A Little Graph Theory for the Busy Developer

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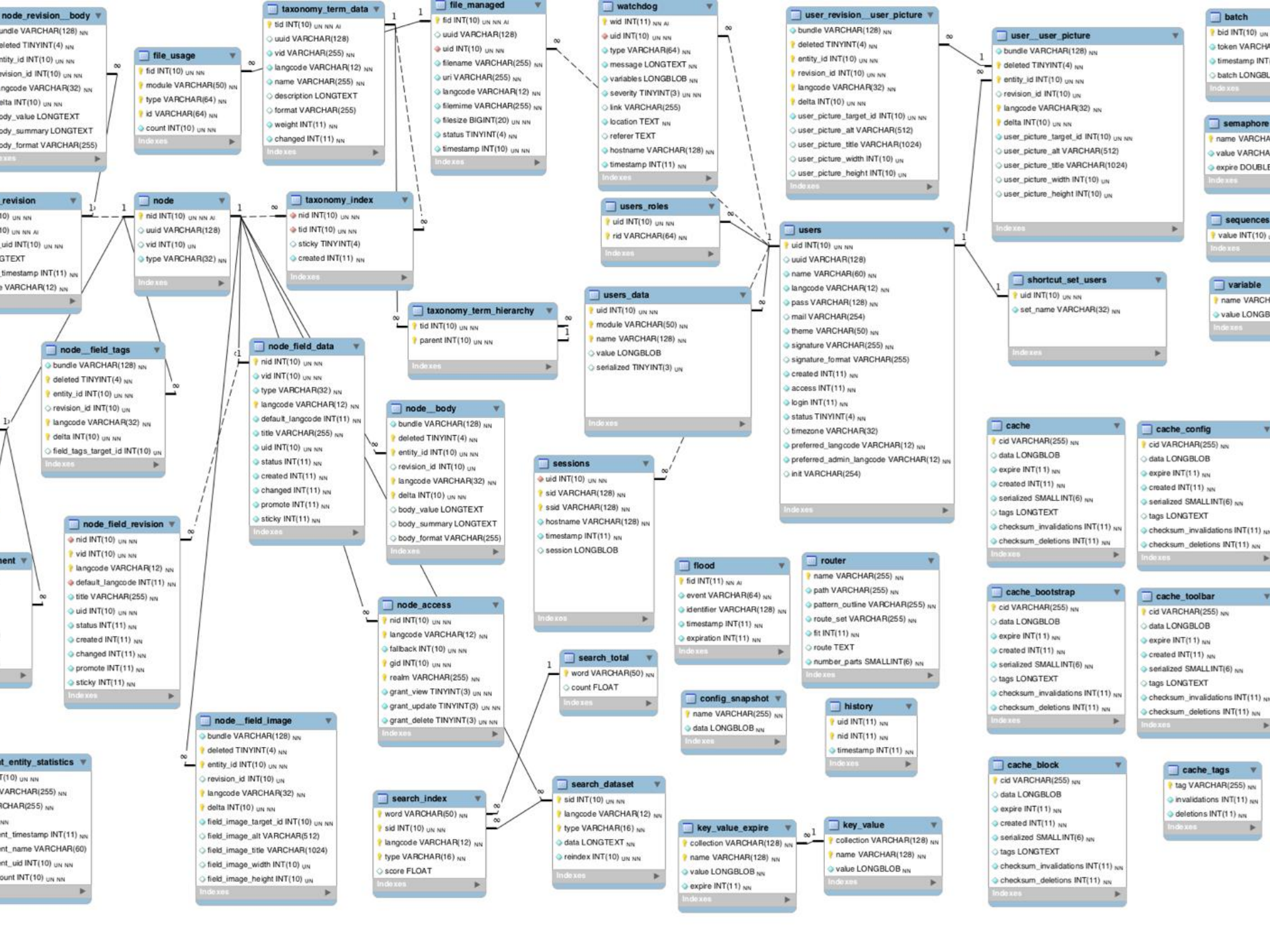
Roadmap

- Imprisoned data models
  - Why most NoSQL stores and RDBMS are clumsy for connected data
- Labeled Property Graph model
- Graph theory for predictive analytics
  - South East London and World War I
- Graph matching for real-time insight
  - Beer, nappies and Xbox
- Q&A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http://www.flickr.com/photos/crazyneighborlady/355232758/


