Fundamental Concepts in Data Insight:

Demo: Unsupervised Learning & Network Science

Fundamentals for a General Audience

The following code sets up the datasets needed for the demo.

Data

We obtain,

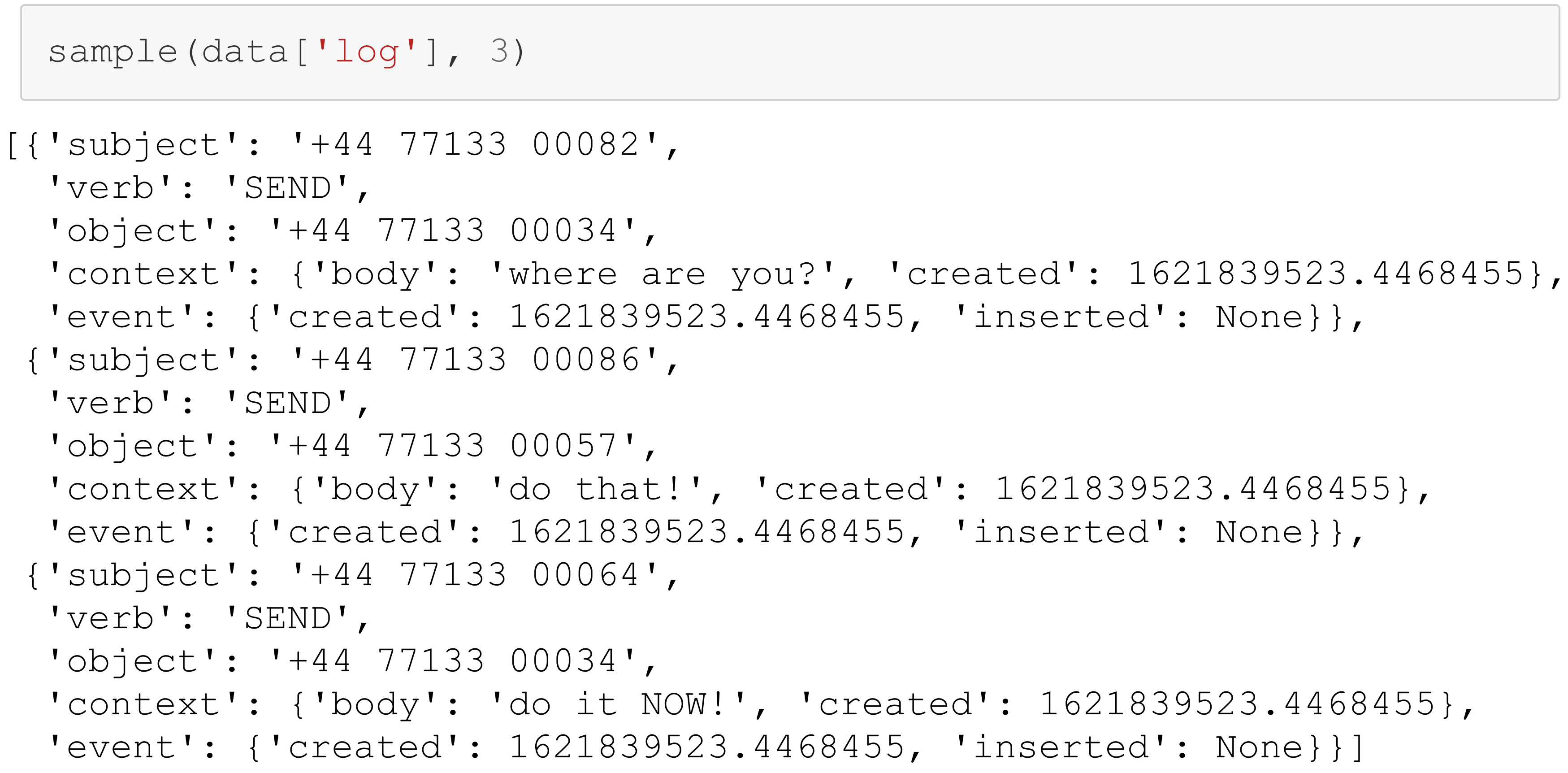
- a dataset of messages between possible criminal (gang) suspects
- statistical metrics which describe this messaging behaviour
- a predictive model which connects these metrics to gang rank hierachies

