python-igraph Manual

For using igraph from Python

Installing igraph (install.html) | (index.html) | Graph generation (generation.html)

Tutorial

This chapter contains a short overview of *igraph*'s capabilities. It is highly recommended to read it at least once if you are new to *igraph*. I assume that you have already installed *igraph*; if you did not, see *Installing igraph* (install.html#installing-igraph) first. Familiarity with the Python language is also assumed; if this is the first time you are trying to use Python, there are many good Python tutorials on the Internet to get you started. Mark Pilgrim's Dive Into Python (http://www.diveintopython.net) is one that I personally suggest. If this is the first time you ever try to use a programming language, A Byte of Python (http://swaroopch.com/notes/Python) is even better. If you already have a stable programming background in other languages and you just want a quick overview of Python, Learn Python in 10 minutes (http://www.poromenos.org/tutorials/python) is probably your best bet.

Starting *igraph*

igraph is a Python module, hence it can be imported exactly the same way as any other ordinary Python module at the Python prompt:

```
$ python
Python 2.7.1 (r271:86832, Jun 16 2011, 16:59:05)
[GCC 4.2.1 (Based on Apple Inc. build 5658) (LLVM build 2335.15.00)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> import igraph
```

This imports *igraph*'s objects and methods inside an own namespace called **`igraph`**. Whenever you would like to call any of *igraph*'s methods, you will have to provide the appropriate namespace-qualification. E.g., to check which *igraph* version you are using, you could do the following:

```
>>> import igraph
>>> print igraph.__version__
0.6
```

Another way to make use of *igraph* is to import all its objects and methods into the main Python namespace (so you do not have to type the namespace-qualification every time). This is fine as long as none of your own objects and methods do not conflict with the ones provided by *igraph*:

```
>>> from igraph import *
```

The third way to start *igraph* is to simply call the startup script that was supplied with the *igraph* package you installed. Not too surprisingly, the script is called **igraph**, and provided that the script is on your path in the command line of your operating system (which is almost surely the case on Linux and OS X), you can simply type **igraph** at the command line. Windows users will find the script inside the `scripts` subdirectory of Python and you may have to add it manually to your path in order to be able to use the script from the command line without typing the whole path.

When you start the script, you will see something like this:

```
$ igraph
No configuration file, using defaults
igraph 0.6 running inside Python 2.7.1 (r271:86832, Jun 16 2011, 16:59:05)
Type "copyright", "credits" or "license" for more information.
>>>
```

The command-line startup script imports all of *igraph*‘s methods and objects into the main namespace, so it is practically equivalent to `from igraph import *`. The difference between the two approaches (apart from saving some typing) is that the command-line script checks whether you have any of Python’s more advanced shells installed and uses that instead of the standard Python shell. Currently the module looks for IPython (http://ipython.scipy.org) and IDLE (the Tcl/Tk-based graphical shell supplied with Python). If neither IPython nor IDLE is installed, the startup script launches the default Python shell. You can also modify the order in which these shells are searched by tweaking *igraph*‘s configuration file (see *configuring-igraph*).

In general, it is advised to use the command line startup script when using *igraph* interactively (i.e., when you just want to quickly load or generate some graphs, calculate some basic properties and save the results somewhere). For non-disposable graph analysis routines that you intend to re-run from time to time, you should write a script separately in a `.py` source file and import *igraph* using one of the above methods at the start of the script, then launch the script using the Python interpreter.

From now on, every example in the documentation will assume that *igraph*'s objects and methods are imported into the main namespace (i.e., we used `from igraph import *` instead of `import igraph`). If you let *igraph* take its own namespace, please adjust all the examples accordingly.

Creating a graph from scratch

Assuming that you have started *igraph* successfully, it is time to create your first *igraph* graph. This is pretty simple:

```
>>> g = Graph()
```

The above statement created an undirected graph with no vertices or edges and assigned it to the variable g. To confirm that it's really an *igraph* graph, we can print it:

```
>>> g
<igraph.Graph object at 0x4c87a0>
```

This tells us that g is an instance of *igraph*'s **`Graph`** class and that it is currently living at the memory address `0x4c87a0` (the exact output will almost surely be different for your platform). To obtain a more user-friendly output, we can try to print the graph using Python's `print` statement:

```
>>> print(g)
IGRAPH U--- 0 0 --
```

TODO: explain it

This is not too exciting so far; a graph with a single vertex and no edges is not really useful for us. Let’s add some vertices first!

```
>>> g.add_vertices(3)
```

`Graph.add_vertices()` (i.e., the **`add_vertices()`** method of the **`Graph`** class) adds the given number of vertices to the graph.