http://gallery.nen.gov.uk/image82582-.html

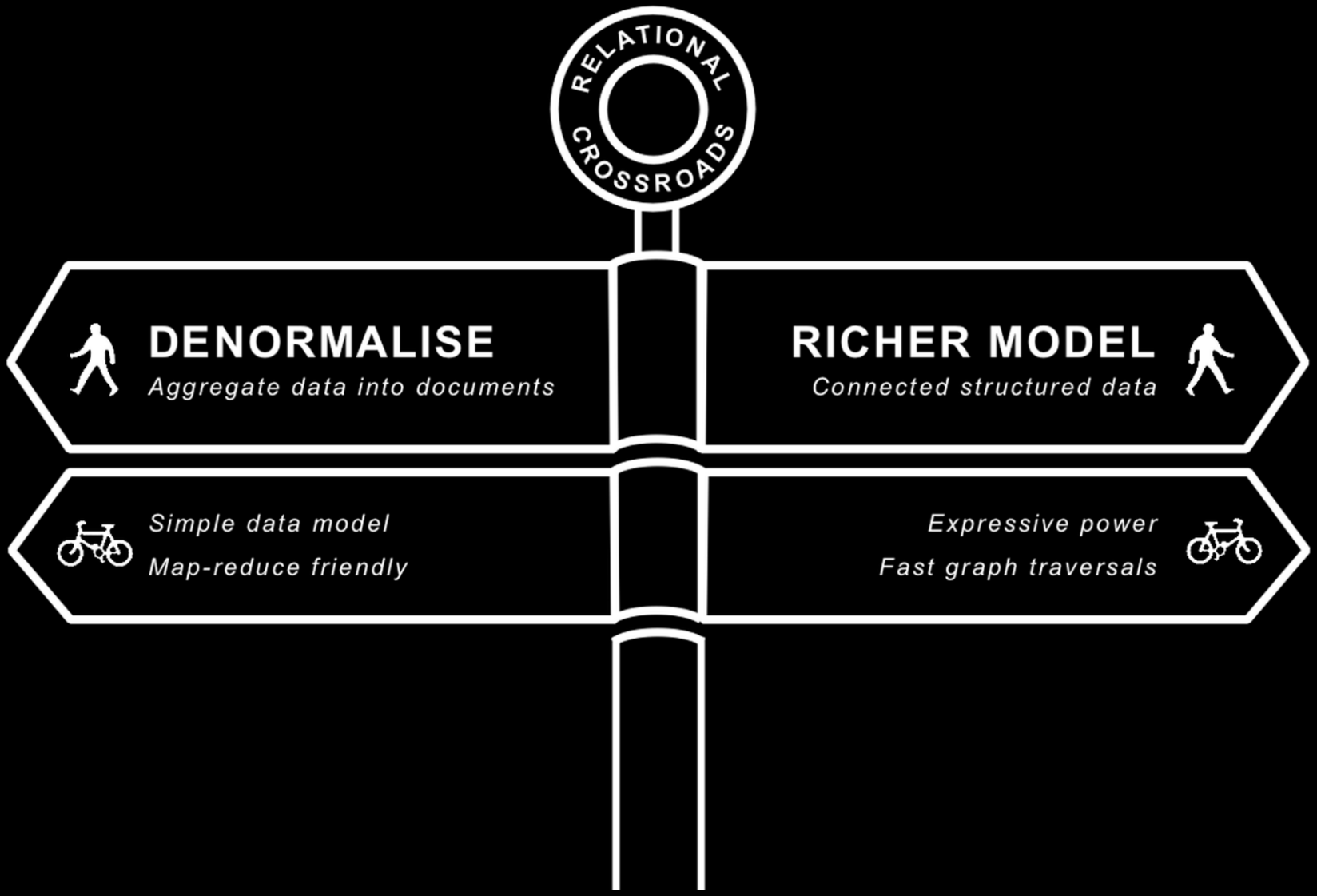
Aggregate-Oriented Data

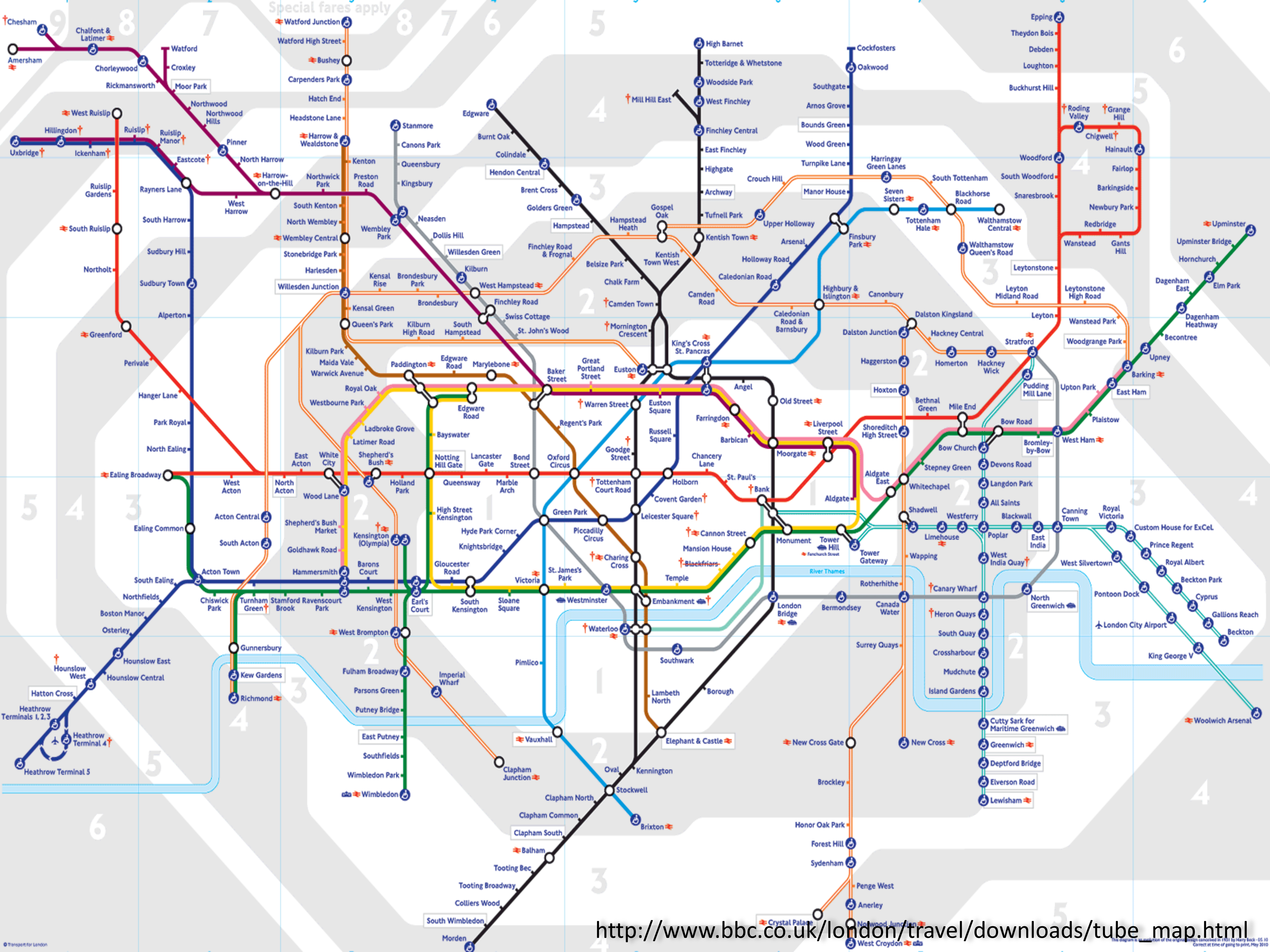
http://martinfowler.com/bliki/AggregateOrientedDatabase.html

"There is a significant downside - the whole approach works really well when data access is aligned with the aggregates, but what if you want to look at the data in a different way? Order entry naturally stores orders as aggregates, but analyzing product sales cuts across the aggregate structure. The advantage of not using