NB

This derives from a simulation of messaging behaviour. This simulation is available in a separate notebook. The simulation generates messages; and everything else is statistically derived.

```
data    = pickle.load(open('data/suspectgraph.pkl', 'rb'))
metrics = pd.read_csv('data/gmetrics.csv')
model   = pickle.load(open('data/gmodel.pkl', 'rb'))
```

The message log shows communication events between suspects,



```
sample(data['log'], 3)
```

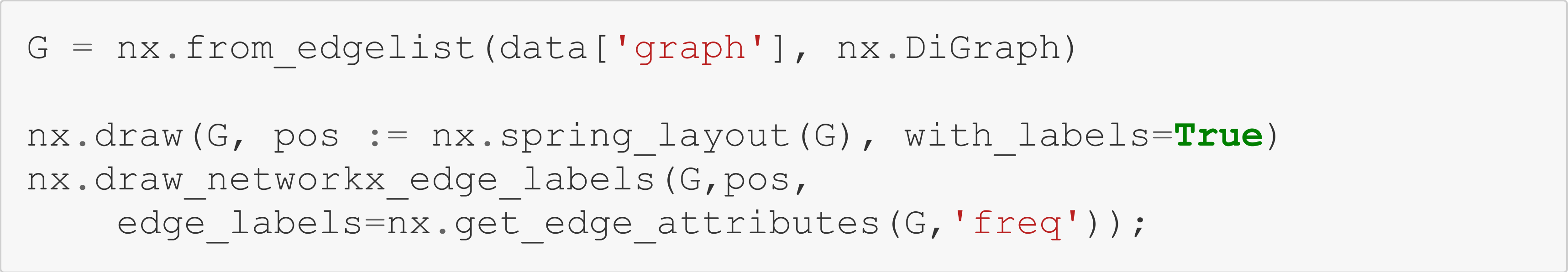
```
[{'subject': '+44 77133 00082',
  'verb': 'SEND',
  'object': '+44 77133 00034',
  'context': {'body': 'where are you?', 'created': 1621839523.4468455},
  'event': {'created': 1621839523.4468455, 'inserted': None}},
 {'subject': '+44 77133 00086',
  'verb': 'SEND',
  'object': '+44 77133 00057',
  'context': {'body': 'do that!', 'created': 1621839523.4468455},
  'event': {'created': 1621839523.4468455, 'inserted': None}},
 {'subject': '+44 77133 00064',
  'verb': 'SEND',
  'object': '+44 77133 00034',
  'context': {'body': 'do it NOW!', 'created': 1621839523.4468455},
  'event': {'created': 1621839523.4468455, 'inserted': None}}]
```

From this we can generate a graph whose *nodes* are the suspect IDs (mobile numbers), and whose *edges* are the communication activity,

