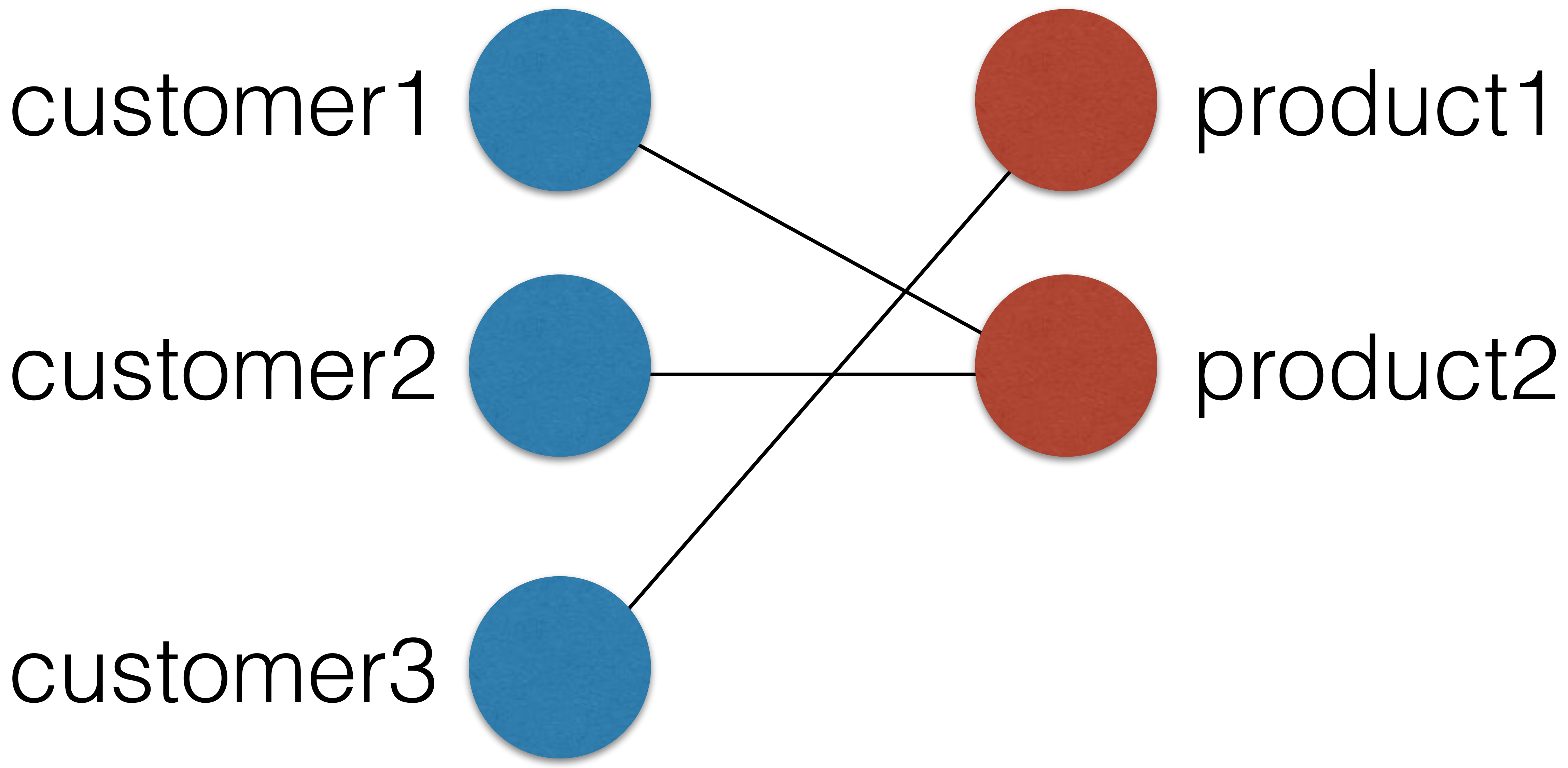
Concept of projection

Projection

- Useful to investigate the relationships between nodes on one partition
    - Conditioned on the connections to the nodes in the other partition