an aggregate structure in the database is that it allows you to slice and dice your data different ways for different audiences.

This is why aggregate-oriented stores talk so much about map-reduce."

$$complexity = f(size, connectedness, uniformity)$$


RELATIONAL
CROSSROADS
DENORMALISE
Aggregate data into documents
RICHER MODEL
Connected structured data
Simple data model
Map-reduce friendly
Expressive power
Fast graph traversals



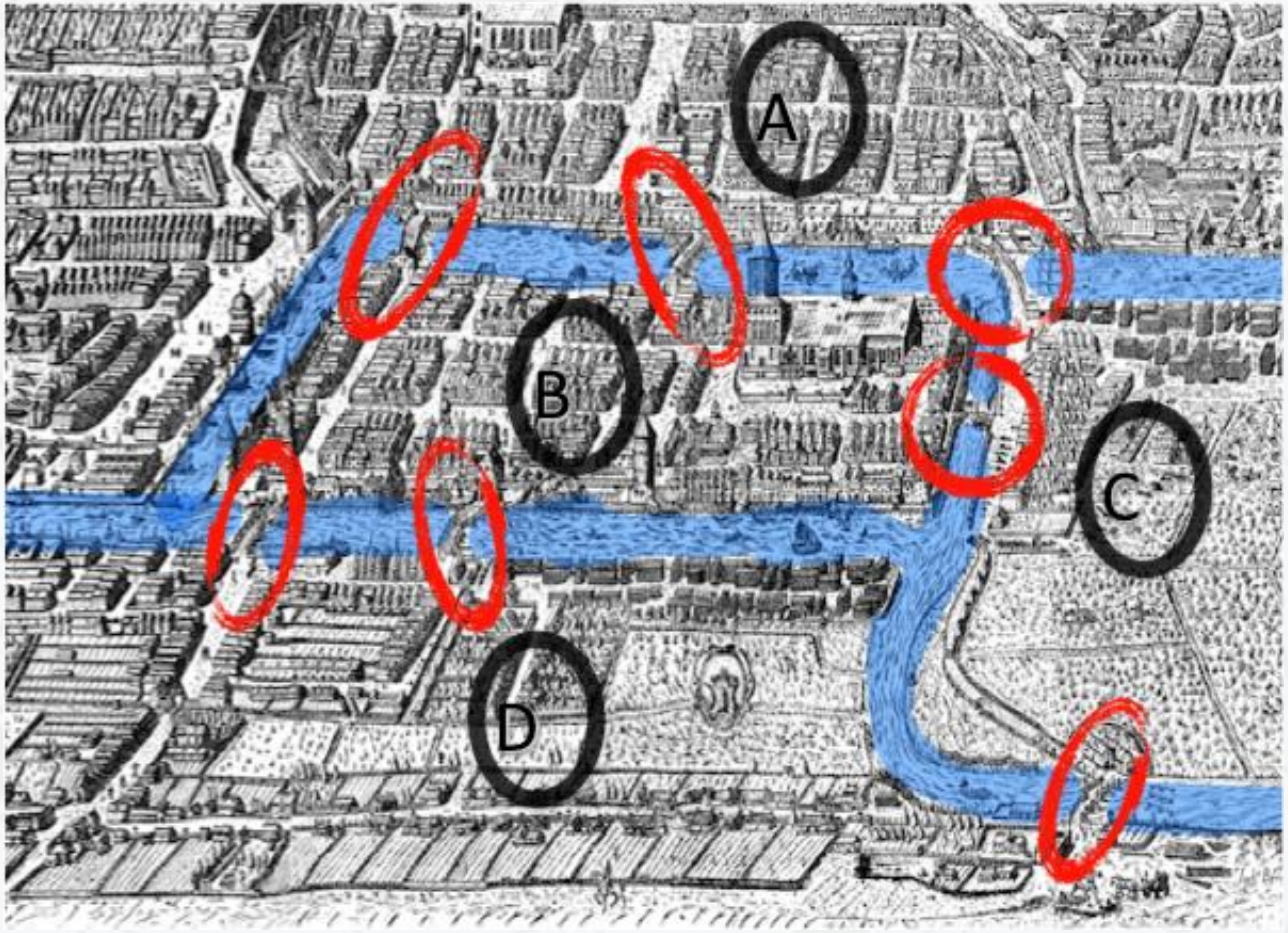
http://www.bbc.co.uk/london/travel/downloads/tube_map.html

