# network *representations*

introduction to *network analysis in Python* (*NetPy*)

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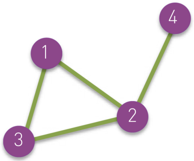
# network *representations*



*undirected graph*

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

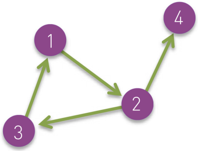
*adjacency matrix*

1: [2, 3]
2: [1, 3, 4]
3: [1, 2]
4: [2]

*adjacency list*

$\{1, 2\}$
$\{1, 3\}$
$\{2, 3\}$
$\{2, 4\}$

*edge list*



*directed graph*

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

*adjacency matrix*

[3] :1: [2]
[1] :2: [3, 4]
[2] :3: [1]
[2] :4: [ ]

*adjacency list*

$(1, 2)$
$(2, 3)$
$(2, 4)$
$(3, 1)$

*edge list*

* adjacency list can also be implemented with maps or trees & edge list cannot represent isolated nodes

# network *representations*

— *adjacency matrix* for elegant *analytical derivations*

most derivations based on matrix representation†

— *adjacency list* for efficient *algorithms implementation*

ideal complexity while most algorithms require incidence†

— *edge list* for efficient *network storing/manipulation*

easy editing while each edge stored only once

† many derivations can also be based on adjacency list & some algorithms require edge list

# network *structures*

- *edge list edges data structures* complexity

| **data structure** | **link manipulation** | **random node** | **random link** |
|---|---|---|---|
| array | none | $\mathcal{O}(m)$ | $\mathcal{O}(1)$ |
| array list | addition | $\mathcal{O}(m)$ | $\mathcal{O}(1)$ |
| hash map | any | $\mathcal{O}(m)$ | $\mathcal{O}(m)$ |

- *adjacency list nodes data structures* complexity

| **data structure** | **node manipulation** | **random node** | **random link** |
|---|---|---|---|
| array | none | $\mathcal{O}(1)$ | $\mathcal{O}(m)$ |
| array list | addition | $\mathcal{O}(1)$ | $\mathcal{O}(m)$ |
| hash map | any | $\mathcal{O}(n)$ | $\mathcal{O}(m)$ |

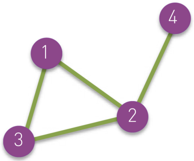
- *adjacency list neighbors data structures* complexity

| **data structure** | **link manipulation** | **node incidence** | **random neighbor** |
|---|---|---|---|
| array | none | $\mathcal{O}(k)$ | $\mathcal{O}(1)$ |
| array list | addition | $\mathcal{O}(k)$ | $\mathcal{O}(1)$ |
| hash map | any | $\approx \mathcal{O}(1)$ | $\mathcal{O}(k)$ |
| tree map | any | $\mathcal{O}(\log k)$ | $\mathcal{O}(k)$ |

- *hash maps* for *construction* and *arrays* for *analysis*
- usually *directed adjacency list* with *undirected flag*

[‡] random link selection equivalent to random node selection by degree

# network *formats*



*undirected graph*

```
# undirect
1 2
1 3
2 3
2 4
```

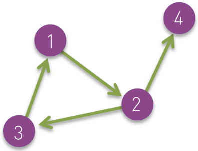
*edge list*

```
*vertices 4
1 "1"
2 "2"
3 "3"
4 "4"
*edges
1 2
1 3
2 3
2 4
```

*Pajek format*

```
# undirect
# 0 "1"
# 1 "2"
# 2 "3"
# 3 "4"
#
0 1
0 2
1 2
1 3
```

*LNA format*



*directed graph*

```
# directed
1 2
2 3
2 4
3 1
```

*edge list*

```
*vertices 4
1 "1"
2 "2"
3 "3"
4 "4"
*arcs
1 2
2 3
2 4
3 1
```

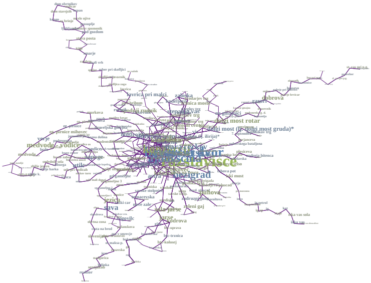
```
# directed
# 0 "1"
# 1 "2"
# 2 "3"
# 3 "4"
#
0 1
1 2
1 3
2 0
```

§ ad-hoc edge list and Pajek format most popular & other formats GML, GraphML and JSON proposal

# network *data*

- present in many *standard datasets*
- easily obtained from *online sources*
- popular *network repositories/collections*

KONECT ICON SNAP Pajek



dom obrtnikov
dom starejsih
pod gozdom
stara posta
smarje
mali vrh
skofljica zaga
lavrica
lavrica pri malci
zaloska
kodeljevo
markova
dobrova
dolgi most rotar
medvode
vodice
plesiceva
andreja bitenca
bezigrad
jezica
sava
tomacevska
zeleni gaj
jarse
kodrova
btc-trznica
btc-kolosej
reaktor