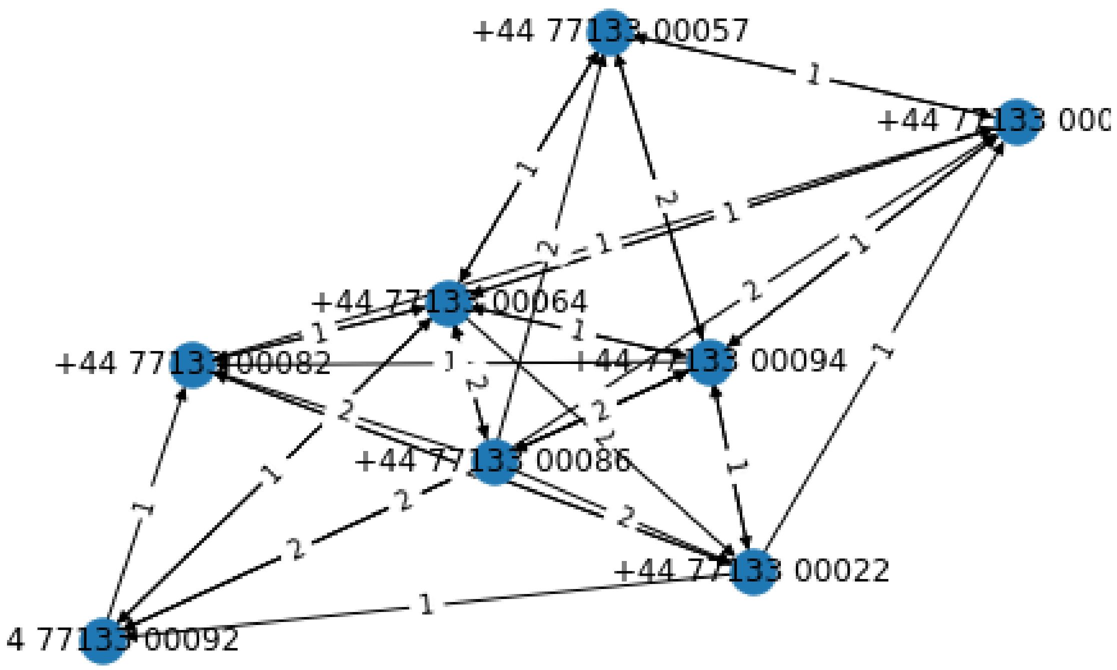
```
sample(data['graph'], 3)
```

```
[('+44 77133 00094', '+44 77133 00086', {'freq': 2}),
 ('+44 77133 00092', '+44 77133 00064', {'freq': 2}),
 ('+44 77133 00064', '+44 77133 00057', {'freq': 2})]
```

We can vizulize this graph,



```
G = nx.from_edgelist(data['graph'], nx.DiGraph)

nx.draw(G, pos := nx.spring_layout(G), with_labels=True)
nx.draw_networkx_edge_labels(G,pos,
    edge_labels=nx.get_edge_attributes(G,'freq'));
```



The inferential challenge is to assign each node a *rank* within a possible gang hierachy. To do this we compute *metrics* on this graph,

```
metrics
```

	node	degree_in	degree_out	freq_in	freq_out
0	+44 77133 00092	0.142857	0.107143	0.103448	0.086207
1	+44 77133 00094	0.214286	0.250000	0.155172	0.224138
2	+44 77133 00086	0.071429	0.250000	0.051724	0.241379
3	+44 77133 00064	0.214286	0.250000	0.155172	0.189655
4	+44 77133 00057	0.142857	0.107143	0.120690	0.068966
5	+44 77133 00082	0.178571	0.107143	0.137931	0.051724
6	+44 77133 00022	0.142857	0.142857	0.120690	0.086207
7	+44 77133 00034	0.214286	0.107143	0.155172	0.051724

Here these metrics represent, for each suspect,

- **degree in**
  - number of people *sent* messages **to** / total possible
- **degree out**
  - number of people *received* messages **from** / total possible
- **freq in**
  - number of messages received / total sent in network
- **freq out**
  - number of messages sent / total sent in network

These metrics are computed in an "unsupervised manner": they merely summarise patterns in data we can already observe.

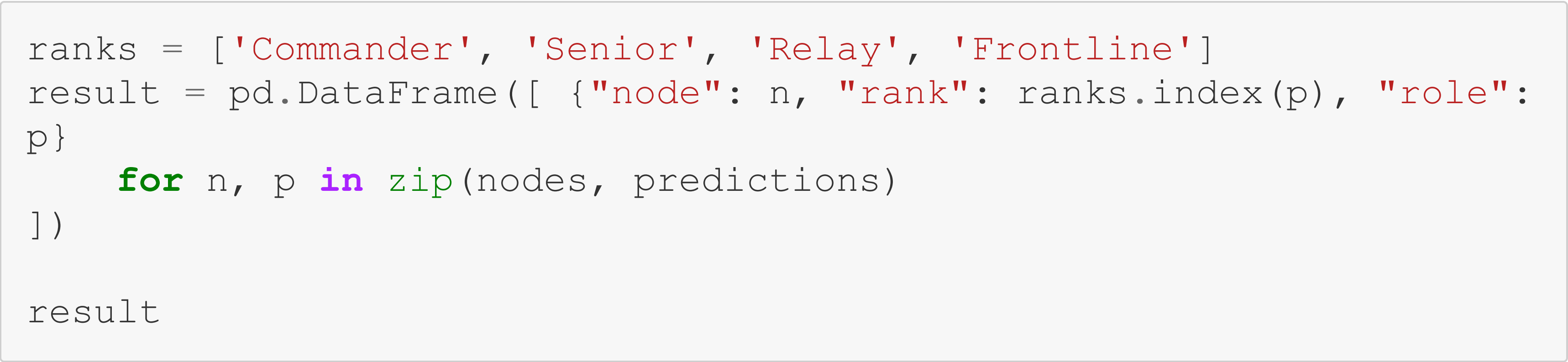
We can use these metrics in a supervised machine learning model to *predict* ranks,

```
features = metrics.copy()
nodes = features.pop('node')
predictions = model.predict(features)
```