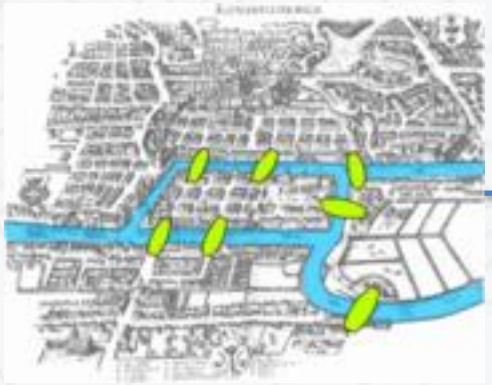
Meet Leonhard Euler

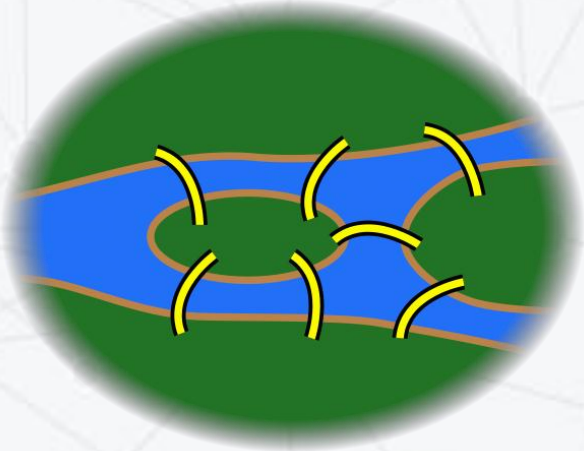
- Swiss mathematician
- Inventor of Graph Theory (1736)

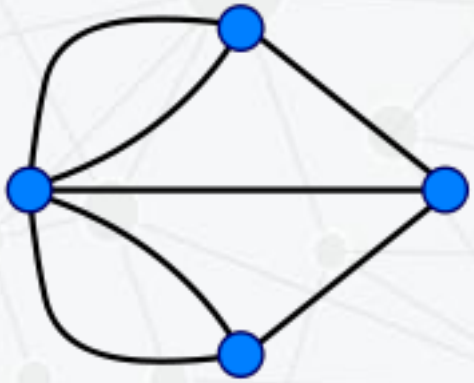
http://en.wikipedia.org/wiki/File:Leonhard_Euler_2.jpg