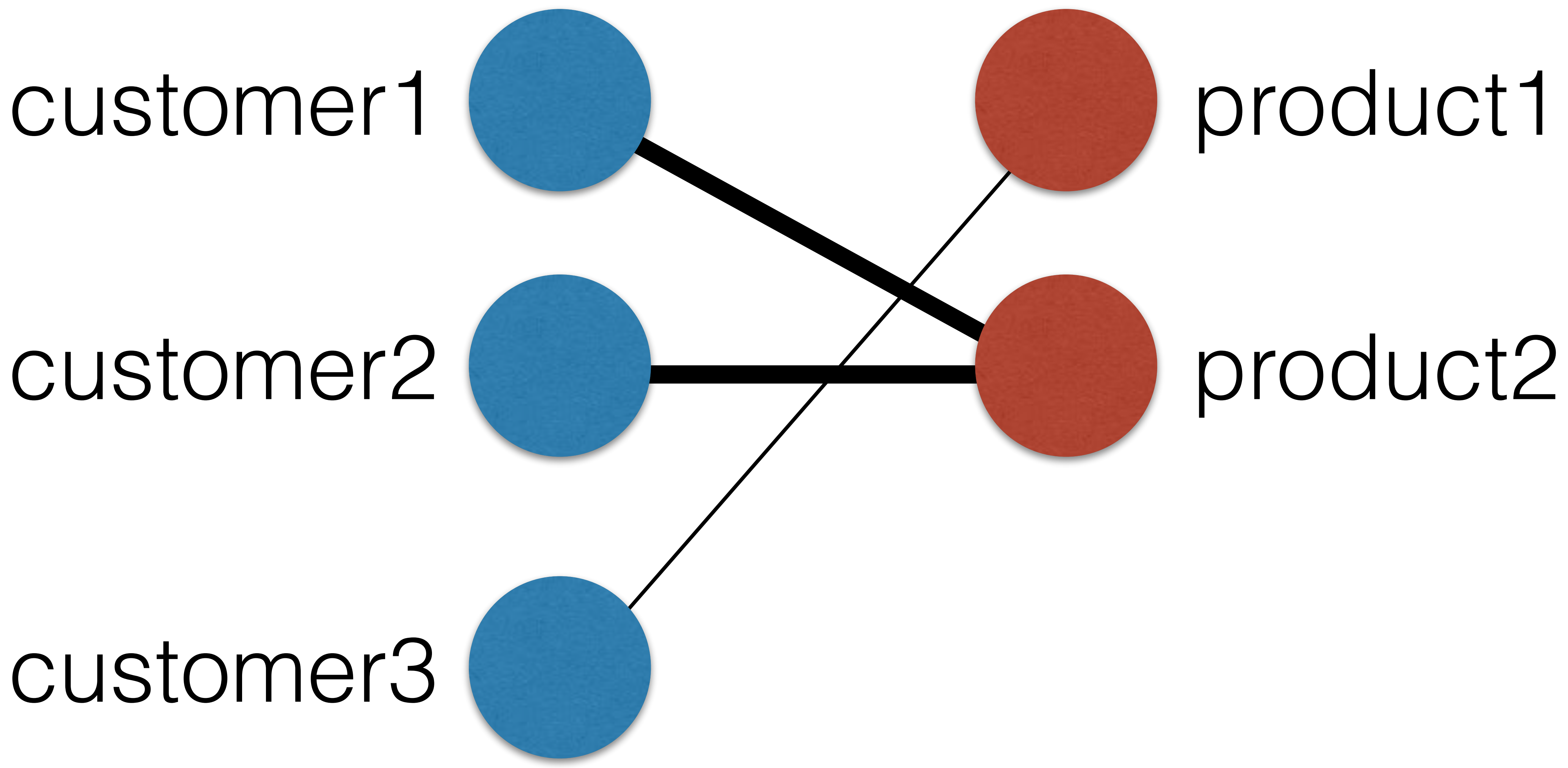
Projection

- Unipartite representation of bipartite connectivity



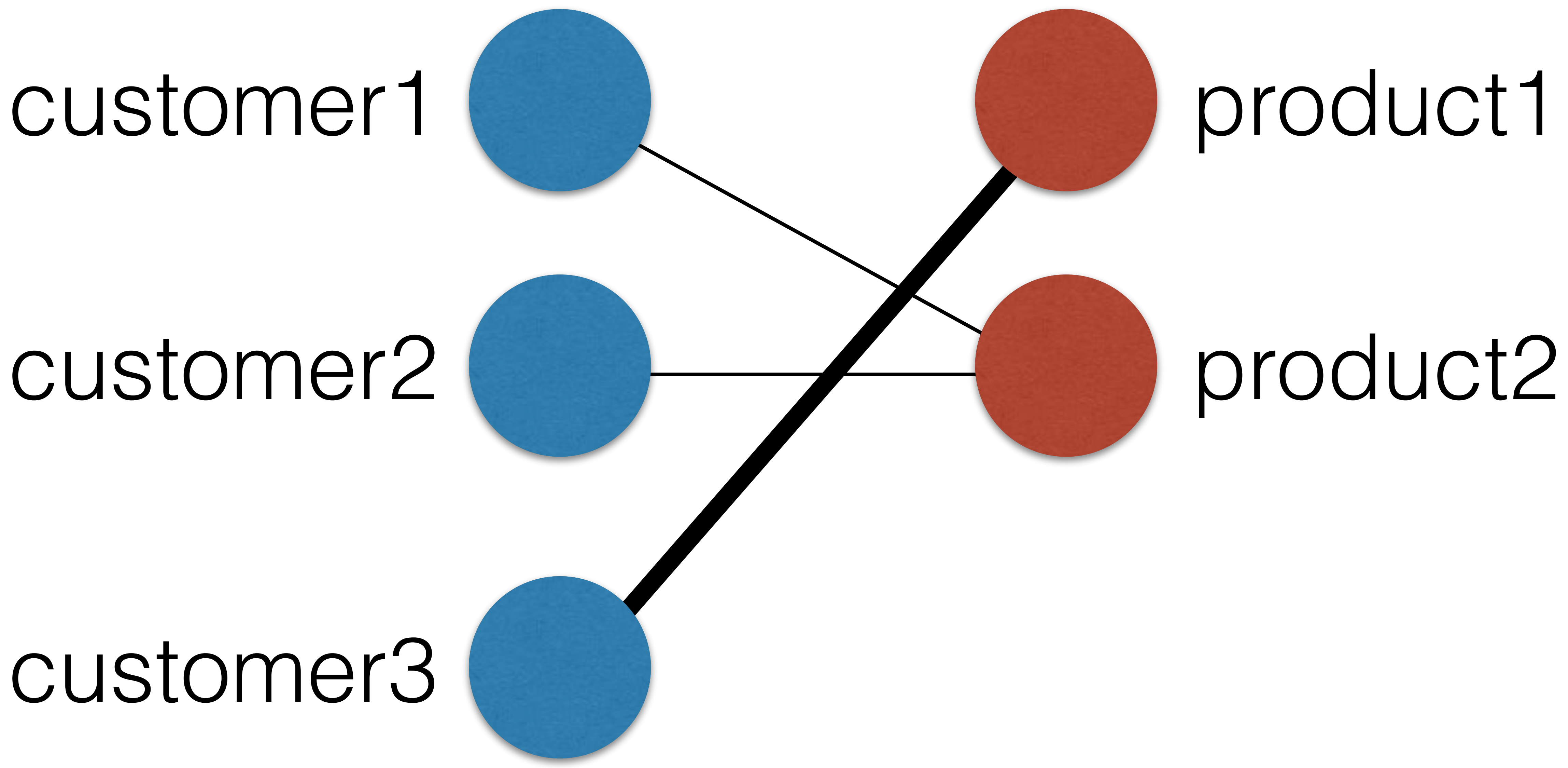
Projection

- Unipartite representation of bipartite connectivity



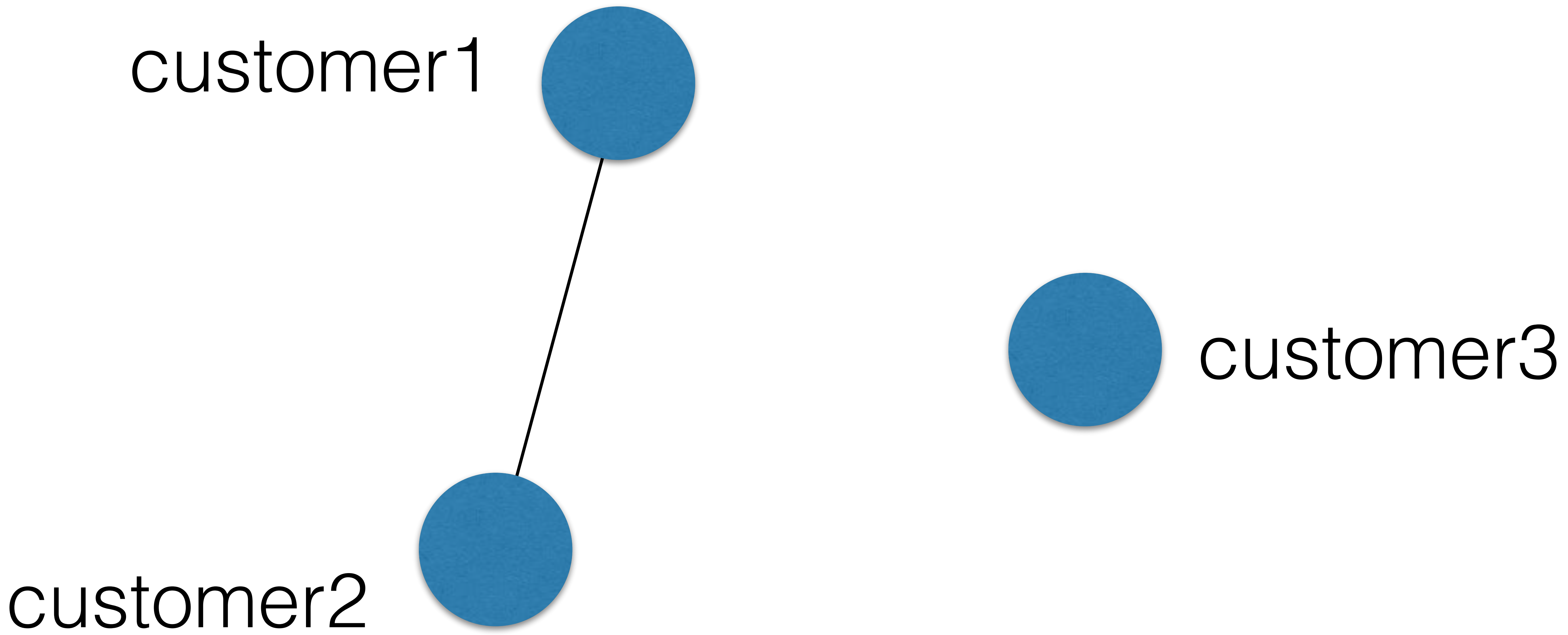
Projection

- Unipartite representation of bipartite connectivity



Projection

- Unipartite representation of bipartite connectivity



Graphs on Disk

- Flat edge lists
- CSV files: nodelist + metadata, edgelist + metadata

Reading network data

```
In [1]: import networkx as nx

In [2]: G = nx.read_edgelist('american-revolution.txt')

In [3]: G.edges(data=True)[0:5]
Out[3]:
[('Parkman.Elias', 'LondonEnemies', {'weight': 1}),
 ('Parkman.Elias', 'NorthCaucus', {'weight': 1}),
 ('Inglish.Alexander', 'StAndrewsLodge', {'weight': 1}),
 ('NorthCaucus', 'Chadwell.Mr', {'weight': 1}),
 ('NorthCaucus', 'Pearce.IsaacJun', {'weight': 1})]
```

```
----Text File----
Barrett.Samuel LondonEnemies {'weight': 1}
Barrett.Samuel StAndrewsLodge {'weight': 1}
Marshall.Thomas LondonEnemies {'weight': 1}
Eaton.Joseph TeaParty {'weight': 1}
Bass.Henry LondonEnemies {'weight': 1}
```

Bipartite projection

```
In [4]: G.nodes()
Out[4]: ['product2', 'customer3', 'customer1', 'product3',