Now our graph has three vertices but no edges, so let’s add some edges as well! You can add edges by calling **`Graph.add_edges()`** - but in order to add edges, you have to refer to existing vertices somehow. *igraph* uses integer vertex IDs starting from zero, thus the first vertex of your graph has index zero, the second vertex has index 1 and so on. Edges are specified by pairs of integers, so `[(0,1), (1,2)]` denotes a list of two edges: one between the first and the second, and the other one between the second and the third vertices of the graph. Passing this list to **`Graph.add_edges()`** adds these two edges to your graph:

```
>>> g.add_edges([(0,1), (1,2)])
```

`add_edges()` is clever enough to figure out what you want to do in most of the cases: if you supply a single pair of integers, it will automatically assume that you want to add a single edge. However, if you try to add edges to vertices with invalid IDs (i.e., you try to add an edge to vertex 5 when you only have three edges), you will get an exception:

```
>>> g.add_edges((5, 0))
Traceback (most recent call last):
  File "<stdin>", line 6, in <module>
igraph.core.InternalError: Error at ../../src/type_indexededgelist.c:245: cannot add edges, inval
id vertex id
```

Most *igraph* functions will raise an **`igraph.core.InternalError`** if something goes wrong. The message corresponding to the exception gives you a short textual explanation of what went wrong (`cannot add edges, invalid vertex id`) along with the corresponding line in the C source where the error occurred. The exact filename and line number may not be too informative to you, but it is invaluable for *igraph* developers if you think you found an error in *igraph* and you want to report it.

Let us go on with our graph `g` and add some more vertices and edges to it:

```
>>> g.add_edges((2,0))
>>> g.add_vertices(3)
>>> g.add_edges([(2,3),(3,4),(4,5),(5,3)])
>>> print g
IGRAPH U---- 6 7 --
+ edges:
0--1 1--2 0--2 2--3 3--4 4--5 3--5
```

Now, this is better. We have an undirected graph with six vertices and seven edges, and you can also see the list of edges in *igraph*'s output. Edges also have IDs, similarly to vertices; they also start from zero and edges that were added later have higher IDs than edges that were added earlier. Vertex and edge IDs are always *continuous*, and a direct consequence of this fact is that if you happen to delete an edge, chances are that some (or all) of the edges will be renumbered. Moreover, if you delete a vertex, even the vertex IDs will change. Edges can be deleted by **`delete_edges()`** and it requires a list of edge IDs to be deleted (or a single edge ID). Vertices can be deleted by **`delete_vertices()`** and you may have already guessed that it requires a list of vertex IDs to be deleted (or a single vertex ID). If you do not know the ID of an edge you wish to delete, but you know the IDs of the vertices at its two endpoints, you can use **`get_eid()`** to get the edge ID. Remember, all these are *methods* of the **`Graph`** class and you must call them on the appropriate **`Graph`** instance!

```
>>> g.get_eid(2,3)
3
>>> g.delete_edges(3)
>>> summary(g)
IGRAPH U--- 6 6 --
```

`summary()` is a new command that you haven't seen before; it is a member of *igraph*'s own namespace and it can be used to get an overview of a given graph object. Its output is similar to the output of `print` but it does not print the edge list to avoid cluttering up the display for large graphs. In general, you should use **`summary()`** instead of `print` when working interactively with large graphs because printing the edge list of a graph with millions of vertices and edges could take quite a lot of time.

Generating graphs

igraph includes a large set of graph generators which can be divided into two groups: deterministic and stochastic graph generators. Deterministic generators produce the same graph if you call them with exactly the same parameters, while stochastic generators produce a different graph every time. Deterministic generators include methods for creating trees, regular lattices, rings, extended chordal rings, several famous graphs and so on, while stochastic generators are used to create Erdős-Rényi random networks, Barabási-Albert networks, geometric random graphs and such. *igraph* has too many generators to cover them all in this tutorial, so we will only try a deterministic and a stochastic generator instead:

```
>>> g = Graph.Tree(127, 2)
>>> summary(g)
IGRAPH U--- 127 126 --
```

`Graph.Tree()` generates a regular tree graph. The one that we generated has 127 vertices and each vertex (apart from the leaves) has two children (and of course one parent). No matter how many times you call **`Graph.Tree()`**, the generated graph will always be the same if you use the same parameters:

```
>>> g2 = Graph.Tree(127, 2)
>>> g2.get_edgelist() == g.get_edgelist()
True
```

The above code snippet also shows you that the **`get_edgelist()`** method of **`Graph`** graph objects return a list that contains pairs of integers, one for each edge. The first member of the pair is the source vertex ID and the second member is the target vertex ID of the corresponding edge. This list is too long, so let’s just print the first 10 elements!

```
>>> g2.get_edgelist()[0:10]
[(0, 1), (0, 2), (1, 3), (1, 4), (2, 5), (2, 6), (3, 7), (3, 8), (4, 9), (4, 10)]
```

Let’s do the same with a stochastic generator!

```
>>> g = Graph.GRG(100, 0.2)
>>> summary(g)
IGRAPH U---- 100 516 --
+ attr: x (v), y (v)
```

TODO: discuss what the `+ attr` line means.

`Graph.GRG()` generates a geometric random graph: *n* points are chosen randomly and uniformly inside the unit square and pairs of points closer to each other than a predefined distance *d* are connected by an edge. In our case, *n* is 100 and *d* is 0.2. Due to the random nature of the algorithm, chances are that the exact graph you got is different from the one that was generated when I wrote this tutorial, hence the values above in the summary will not match the ones you got. This is normal and expected. Even if you generate two geometric random graphs on the same machine, they will be different for the same parameter set:

```
>>> g2 = Graph.GRG(100, 0.2)
>>> g.get_edgelist() == g2.get_edgelist()
False
>>> g.isomorphic(g2)
False
```

`isomorphic()` tells you whether two graphs are isomorphic or not. In general, it might take quite a lot of time, especially for large graphs, but in our case, the answer can quickly be given by checking the degree distributions of the two graphs.