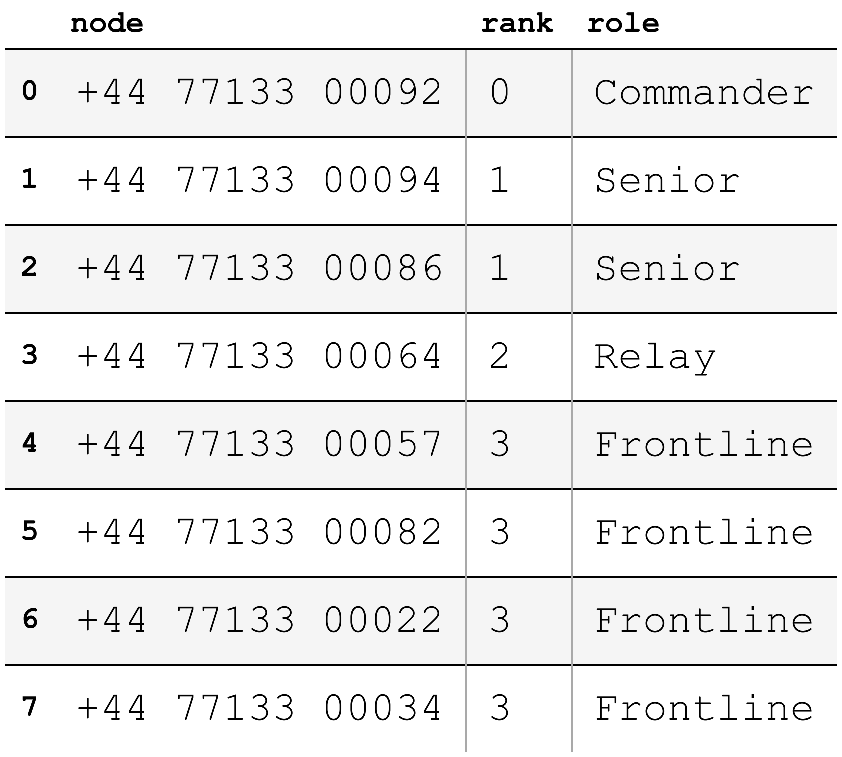
```
predictions
```

```
array(['Commander', 'Senior', 'Senior', 'Relay', 'Frontline', 'Frontline',
       'Frontline', 'Frontline'], dtype=object)
```

For the sake of clairty, we can put these in a table alongside the original suspect IDs,