   ...: 'customer2', 'product1']

In [5]: G.edges()
Out[5]:
[('product2', 'customer1'),
 ('product2', 'customer2'),
 ('customer3', ‘product1')]

In [6]: cust_nodes = [n for n in G.nodes() if G.node[n]
   ...:                  ['bipartite'] == 'customers']

In [7]: cust_nodes
Out[7]: ['customer3', 'customer1', 'customer2']
```

Bipartite projection

```
In [8]: G_cust = nx.bipartite.projected_graph(G, cust_nodes)

In [9]: G_cust.nodes()
Out[9]: ['customer1', 'customer3', 'customer2']

In [10]: G_cust.edges()
Out[10]: [('customer1', 'customer2')]
```

Degree centrality

- Recall degree centrality definition

$$\frac{\text{number of neighbors}}{\text{number of possible neighbors}}$$

- Denominator: number of nodes on opposite partition

Bipartite degree centrality

```
In [11]: nx.bipartite.degree_centrality(G, cust_nodes)
Out[11]:
{'customer1': 0.3333333333333333,
 'customer2': 0.3333333333333333,
 'customer3': 0.3333333333333333,
 'product1': 0.3333333333333333,
 'product2': 0.6666666666666666,
 'product3': 0.0}

In [12]: nx.degree_centrality(G)
Out[12]:
{'customer1': 0.2,
 'customer2': 0.2,
 'customer3': 0.2,
 'product1': 0.2,
 'product2': 0.4,
 'product3': 0.0}
```

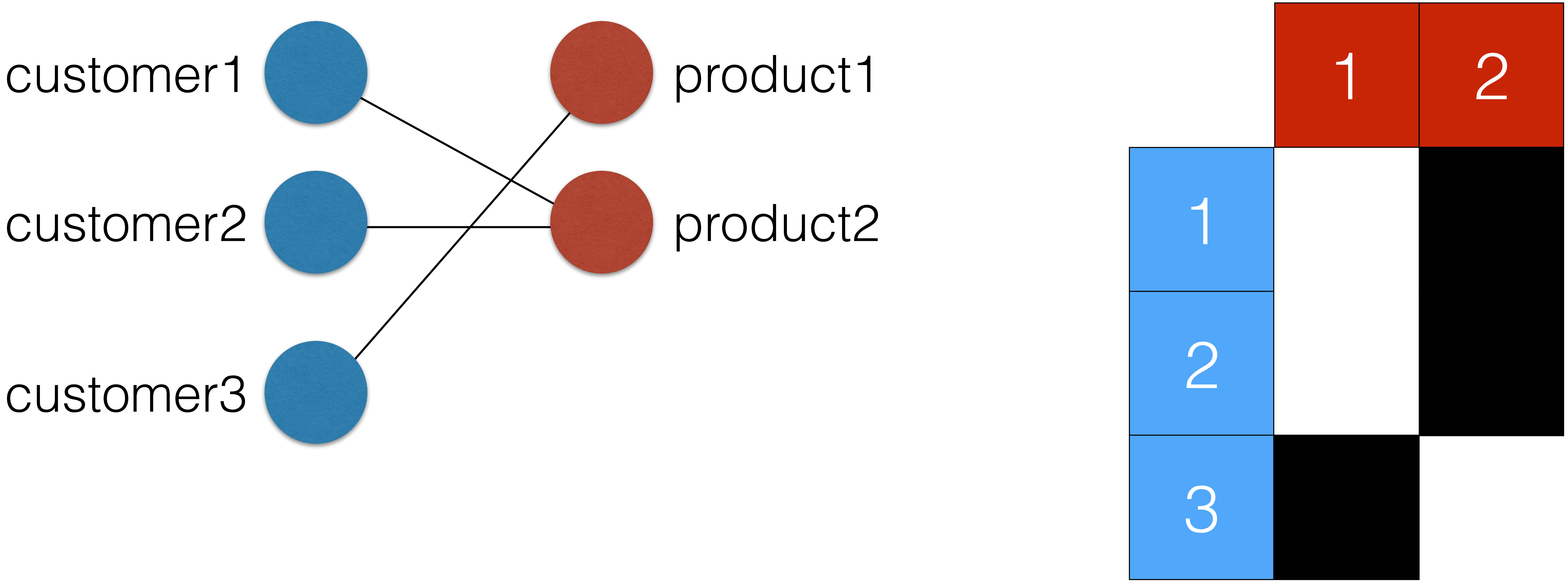
Let's practice!