Setting and retrieving attributes

igraph uses vertex and edge IDs in its core. These IDs are integers, starting from zero, and they are always continuous at any given time instance during the lifetime of the graph. This means that whenever vertices and edges are deleted, a large set of edge and possibly vertex IDs will be renumbered to ensure the continuiuty. Now, let us assume that our graph is a social network where vertices represent people and edges represent social connections between them. One way to maintain the association between vertex IDs and say, the corresponding names is to have an additional Python list that maps from vertex IDs to names. The drawback of this approach is that this additional list must be maintained in parallel to the modifications of the original graph. Luckily, *igraph* knows the concept of *attributes*, i.e., auxiliary objects associated to a given vertex or edge of a graph, or even to the graph as a whole. Every *igraph* **`Graph`**, vertex and edge behaves as a standard Python dictionary in some sense: you can add key-value pairs to any of them, with the key representing the name of your attribute (the only restriction is that it must be a string) and the value representing the attribute itself.

Warning

Attributes can be arbitrary Python objects, but if you are saving graphs to a file, only string and numeric attributes will be kept. See the **`pickle`** module in the standard Python library if you are looking for a way to save other attribute types. You can either pickle your attributes individually, store them as strings and save them, or you can pickle the whole **`Graph`** if you know that you want to load the graph back into Python only.

Let us create a simple imaginary social network the usual way by hand.

```
>>> g = Graph([(0,1), (0,2), (2,3), (3,4), (4,2), (2,5), (5,0), (6,3), (5,6)])
```

Now, let us assume that we want to store the names, ages and genders of people in this network as vertex attributes, and for every connection, we want to store whether this is an informal friendship tie or a formal tie. Every **`Graph`** object contains two special members called **`vs`** and **`es`**, standing for the sequence of all vertices and all edges, respectively. If you try to use **`vs`** or **`es`** as a Python dictionary, you will manipulate the attribute storage area of the graph:

```
>>> g.vs
<igraph.VertexSeq object at 0x1b23b90>
>>> g.vs["name"] = ["Alice", "Bob", "Claire", "Dennis", "Esther", "Frank", "George"]
>>> g.vs["age"] = [25, 31, 18, 47, 22, 23, 50]
>>> g.vs["gender"] = ["f", "m", "f", "m", "f", "m", "m"]
>>> g.es["is_formal"] = [False, False, True, True, True, False, True, False, False]
```

Whenever you use **`vs`** or **`es`** as a dictionary, you are assigning attributes to *all* vertices/edges of the graph. However, you can simply alter the attributes of vertices and edges individually by *indexing* **`vs`** or **`es`** with integers as if they were lists (remember, they are sequences, they contain all the vertices or all the edges). When you index them, you obtain a **`Vertex`** or **`Edge`** object, which refers to (I am sure you already guessed that) a single vertex or a single edge of the graph. **`Vertex`** and **`Edge`** objects can also be used as dictionaries to alter the attributes of that single vertex or edge:

```
>>> g.es[0]
igraph.Edge(<igraph.Graph object at 0x4c87a0>,0,{'is_formal': False})
>>> g.es[0].attributes()
{'is_formal': False}
>>> g.es[0]["is_formal"] = True
>>> g.es[0]
igraph.Edge(<igraph.Graph object at 0x4c87a0>,0,{'is_formal': True})
```

The above snippet illustrates that indexing an **`EdgeSeq`** object returns **`Edge`** objects; the representation above shows the graph the object belongs to, the edge ID (zero in our case) and the dictionary of attributes assigned to that edge. **`Edge`** objects have some useful attributes, too: the **`source`** property gives you the source vertex of that edge, **`target`** gives you the target vertex, **`index`** gives you the corresponding edge ID, **`tuple`** gives you a tuple containing the source and target vertices and **`attributes()`** gives you a dictionary containing the attributes of this edge. **`Vertex`** instances only have **`index`** and **`attributes()`**.

Since **`Graph.es`** always represents all the edges in a graph, indexing it by *i* will always return the edge with ID *i*, and of course the same applies to **`Graph.vs`**. However, keep in mind that an **`EdgeSeq`** object *in general* does not necessarily represent the whole edge sequence of a graph; *later in this tutorial* we will see methods that can filter **`EdgeSeq`** objects and return other **`EdgeSeq`** objects that are restricted to a subset of edges, and of course the same applies to **`VertexSeq`** objects. But before we dive into that, let's see how we can assign attributes to the whole graph. Not too surprisingly, **`Graph`** objects themselves can also behave as dictionaries:

```
>>> g["date"] = "2009-01-10"
>>> print g["date"]
2009-01-10
```

Finally, it should be mentioned that attributes can be deleted by the Python keyword `del` just as you would do with any member of an ordinary dictionary:

```
>>> g.vs[3]["foo"] = "bar"
>>> g.vs["foo"]
[None, None, None, 'bar', None, None, None]
>>> del g.vs["foo"]
>>> g.vs["foo"]
Traceback (most recent call last):
  File "<stdin>", line 25, in <module>
KeyError: 'Attribute does not exist'
```

Structural properties of graphs

Besides the simple graph and attribute manipulation routines described above, *igraph* provides a large set of methods to calculate various structural properties of graphs. It is beyond the scope of this tutorial to document all of them, hence this section will only introduce a few of them for illustrative purposes. We will work on the small social network we built in the previous section.