Königsberg (Prussia) - 1736





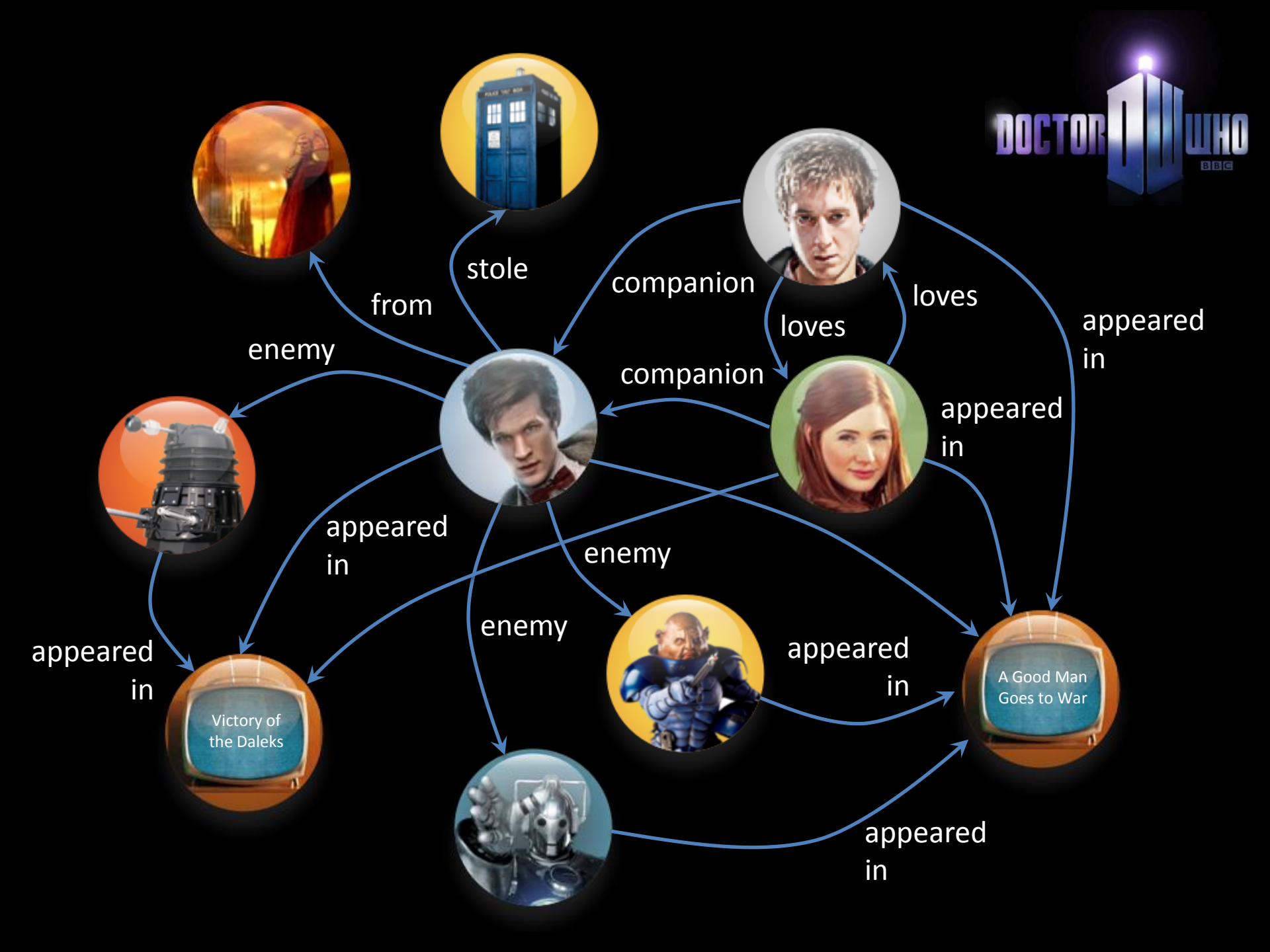




http://en.wikipedia.org/wiki/Seven_Bridges_of_Königsberg

Labeled Property graph model

- Nodes with optional properties and optional labels
- Named, directed relationships with optional properties
  - Relationships have exactly one start and end node
  - Which may be the same node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Victory of the Daleks
