `show_arcs` and `show_nodes` functions are respectively a row vector of arc numbers (or edge numbers if the graph is undirected) or a row vector of node numbers. These sets of arcs and nodes are highlighted in the current Metanet window. Note that the corresponding graph must be displayed in this window, otherwise the numbers might not correspond to arcs or nodes numbers (see 3.2.3 for changing the current Metanet window).

By default, using one of these functions switch off any preceeding highlighting. If you want to keep preceeding highlighting, use the optional argument `'sup'`.

For instance, the following commands displays the graph `g` and highlights 3 arcs and 2 nodes:

```
show_graph(g)
show_arcs([1 10 3]); show_nodes([2 7],'sup')
```

Note that another way to distinguish arcs and nodes in a displayed graph is to give them colors. For that you have to use the elements edge_color and node_color of the graph list (see 1.1). But you have to modify the graph list of the graph and use show_graph again to display the graph with the new colors.

### 3.2.3 Managing Metanet windows

The netwindow function is used to change the current Metanet window. For instance netwindow(2) chooses Metanet window number 2 as the current Metanet window.

The netwindows function returns a list. Its first element is the row vector of all the Metanet windows numbers and the second element is the number of the current Metanet window. This number is equal to 0 if no current Metanet window exists.

In the following example, there are two Metanet windows with numbers 1 and 3 and the Metanet window number 3 is the current Metanet window.

```
-->netwindows()
 ans  =
       ans(1)
!   1.    3. !
       ans(2)
    3.
```

### 3.2.4 Synchronism

By default Metanet windows work with Scilab in asynchronous mode, *i.e.* Scilab proceeds without waiting for graphics commands sent to Metanet windows to terminate. This mode is the most efficient. But when running a lots of graphics commands, problems can arise. For instance, you might highlight a set of nodes in a bad Metanet window because the good one has not yet appeared! So it is possible to use a synchronous mode. Then Scilab waits until the functions dealing with the Metanet windows have terminated.

The metanet_sync function is used to change the mode: metanet_sync(0) changes to asynchronous mode (default), metanet_sync(1) changes to synchronous mode, and metanet_sync() returns the current mode (0 = asynchronous, 1 = synchronous).

# 4 Generating graphs and networks

When working with graphs and particularly with networks, it is very useful to generate them automatically.

The function gen_net can be used in Metanet to generate networks. It uses a triangulation method for generating a planar connected graph and then uses the information of the user to give arcs and nodes good values of costs and capacities.

# 5 Computations on graphs and networks

Most functions of the Metanet toolbox are used to make computations on graphs and networks. We can distinguish four classes of such functions and we will describe them briefly. For more information, see the on line help.

## 5.1 Graph manipulations and transformations

You can use these functions to get information about graphs or to modify existing graphs.

**add_edge** adds an edge or an arc between two nodes

**add_node** adds a disconnected node to a graph

**arc_graph** graph with nodes corresponding to arcs

**arc_number** number of arcs of a graph

**contract_edge** contracts edges between two nodes

**delete_arcs** deletes all the arcs or edges between a set of nodes

**delete_nodes** deletes nodes

**edge_number** number of edges of a graph

**graph_2_mat** node-arc or node-node matrix of a graph

**graph_simp** converts a graph to a simple undirected graph

**graph_sum** sum of two graphs

**graph_union** union of two graphs

**line_graph** graph with nodes corresponding to edges

**mat_2_graph** graph from node-arc or node-node matrix

**node_number** number of nodes of a graph

**nodes_2_path** path from a set of nodes

**path_2_nodes** set of nodes from a path

**split_edge** splits an edge by inserting a node

**subgraph** subgraph of a graph

**supernode** replaces a group of nodes with a single node

## 5.2 Graph computations

These functions are used to make standard computations on graphs.

**articul** finds one or more articulation points

**best_match** best matching of a graph

**circuit** finds a circuit or the rank function in a directed graph

**con_nodes** set of nodes of a connected component

**connex** connected components

**cycle_basis** basis of cycle of a simple undirected graph

**find_path** finds a path between two nodes

**girth** girth of a directed graph

**graph_center** center of a graph

**graph_complement** complement of a graph

**graph_diameter** diameter of a graph

**graph_power** kth power of a directed 1-graph

**hamilton** hamiltonian circuit of a graph

**is_connex** connectivity test

**max_clique** maximum clique of a graph

**min_weight_tree** minimum weight spanning tree

**neighbors** nodes connected to a node

**nodes_degrees** degrees of the nodes of a graph

**perfect_match** min-cost perfect matching

**predecessors** tail nodes of incoming arcs of a node

**shortest_path** shortest path

**strong_con_nodes** set of nodes of a strong connected component

**strong_connex** strong connected components

**successors** head nodes of outgoing arcs of a node

**trans_closure** transitive closure

## 5.3 Network computations

These functions make computations on networks. This means that the graph has capacities and/or costs values on the edges.

**max_cap_path** maximum capacity path

**max_flow** maximum flow between two nodes

**min_lcost_cflow** minimum linear cost constrained flow

**min_lcost_flow1** minimum linear cost flow

**min_lcost_flow2** minimum linear cost flow

**min_qcost_flow** minimum quadratic cost flow

**pipe_network** pipe network problem

### 5.4 Other computations

These functions do not make computations directly on graphs and networks, but they have strong links with them.

**bandwr** bandwidth reduction for a sparse matrix

**convex_hull** convex hull of a set of points in the plane

**knapsack** solves a 0-1 multiple knapsack problem

**mesh2d** triangulation of n points in the plane

**qassign** solves a quadratic assignment problem

**salesman** solves the travelling salesman problem

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