Probably the simplest property one can think of is the *vertex degree*. The degree of a vertex equals the number of edges adjacent to it. In case of directed networks, we can also define *in-degree* (the number of edges pointing towards the vertex) and *out-degree* (the number of edges originating from the vertex). *igraph* is able to calculate all of them using a simple syntax:

```
>>> g.degree()
[3, 1, 4, 3, 2, 3, 2]
```

If the graph was directed, we would have been able to calculate the in- and out-degrees separately using `g.degree(type="in")` and `g.degree(type="out")`. You can also pass a single vertex ID or a list of vertex IDs to **`degree()`** if you want to calculate the degrees for only a subset of vertices:

```
>>> g.degree(6)
2
>>> g.degree([2,3,4])
[4, 3, 2]
```

This calling convention applies to most of the structural properties *igraph* can calculate. For vertex properties, the methods accept a vertex ID or a list of vertex IDs (and if they are omitted, the default is the set of all vertices). For edge properties, the methods accept a single edge ID or a list of edge IDs. Instead of a list of IDs, you can also supply a **`VertexSeq`** or an **`EdgeSeq`** instance appropriately. Later in the *next chapter*, you will learn how to restrict them to exactly the vertices or edges you want.

Note

For some measures, it does not make sense to calculate them only for a few vertices or edges instead of the whole graph, as it would take the same time anyway. In this case, the methods won't accept vertex or edge IDs, but you can still restrict the resulting list later using standard list indexing and slicing operators. One such example is eigenvector centrality (**`Graph.evcent()`**).

Besides degree, *igraph* includes built-in routines to calculate many other centrality properties, including vertex and edge betweenness (**`Graph.betweenness()`**, **`Graph.edge_betweenness()`**) or Google's PageRank (**`Graph.pagerank()`**) just to name a few. Here we just illustrate edge betweenness:

```
>>> g.edge_betweenness()
[6.0, 6.0, 4.0, 2.0, 4.0, 3.0, 4.0, 3.0. 4.0]
```

Now we can also figure out which connections have the highest betweenness centrality with some Python magic:

```
>>> ebs = g.edge_betweenness()
>>> max_eb = max(ebs)
>>> [g.es[idx].tuple for idx, eb in enumerate(ebs) if eb == max_eb]
[(0, 1), (0, 2)]
```

Most structural properties can also be retrieved for a subset of vertices or edges or for a single vertex or edge by calling the appropriate method on the **`VertexSeq`**, **`EdgeSeq`**, **`Vertex`** or **`Edge`** object of interest:

```
>>> g.vs.degree()
[3, 1, 4, 3, 2, 3, 2]
>>> g.es.edge_betweenness()
[6.0, 6.0, 4.0, 2.0, 4.0, 3.0, 4.0, 3.0. 4.0]
>>> g.vs[2].degree()
4
```

Querying vertices and edges based on attributes

Selecting vertices and edges

Imagine that in a given social network, you would like to find out who has the largest degree or betweenness centrality. You can do that with the tools presented so far and some basic Python knowledge, but since it is a common task to select vertices and edges based on attributes or structural properties, *igraph* gives you an easier way to do that:

```
>>> g.vs.select(_degree = g.maxdegree())["name"]
["Alice", "Bob"]
```

The syntax may seem a little bit awkward for the first sight, so let's try to interpret it step by step. **`select()`** is a method of **`VertexSeq`** and its sole purpose is to filter a **`VertexSeq`** based on the properties of individual vertices. The way it filters the vertices depends on its positional and keyword arguments. Positional arguments (the ones without an explicit name like `_degree` above) are always processed before keyword arguments as follows:

- If the first positional argument is `None`, an empty sequence (containing no vertices) is returned:

```
>>> seq = g.vs.select(None)
>>> len(seq)
0
```

- If the first positional argument is a callable object (i.e., a function, a bound method or anything that behaves like a function), the object will be called for every vertex that’s currently in the sequence. If the function returns `True`, the vertex will be included, otherwise it will be excluded:

```
>>> graph = Graph.Full(10)
>>> only_odd_vertices = graph.vs.select(lambda vertex: vertex.index % 2 == 1)
>>> len(only_odd_vertices)
5
```

- If the first positional argument is an iterable (i.e., a list, a generator or anything that can be iterated over), it *must* return integers and these integers will be considered as indices into the current vertex set (which is *not* necessarily the whole graph). Only those vertices that match the given indices will be included in the filtered vertex set. Floats, strings, invalid vertex IDs will silently be ignored:

```
>>> seq = graph.vs.select([2, 3, 7])
>>> len(seq)
3
>>> [v.index for v in seq]
[2, 3, 7]
>>> seq = seq.select([0, 2])         # filtering an existing vertex set
>>> [v.index for v in seq]
[2, 7]
>>> seq = graph.vs.select([2, 3, 7, "foo", 3.5])
>>> len(seq)
3
```

- If the first positional argument is an integer, all remaining arguments are also expected to be integers and they are interpreted as indices into the current vertex set. This is just syntactic sugar, you could achieve an equivalent effect by passing a list as the first positional argument, but this way you can omit the square brackets:

  ```
  >>> seq = graph.vs.select(2, 3, 7)
  >>> len(seq)
  3
  ```