A Good Man Goes to War
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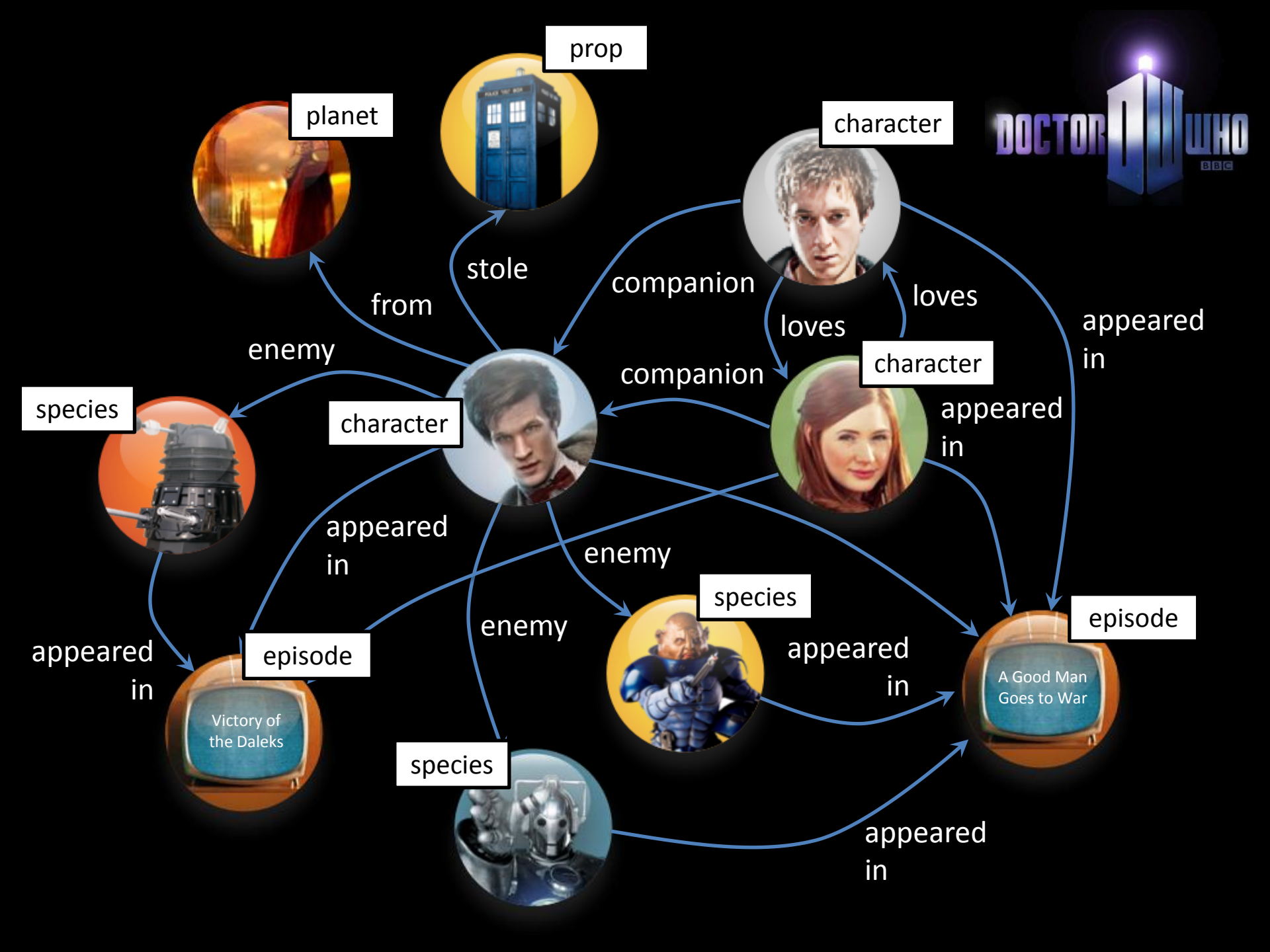
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the Daleks
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http://blogs.adobe.com/digitalmarketing/analytics/predictive-analytics/predictive-analytics-and-the-digital-marketer/