Bipartite graphs as matrices

Matrix representation

- Rows: nodes on one partition
- Columns: nodes on other partition
- Cells: 1 if edge present, else 0

Matrix representation

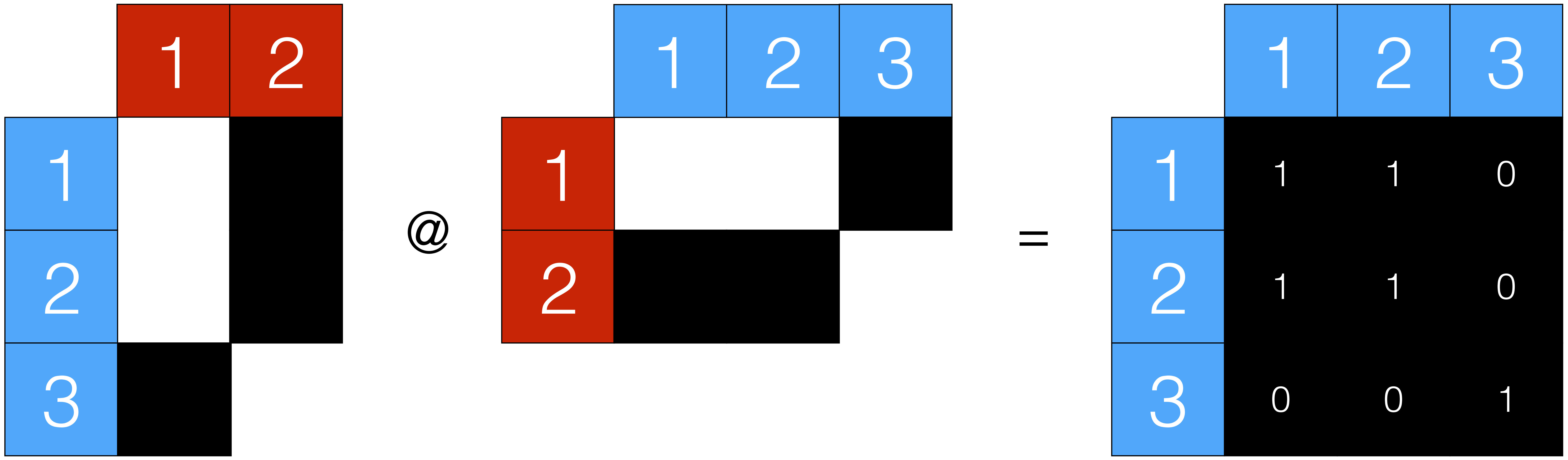


Example code

```
In [1]: cust_nodes = [n for n in G.nodes() if G.node[n]
   ...:               ['bipartite'] == 'customers']

In [2]: prod_nodes = [n for n in G.nodes() if G.node[n]
   ...:               ['bipartite'] == 'products']

In [3]: mat = nx.bipartite.biadjacency_matrix(G,
   ...:       row_order=cust_nodes, column_order=prod_nodes)

In [4]: mat
Out[4]:
<3x2 sparse matrix of type '<class 'numpy.int64'>'
        with 3 stored elements in Compressed Sparse Row format>
```