Keyword arguments can be used to filter the vertices based on their attributes or their structural properties. The name of each keyword argument should consist of at most two parts: the name of the attribute or structural property and the filtering operator. The operator can be omitted; in that case, we automatically assume the equality operator. The possibilities are as follows (where *name* denotes the name of the attribute or property):

Keyword argument	Meaning
`name_eq`	The attribute/property value must be *equal to* the value of the keyword argument
`name_ne`	The attribute/property value must *not be equal to* the value of the keyword argument
`name_lt`	The attribute/property value must be *less than* the value of the keyword argument

Keyword argument	Meaning
`name_le`	The attribute/property value must be *less than or equal to* the value of the keyword argument
`name_gt`	The attribute/property value must be *greater than* the value of the keyword argument
`name_ge`	The attribute/property value must be *greater than or equal to* the value of the keyword argument
`name_in`	The attribute/property value must be *included in* the value of the keyword argument, which must be a sequence in this case
`name_notin`	The attribute/property value must *not be included in* the value of the the keyword argument, which must be a sequence in this case

For instance, the following command gives you people younger than 30 years in our imaginary social network:

```
>>> g.vs.select(age_lt=30)
```

Note

Due to the syntactical constraints of Python, you cannot use the admittedly simpler syntax of `g.vs.select(age < 30)` as only the equality operator is allowed to appear in an argument list in Python.

To save you some typing, you can even omit the **`select()`** method if you wish:

```
>>> g.vs(age_lt=30)
```

Theoretically, it can happen that there exists an attribute and a structural property with the same name (e.g., you could have a vertex attribute named `degree`). In that case, we would not be able to decide whether the user meant `degree` as a structural property or as a vertex attribute. To resolve this ambiguity, structural property names *must* always be preceded by an underscore (`_`) when used for filtering. For example, to find vertices with degree larger than 2:

```
>>> g.vs(_degree_gt=2)
```

There are also a few special structural properties for selecting edges:

- Using `_source` or `_from` in the keyword argument list of **`EdgeSeq.select()`** filters based on the source vertices of the edges. E.g., to select all the edges originating from Claire (who has vertex index 2):

  ```
  >>> g.es.select(_source=2)
  ```

- Using `_target` or `_to` filters based on the target vertices. This is different from `_source` and `_from` if the graph is directed.

- `_within` takes a **`VertexSeq`** object or a list or set of vertex indices and selects all the edges that originate and terminate in the given vertex set. For instance, the following expression selects all the edges between Claire (vertex index 2), Dennis (vertex index 3) and Esther (vertex index 4):

  ```
  >>> g.es.select(_within=[2,3,4])
  ```

  We could also have used a **`VertexSeq`** object:

  ```
  >>> g.es.select(_within=g.vs[2:5])
  ```

- `_between` takes a tuple consisting of two **`VertexSeq`** objects or lists containing vertex indices or **`Vertex`** objects and selects all the edges that originate in one of the sets and terminate in the other. E.g., to select all the edges that connect men to women:

  ```
  >>> men = g.vs.select(gender="m")
  >>> women = g.vs.select(gender="f")
  >>> g.es.select(_between=(men, women))
  ```

Finding a single vertex or edge with some properties

In many cases we are looking for a single vertex or edge of a graph with some properties, and either we do not care which one of the matches is returned if there are multiple matches, or we know in advance that there will be only one match. A typical example is looking up vertices by their names in the `name` property. **`VertexSeq`** and **`EdgeSeq`** objects provide the **`find()`** method for such use-cases. **`find()`** works similarly to **`select()`**, but it returns only the first match if there are multiple matches, and throws an exception if no match is found. For instance, to look up the vertex corresponding to Claire, one can do this:

```
>>> claire = g.vs.find(name="Claire")
>>> type(claire)
igraph.Vertex
>>> claire.index
2
```

Looking up an unknown name will yield an exception:

```
>>> g.vs.find(name="Joe")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: no such vertex
```

Looking up vertices by names

Looking up vertices by names is a very common operation, and it is usually much easier to remember the names of the vertices in a graph than their IDs. To this end, *igraph* treats the `name` attribute of vertices specially; they are indexed such that vertices can be looked up by their names in amortized constant time. To make things even easier, *igraph* accepts vertex names (almost) anywhere where it expects vertex IDs, and also accepts collections (list, tuples etc) of vertex names anywhere where it expects lists of vertex IDs or **`VertexSeq`** instances. E.g, you can simply look up the degree (number of connections) of Dennis as follows:

```
>>> g.degree("Dennis")
3
```

or, alternatively:

```
>>> g.vs.find("Dennis").degree()
3
```

The mapping between vertex names and IDs is maintained transparently by *igraph* in the background; whenever the graph changes, *igraph* also updates the internal mapping. However, uniqueness of vertex names is *not* enforced; you can easily create a graph where two vertices have the same name, but *igraph* will return only one of them when you look them up by names, the other one will be available only by its index.

Treating a graph as an adjacency matrix

TODO

Layouts and plotting

A graph is an abstract mathematical object without a specific representation in 2D or 3D space. This means that whenever we want to visualise a graph, we have to find a mapping from vertices to coordinates in two- or three-dimensional space first, preferably in a way that is pleasing for the eye. A separate branch of graph theory, namely graph drawing, tries to solve this problem via several graph layout algorithms. *igraph* implements quite a few layout algorithms and is also able to draw them onto the screen or to a PDF, PNG or SVG file using the Cairo library (http://www.cairographics.org).