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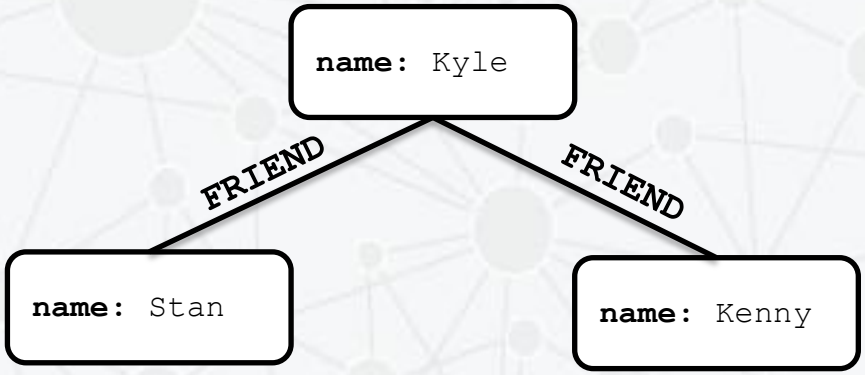
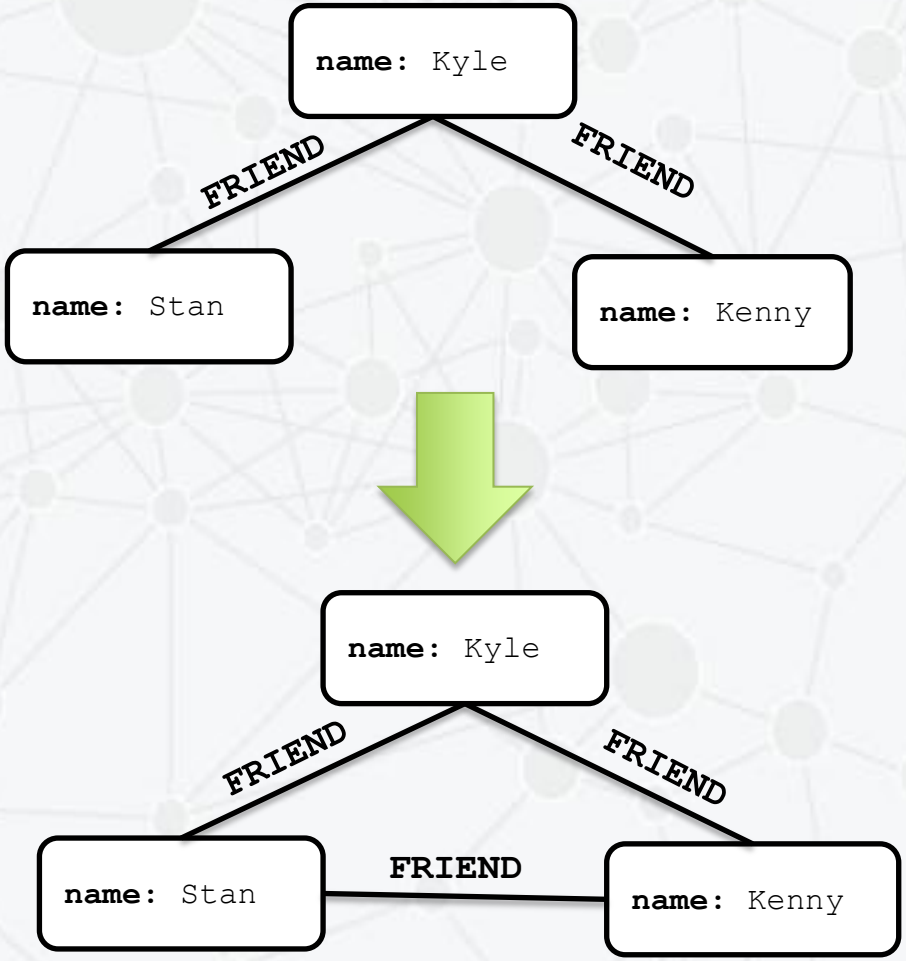
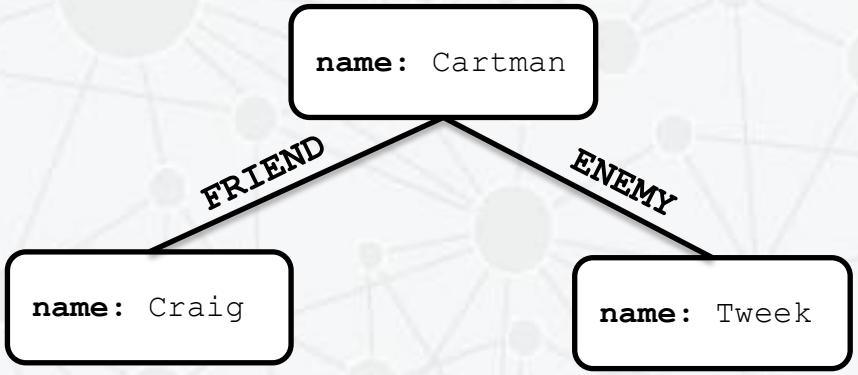
Triadic Closure