Matrix projection

- Projection computable using matrix multiplication



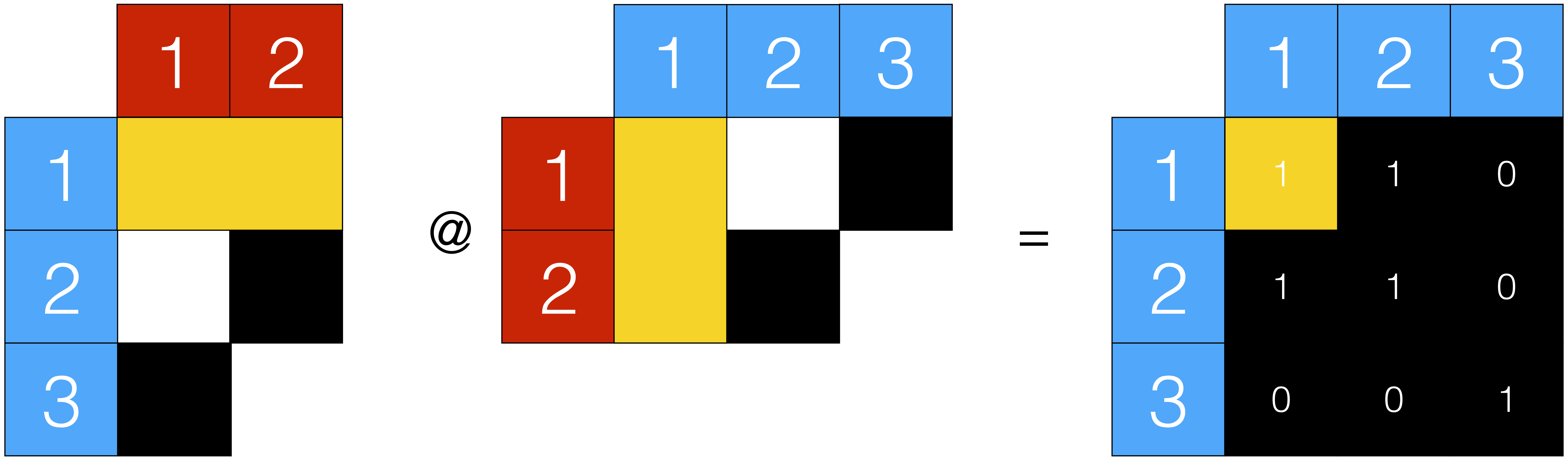
matrix

transposed matrix

projection

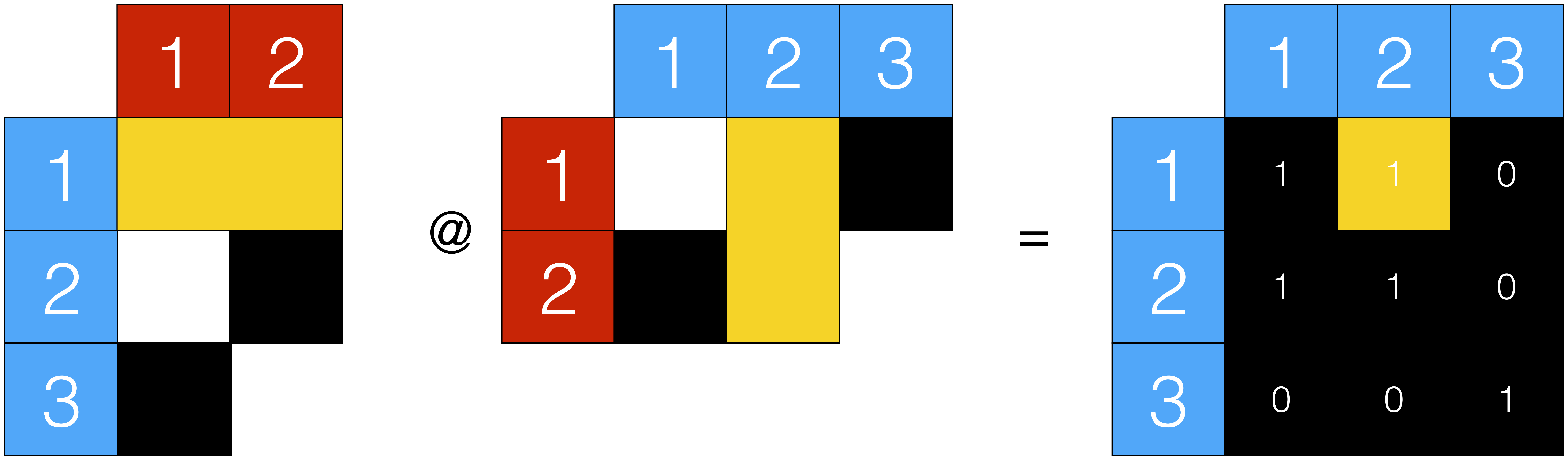
Matrix projection

- Projection computable using matrix multiplication



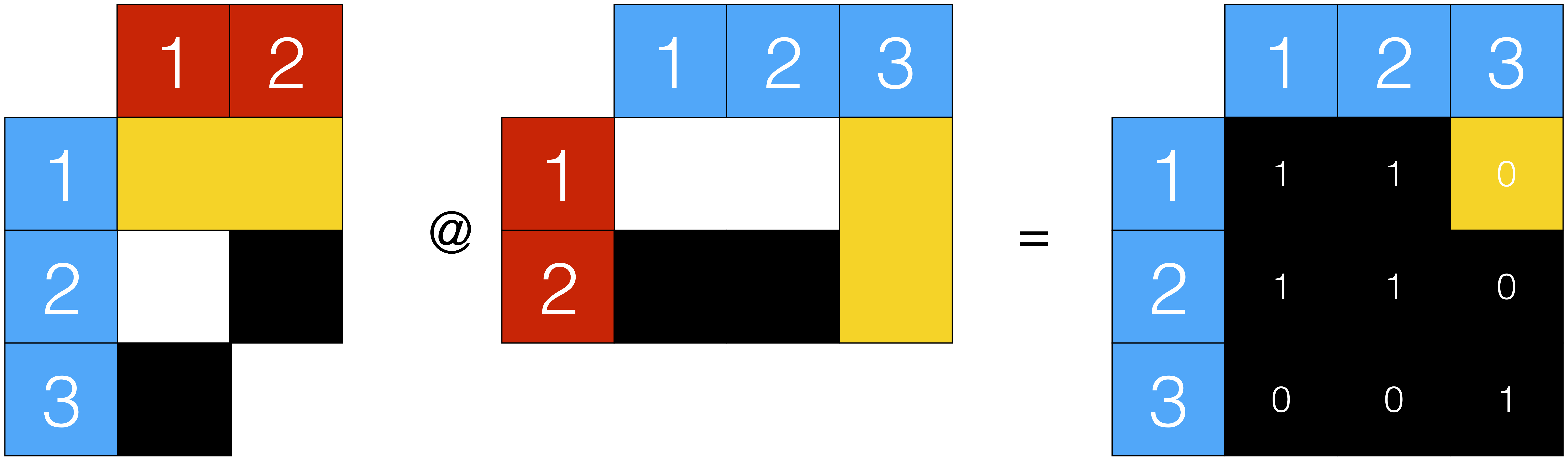
Matrix projection

- Projection computable using matrix multiplication



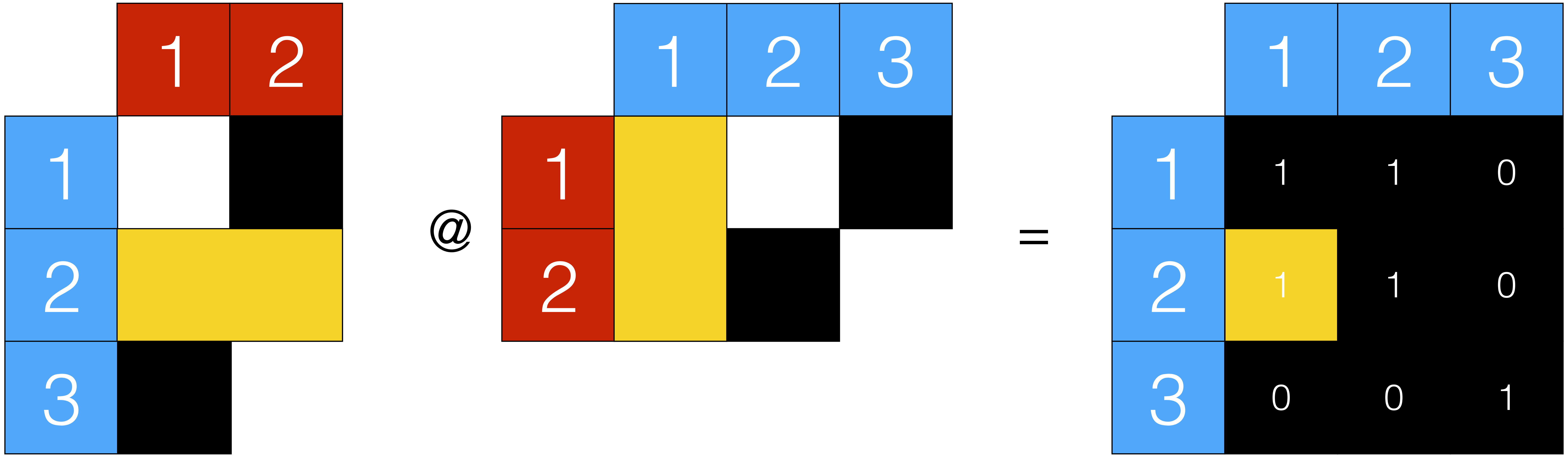
Matrix projection

- Projection computable using matrix multiplication



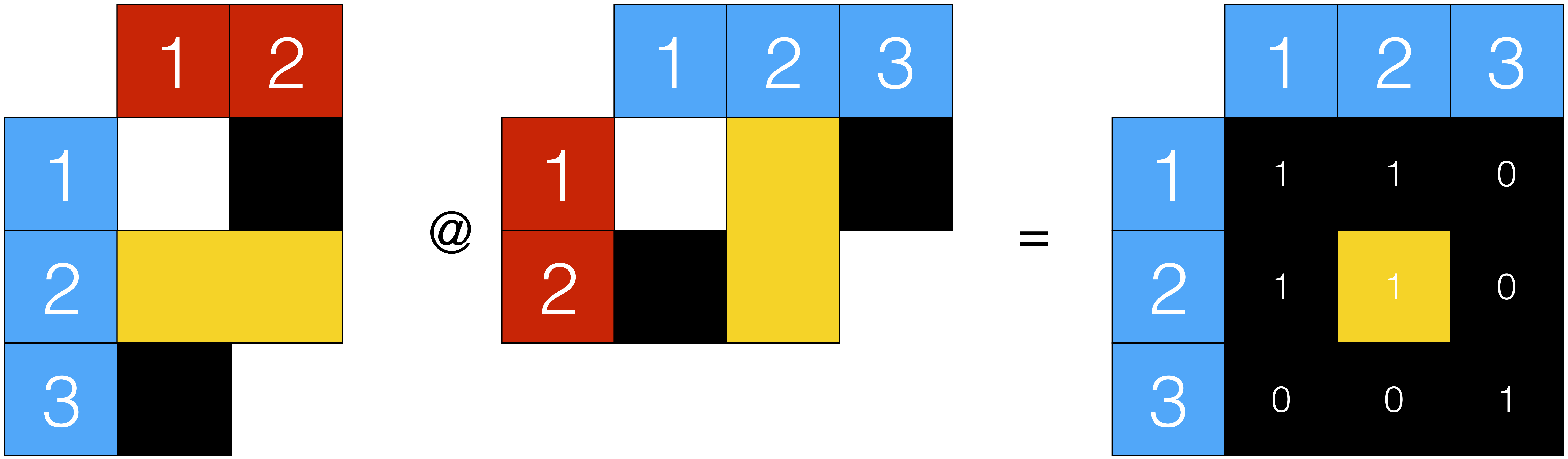
Matrix projection

- Projection computable using matrix multiplication



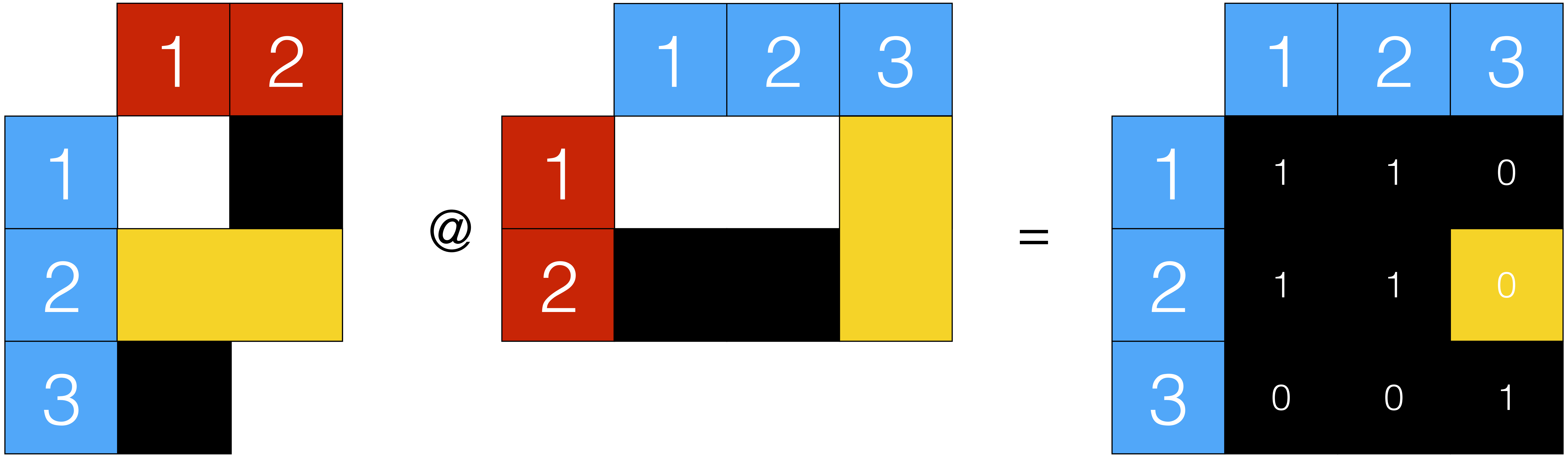
Matrix projection

- Projection computable using matrix multiplication



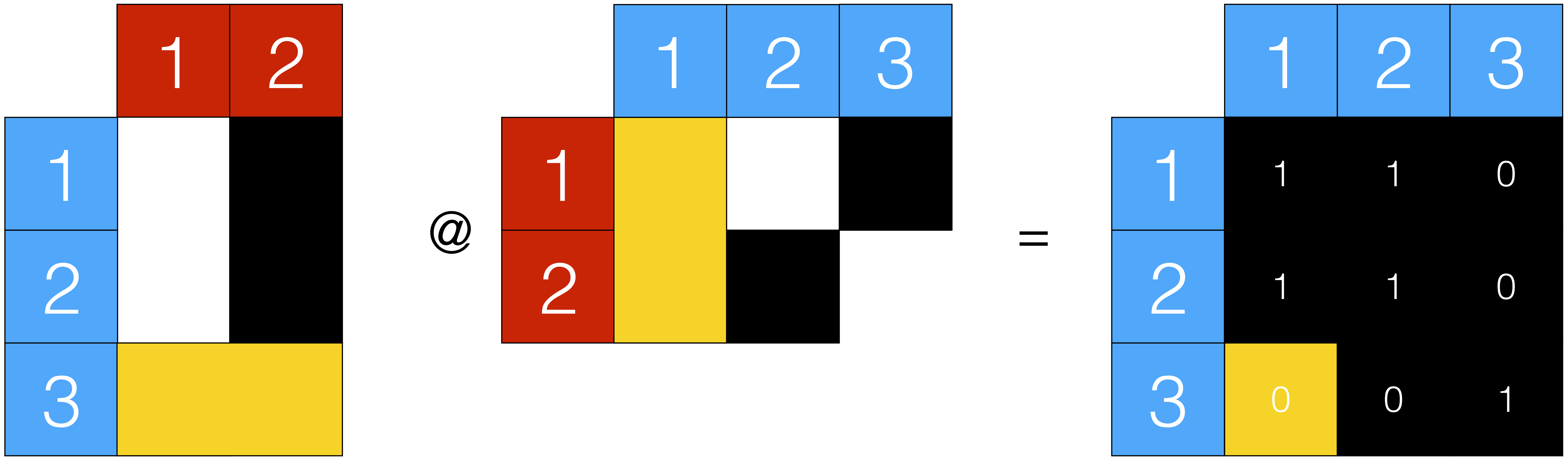
Matrix projection

- Projection computable using matrix multiplication