Important

To follow the examples of this subsection, you need the Python bindings of the Cairo library. The previous chapter (*Installing igraph* (install.html#installing-igraph)) tells you more about how to install Cairo's Python bindings.

Layout algorithms

The layout methods in *igraph* are to be found in the **`Graph`** object, and their always start with `layout_`. The following table summarises them:

Method name	Short name	Algorithm description
`layout_circle`	`circle`, `circular`	Deterministic layout that places the vertices on a circle
`layout_drl`	`drl`	The Distributed Recursive Layout (http://www.cs.sandia.gov/~smartin/software.html) algorithm for large graphs
`layout_fruchterman_reingold`	`fr`	Fruchterman-Reingold force-directed algorithm
`layout_fruchterman_reingold_3d`	`fr3d`, `fr_3d`	Fruchterman-Reingold force-directed algorithm in three dimensions
`layout_grid_fruchterman_reingold`	`grid_fr`	Fruchterman-Reingold force-directed algorithm with grid heuristics for large graphs

Method name	Short name	Algorithm description
`layout_kamada_kawai`	`kk`	Kamada-Kawai force-directed algorithm
`layout_kamada_kawai_3d`	`kk3d`, `kk_3d`	Kamada-Kawai force-directed algorithm in three dimensions
`layout_lgl`	`large`, `lgl`, `large_graph`	The Large Graph Layout (http://sourceforge.net/projects/lgl/) algorithm for large graphs
`layout_random`	`random`	Places the vertices completely randomly
`layout_random_3d`	`random_3d`	Places the vertices completely randomly in 3D
`layout_reingold_tilford`	`rt`, `tree`	Reingold-Tilford tree layout, useful for (almost) tree-like graphs
`layout_reingold_tilford_circular`	`rt_circular` `tree`	Reingold-Tilford tree layout with a polar coordinate post-transformation, useful for (almost) tree-like graphs
`layout_sphere`	`sphere`, `spherical`, `circular`, `circular_3d`	Deterministic layout that places the vertices evenly on the surface of a sphere

Layout algorithms can either be called directly or using the common layout method called **`layout()`**:

```
>>> layout = g.layout_kamada_kawai()
>>> layout = g.layout("kamada_kawai")
```

The first argument of the **`layout()`** method must be the short name of the layout algorithm (see the table above). All the remaining positional and keyword arguments are passed intact to the chosen layout method. For instance, the following two calls are completely equivalent:

```
>>> layout = g.layout_reingold_tilford(root=2)
>>> layout = g.layout("rt", 2)
```

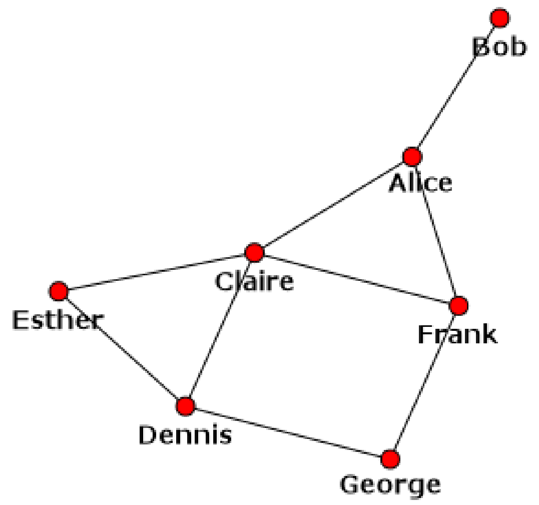
Layout methods return a **`Layout`** object which behaves mostly like a list of lists. Each list entry in a **`Layout`** object corresponds to a vertex in the original graph and contains the vertex coordinates in the 2D or 3D space. **`Layout`** objects also contain some useful methods to translate, scale or rotate the coordinates in a batch. However, the primary utility of **`Layout`** objects is that you can pass them to the **`plot()`** function along with the graph to obtain a 2D drawing.

Drawing a graph using a layout

For instance, we can plot our imaginary social network with the Kamada-Kawai layout algorithm as follows:

```
>>> layout = g.layout("kk")
>>> plot(g, layout = layout)
```

This should open an external image viewer showing a visual representation of the network, something like the one on the following figure (although the exact placement of nodes may be different on your machine since the layout is not deterministic):

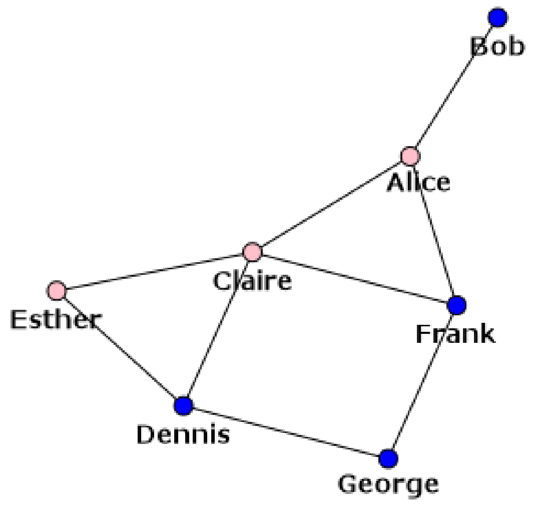


Our social network with the Kamada-Kawai layout algorithm

Hmm, this is not too pretty so far. A trivial addition would be to use the names as the vertex labels and to color the vertices according to the gender. Vertex labels are taken from the `label` attribute by default and vertex colors are determined by the `color` attribute, so we can simply create these attributes and re-plot the graph:

```
>>> g.vs["label"] = g.vs["name"]
>>> color_dict = {"m": "blue", "f": "pink"}
>>> g.vs["color"] = [color_dict[gender] for gender in g.vs["gender"]]
>>> plot(g, layout = layout, bbox = (300, 300), margin = 20)
```