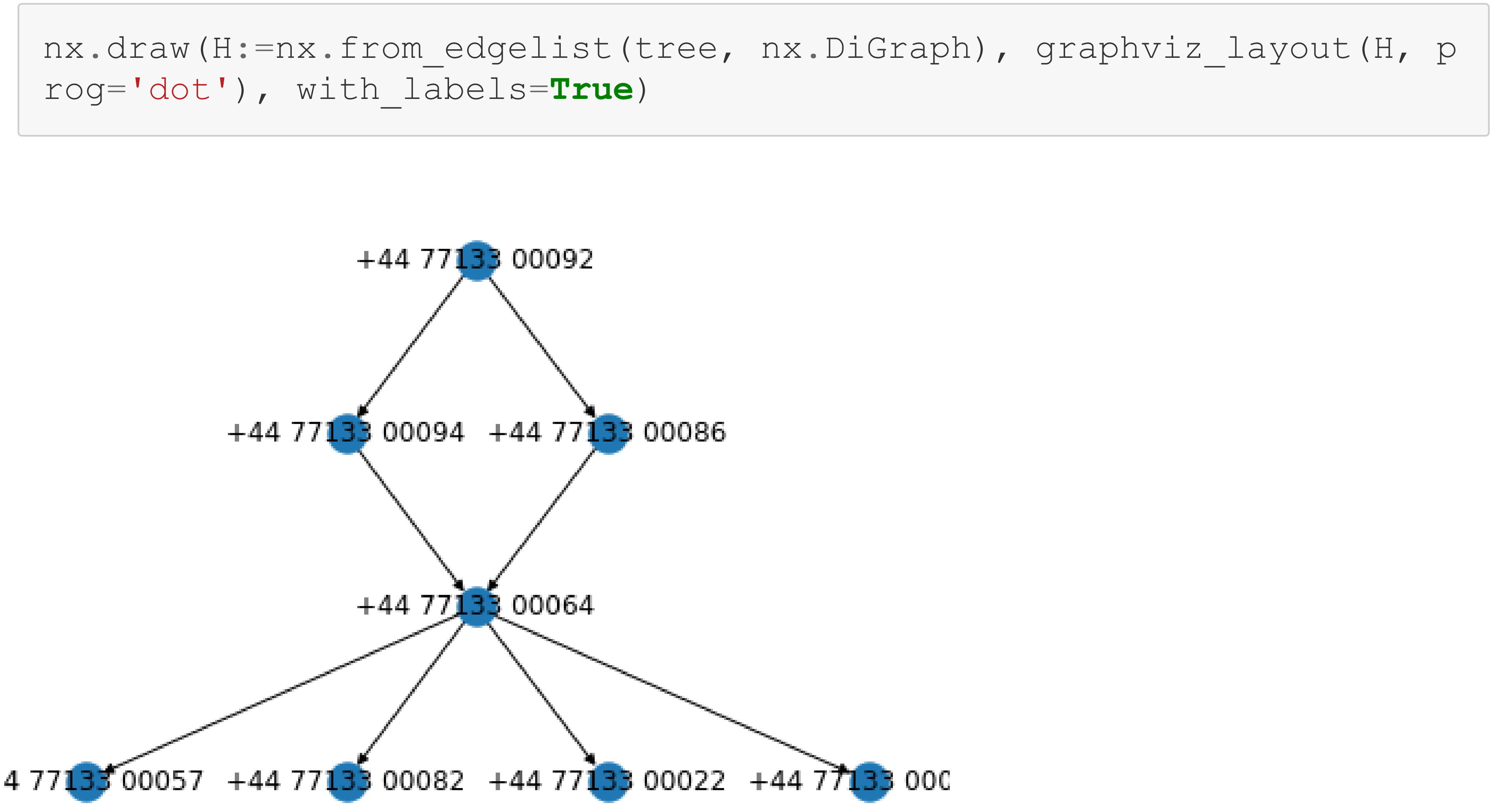
```
ranks = ['Commander', 'Senior', 'Relay', 'Frontline']
result = pd.DataFrame([ {"node": n, "rank": ranks.index(p), "role":
p}
    for n, p in zip(nodes, predictions)
])

result
```



	node	rank	role
0	+44 77133 00092	0	Commander
1	+44 77133 00094	1	Senior
2	+44 77133 00086	1	Senior
3	+44 77133 00064	2	Relay
4	+44 77133 00057	3	Frontline
5	+44 77133 00082	3	Frontline
6	+44 77133 00022	3	Frontline
7	+44 77133 00034	3	Frontline

Aside: Visualizing the Hierachy

With some extra steps we can visualize the table above as a hierachical graph ("tree"),



```
nx.draw(H:=nx.from_edgelist(tree, nx.DiGraph), graphviz_layout(H, p
rog='dot'), with_labels=True)
```