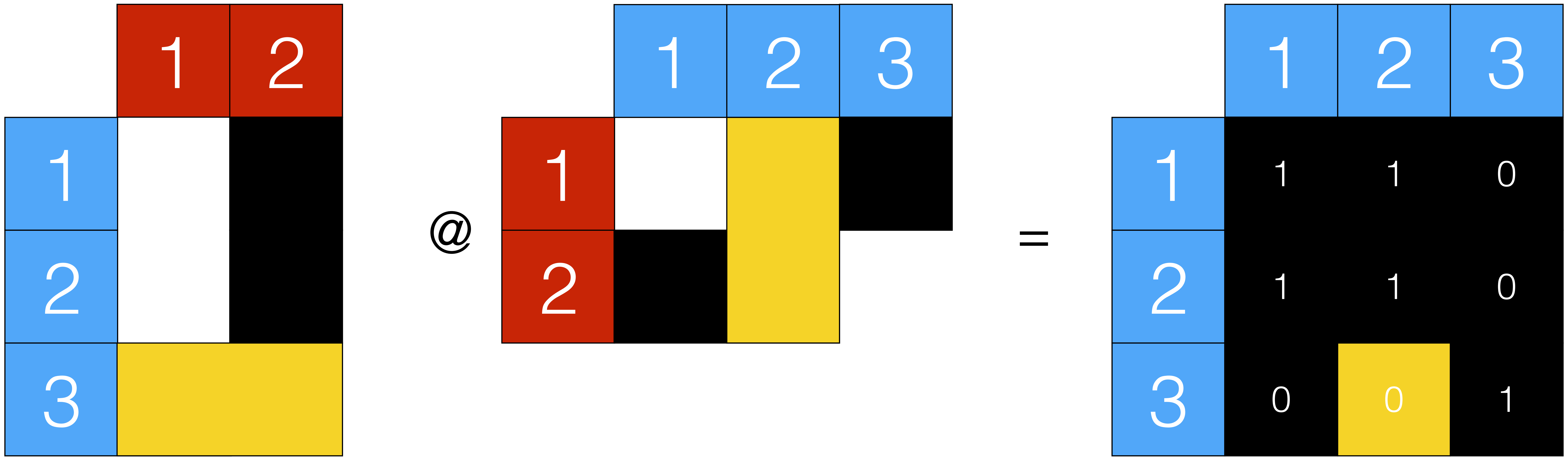
Matrix projection

- Projection computable using matrix multiplication



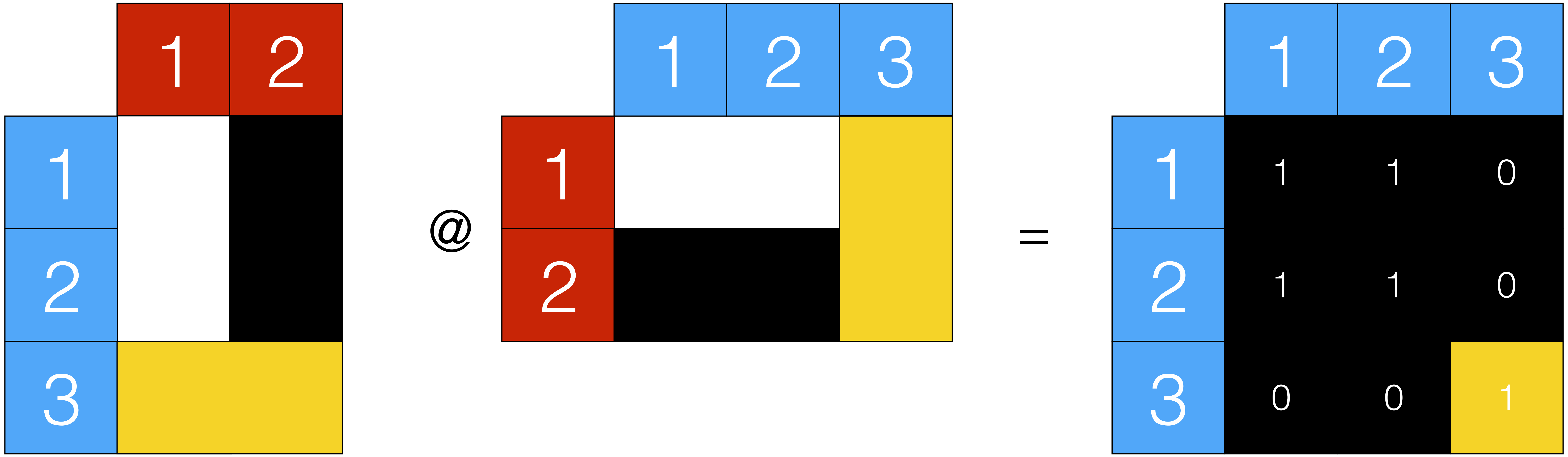
Matrix projection

- Projection computable using matrix multiplication



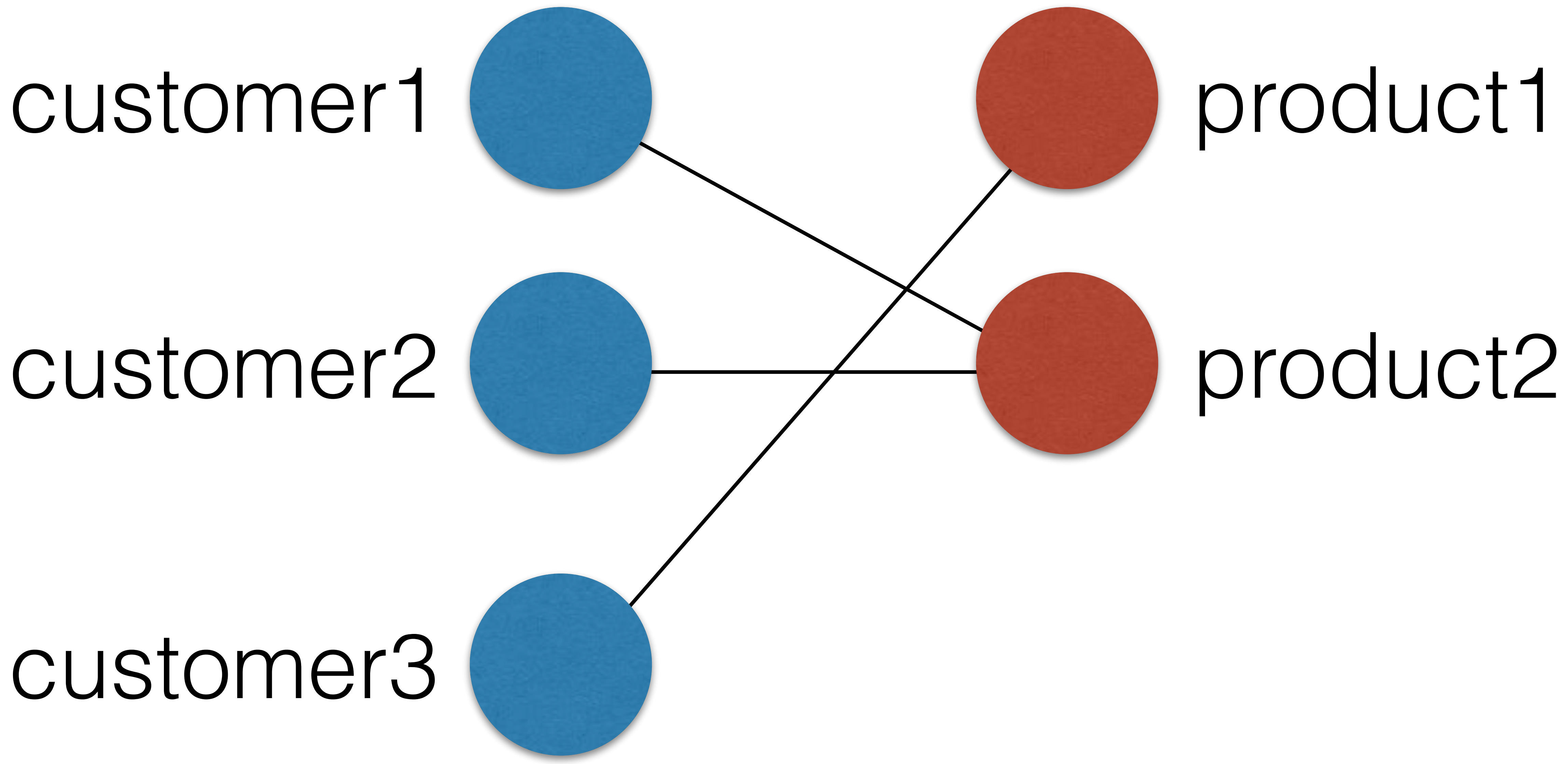
Matrix projection

- Projection computable using matrix multiplication



Matrix projection

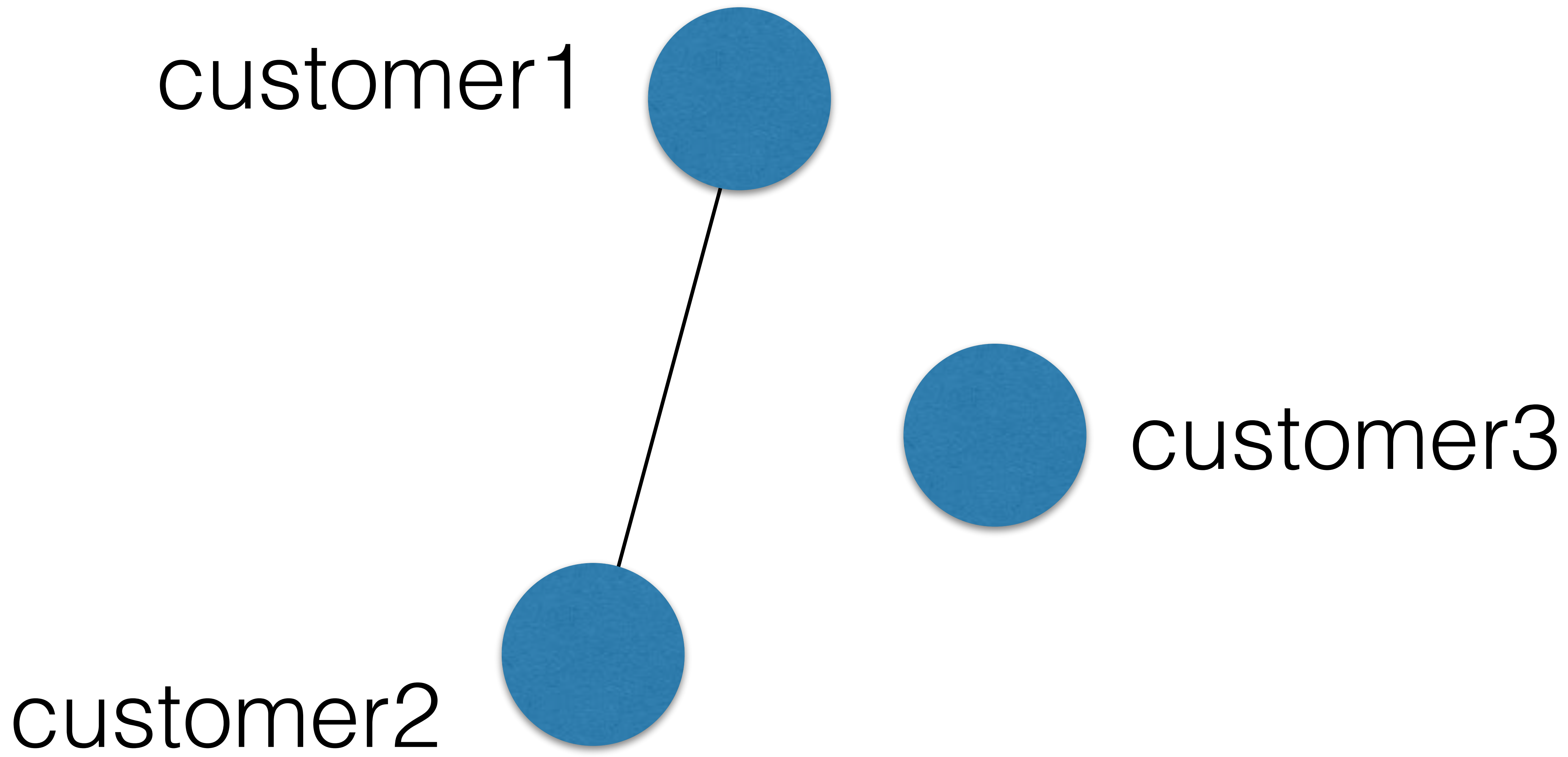
- Projection computable using matrix multiplication



	1	2	3
1	1	1	0
2	1	1	0
3	0	0	1

Matrix projection

- Projection computable using matrix multiplication



	1	2	3
1	1	1	0
2	1	1	0
3	0	0	1

Matrix multiplication in Python

```
In [5]: mat @ mat.T
Out[5]:
<5x5 sparse matrix of type '<class 'numpy.int64'>'
  with 23 stored elements in Compressed Sparse Row format>

In [6]: mat.T @ mat
Out[6]:
<10x10 sparse matrix of type '<class 'numpy.int64'>'
  with 50 stored elements in Compressed Sparse Column format>
```

Let’s practice!

Representing network data with pandas

CSV files for network data storage

```
----CSV File——
person,party,weight
Barrett.Samuel,LondonEnemies,1
Barrett.Samuel,StAndrewsLodge,1
Marshall.Thomas,LondonEnemies,1
Eaton.Joseph,TeaParty,1
Bass.Henry,LondonEnemies,1
```

CSV files for network data storage

- Advantages:
    - Human-readable
    - Do further analysis with pandas
- Disadvantages:
    - Repetitive; disk space
- Two DataFrames: node and edge lists

Node list and edge list

- Node list
  - Each row is one node
  - The columns represent metadata attached to that node
- Edge list
  - Each row is one edge
  - The columns represent the metadata attached to that edge

Pandas and graphs

```
In [1]: G.nodes(data=True)
Out[1]:
[(0, {'bipartite': 0}),
(1, {'bipartite': 0}),
(2, {'bipartite': 0}),
...]

In [2]: nodelist = []

In [3]: for n, d in G.nodes(data=True):
 ...:     node_data = dict()
 ...:     node_data['node'] = n
 ...:     node_data.update(d)
 ...:     nodelist.append(node_data)
```

Pandas and graphs

```
In [4]: nodelist
Out[4]:
[{'bipartite': 0, 'node': 0},
{'bipartite': 0, 'node': 1},
{'bipartite': 0, 'node': 2},
{'bipartite': 0, 'node': 3},
{'bipartite': 0, 'node': 4},...]
```

Pandas and graphs

```
In [5]: import pandas as pd

In [6]: pd.DataFrame(nodelist)
Out[6]:
  bipartite  node
0          0     0
1          0     1
2          0     2
3          0     3
4          0     4
5          1     5
6          1     6
7          1     7

In [7]: pd.DataFrame(nodelist).to_csv('my_file.csv')
```

Let's practice!