Note that we are simply re-using the previous layout object here, but we also specified that we need a smaller plot (300 x 300 pixels) and a larger margin around the graph to fit the labels (20 pixels). The result is:



Our social network - with names as labels and genders as colors

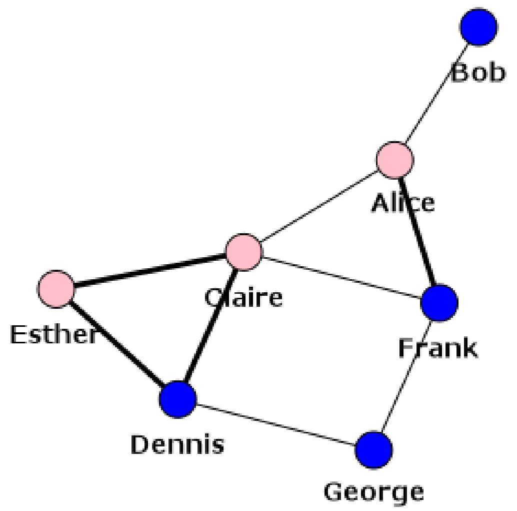
Instead of specifying the visual properties as vertex and edge attributes, you can also give them as keyword arguments to **`plot()`**:

```
>>> color_dict = {"m": "blue", "f": "pink"}
>>> plot(g, layout = layout, vertex_color = [color_dict[gender] for gender in g.vs["gender"]])
```

This latter approach is preferred if you want to keep the properties of the visual representation of your graph separate from the graph itself. You can simply set up a Python dictionary containing the keyword arguments you would pass to **`plot()`** and then use the double asterisk (`**`) operator to pass your specific styling attributes to **`plot()`**:

```
>>> visual_style = {}
>>> visual_style["vertex_size"] = 20
>>> visual_style["vertex_color"] = [color_dict[gender] for gender in g.vs["gender"]]
>>> visual_style["vertex_label"] = g.vs["name"]
>>> visual_style["edge_width"] = [1 + 2 * int(is_formal) for is_formal in g.es["is_formal"]]
>>> visual_style["layout"] = layout
>>> visual_style["bbox"] = (300, 300)
>>> visual_style["margin"] = 20
>>> plot(g, **visual_style)
```

The final plot shows the formal ties with thick lines while informal ones with thin lines:



Our social network - also showing which ties are formal

To sum it all up: there are special vertex and edge properties that correspond to the visual representation of the graph. These attributes override the default settings of *igraph* (see *configuring-igraph* for overriding the system-wide defaults). Furthermore, appropriate keyword arguments supplied to **`plot()`** override the visual properties provided by the vertex and edge attributes. The following two tables summarise the most frequently used visual attributes for vertices and edges, respectively:

Vertex attributes controlling graph plots

Attribute name	Keyword argument	Purpose
`color`	`vertex_color`	Color of the vertex
`label`	`vertex_label`	Label of the vertex
`label_angle`	`vertex_label_angle`	The placement of the vertex label on the circle around the vertex. This is an angle in radians, with zero belonging to the right side of the vertex.
`label_color`	`vertex_label_color`	Color of the vertex label
`label_dist`	`vertex_label_dist`	Distance of the vertex label from the vertex itself, relative to the vertex size
`label_size`	`vertex_label_size`	Font size of the vertex label

Attribute name	Keyword argument	Purpose
`order`	`vertex_order`	Drawing order of the vertices. Vertices with a smaller order parameter will be drawn first.
`shape`	`vertex_shape`	Shape of the vertex. Known shapes are: `rectangle`, `circle`, `hidden`, `triangle-up`, `triangle-down`. Several aliases are also accepted, see **`drawing.known_shapes`**.
`size`	`vertex_size`	Size of the vertex in pixels

Edge attributes controlling graph plots

Attribute name	Keyword argument	Purpose
`color`	`edge_color`	Color of the edge

Attribute name	Keyword argument	Purpose
`curved`	`edge_curved`	The curvature of the edge. Positive values correspond to edges curved in CCW direction, negative numbers correspond to edges curved in clockwise (CW) direction. Zero represents straight edges. `True` is interpreted as 0.5, `False` is interpreted as zero. This is useful to make multiple edges visible. See also the `autocurve` keyword argument to **`plot()`**.
`arrow_size`	`edge_arrow_size`	Size (length) of the arrowhead on the edge if the graph is directed, relative to 15 pixels.
`arrow_width`	`edge_arrow_width`	Width of the arrowhead on the edge if the graph is directed, relative to 10 pixels.
`width`	`edge_width`	Width of the edge in pixels

Generic keyword arguments of `plot()`

These settings can be specified as keyword arguments to the `plot()` function to control the overall appearance of the plot.

Keyword argument	Purpose
`autocurve`	Whether to determine the curvature of the edges automatically in graphs with multiple edges. The default is `True` for graphs with less than 10.000 edges and `False` otherwise.
`bbox`	The bounding box of the plot. This must be a tuple containing the desired width and height of the plot. The default plot is 600 pixels wide and 600 pixels high.
`layout`	The layout to be used. It can be an instance of **`Layout`**, a list of tuples containing X-Y coordinates, or the name of a layout algorithm. The default is `auto`, which selects a layout algorithm automatically based on the size and connectedness of the graph.
`margin`	The top, right, bottom and left margins of the plot in pixels. This argument must be a list or tuple and its elements will be re-used if you specify a list or tuple with less than four elements.

Specifying colors in plots

igraph understands the following color specifications wherever it expects a color (e.g., edge, vertex or label colors in the respective attributes):

X11 color names

See the list of X11 color names (http://en.wikipedia.org/wiki/X11_color_names) in Wikipedia for the complete list.

Color specification in CSS syntax

This is a string according to one of the following formats (where *R*, *G* and *B* denote the red, green and blue components, respectively):

- `#RRGGBB`, components range from 0 to 255 in hexadecimal format. Example: `"#0088ff"`.
- `#RGB`, components range from 0 to 15 in hexadecimal format. Example: `"#08f"`.
- `rgb(R, G, B)`, components range from 0 to 255 or from 0% to 100%. Example: `"rgb(0, 127, 255)"` or `"rgb(0%, 50%, 100%)"`.

List, tuple or whitespace-separated string of RGB values

Example: `(255, 128, 0)`, `[255, 128, 0]` or `"255, 128, 0"`.

Saving plots

igraph can be used to create publication-quality plots by asking the **`plot()`** function to save the plot into a file instead of showing it on a screen. This can be done simply by passing the target filename as an additional argument after the graph itself. The preferred format is inferred from the extension. *igraph* can save to anything that is supported by Cairo, including SVG, PDF and PNG files. SVG or PDF files can then later be converted to PostScript (`.ps`) or Encapsulated PostScript (`.eps`) format if you prefer that, while PNG files can be converted to TIF (`.tif`):

```
>>> plot(g, "social_network.pdf", **visual_style)
```

igraph and the outside world

No graph module would be complete without some kind of import/export functionality that enables the package to communicate with external programs and toolkits. *igraph* is no exception: it provides functions to read the most common graph formats and to save **`Graph`** objects into files obeying these format specifications. The following table summarises the formats *igraph* can read or write:

Format	Short name	Reader method	Writer method
Adjacency list	`lgl`	**`Graph.Read_Lgl()`**	**`Graph.write_lgl()`**
(a.k.a. LGL (http://lgl.sourceforge.net/#FileFormat))			
Adjacency matrix	`adjacency`	**`Graph.Read_Adjacency()`**	**`Graph.write_adjacen`**
DIMACS	`dimacs`	**`Graph.Read_DIMACS()`**	**`Graph.write_dimacs(`**

Format	Short name	Reader method	Writer method
Edge list	`edgelist`, `edges`, `edge`	**`Graph.Read_Edgelist()`**	**`Graph.write_edgelis`**
GraphViz (http://www.graphviz.org)	`graphviz`, `dot`	not supported yet	**`Graph.write_dot()`**
GML	`gml`	**`Graph.Read_GML()`**	**`Graph.write_gml()`**
GraphML	`graphml`	**`Graph.Read_GraphML()`**	**`Graph.write_graphml`**
Gzipped GraphML	`graphmlz`	**`Graph.Read_GraphMLz()`**	**`Graph.write_graphml`**
Labeled edgelist	`ncol`	**`Graph.Read_Ncol()`**	**`Graph.write_ncol()`**
(a.k.a. NCOL (http://lgl.sourceforge.net/#FileFormat))			
Pajek (http://pajek.imfm.si/doku.php) format	`pajek`, `net`	**`Graph.Read_Pajek()`**	**`Graph.write_pajek()`**
Pickled graph	`pickle`	**`Graph.Read_Pickle()`**	**`Graph.write_pickle(`**

As an exercise, download the graph representation of the well-known Zachary karate club study (http://nexus.igraph.org/api/dataset?id=1&format=GraphML) from igraph's own graph repository called Nexus (http://nexus.igraph.org), unzip it and try to load it into *igraph*. Since it is a GraphML file, you must must use the GraphML reader method from the table above (make sure you use the appropriate path to the downloaded file):

```
>>> karate = Graph.Read_GraphML("karate.GraphML")
>>> summary(karate)
IGRAPH UNW- 34 78 -- Zachary's karate club network
+ attr: Author (g), Citation (g), name (g), Faction (v), id (v), name (v), weight (e)
```

If you want to convert the very same graph into, say, Pajek's format, you can do it with the Pajek writer method from the table above:

```
>>> karate.write_pajek("karate.net")
```

Note

Most of the formats have their own limitations; for instance, not all of them can store attributes. Your best bet is probably GraphML or GML if you want to save *igraph* graphs in a format that can be read from an external package and you want to preserve numeric and string attributes. Edge list and NCOL is also fine if you don't have attributes (NCOL supports vertex names and edge weights, though). If you don't want to use your graphs outside *igraph* but you want to store them for a later session, the pickled graph format ensures that you get exactly the same graph back. The pickled graph format uses Python's `pickle` module to store and read graphs.