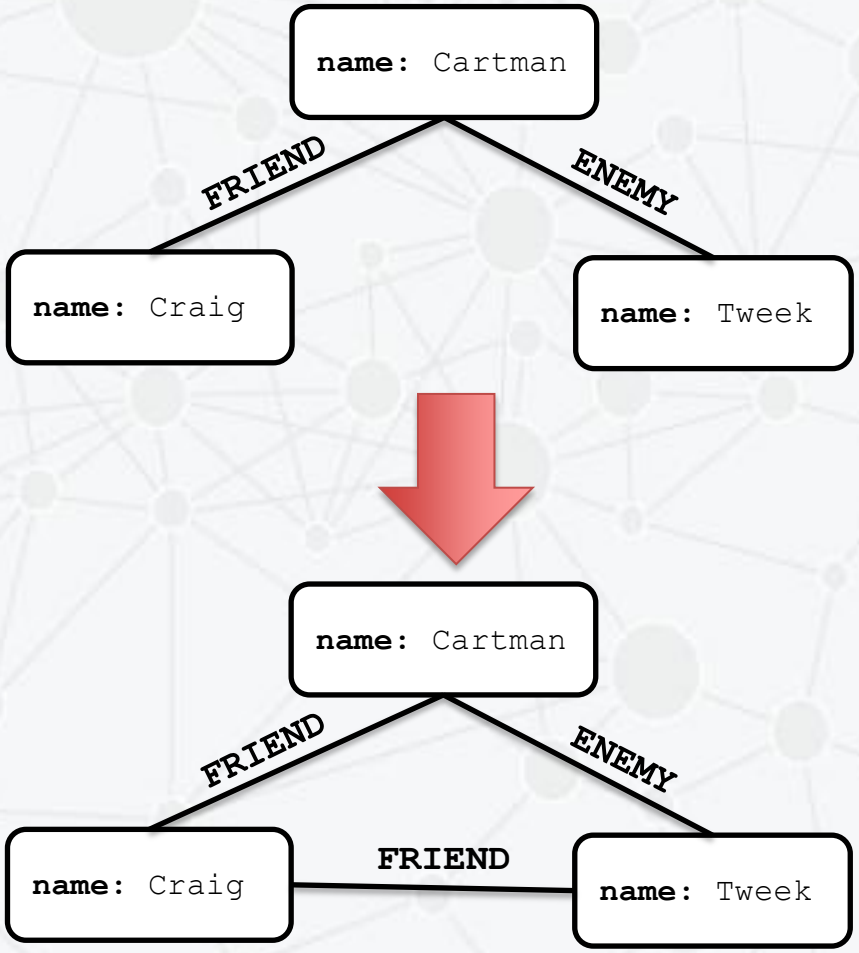
Triadic Closure



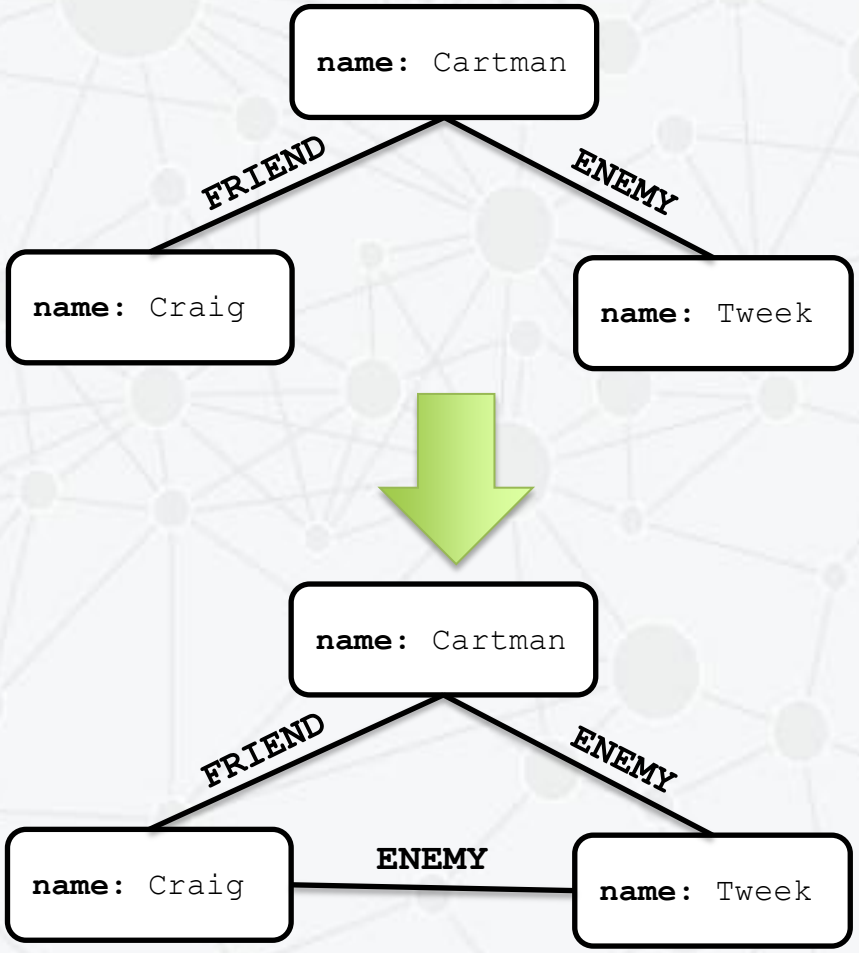
Structural Balance



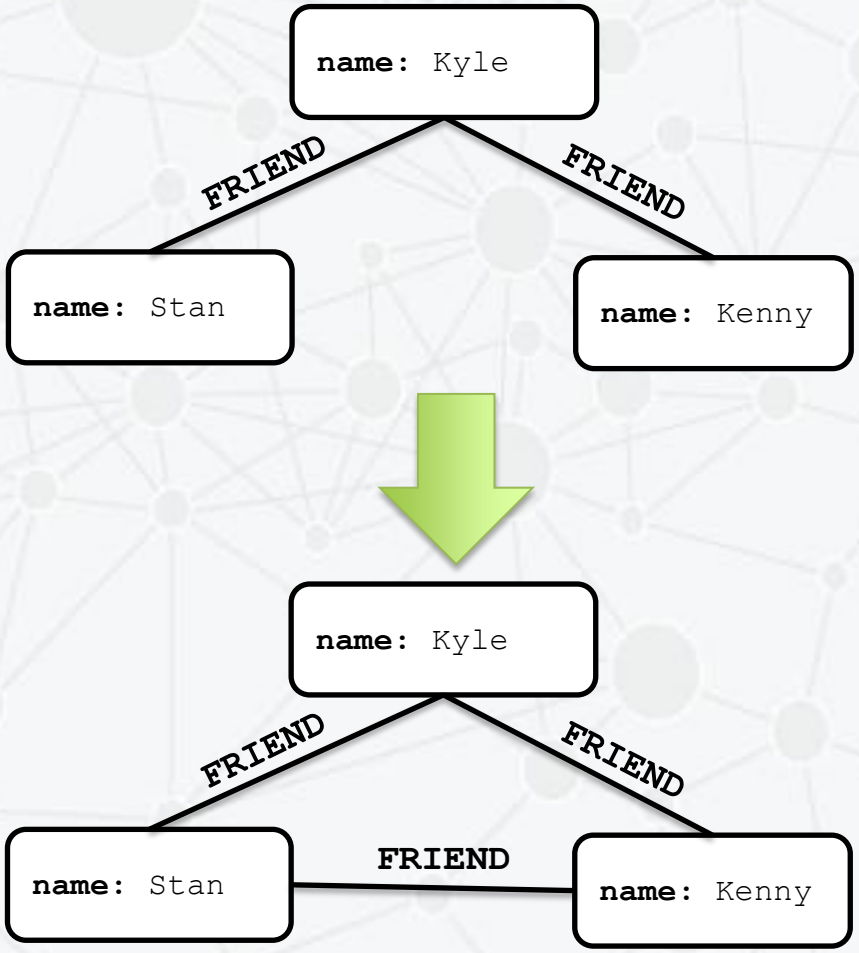
Structural Balance



Structural Balance



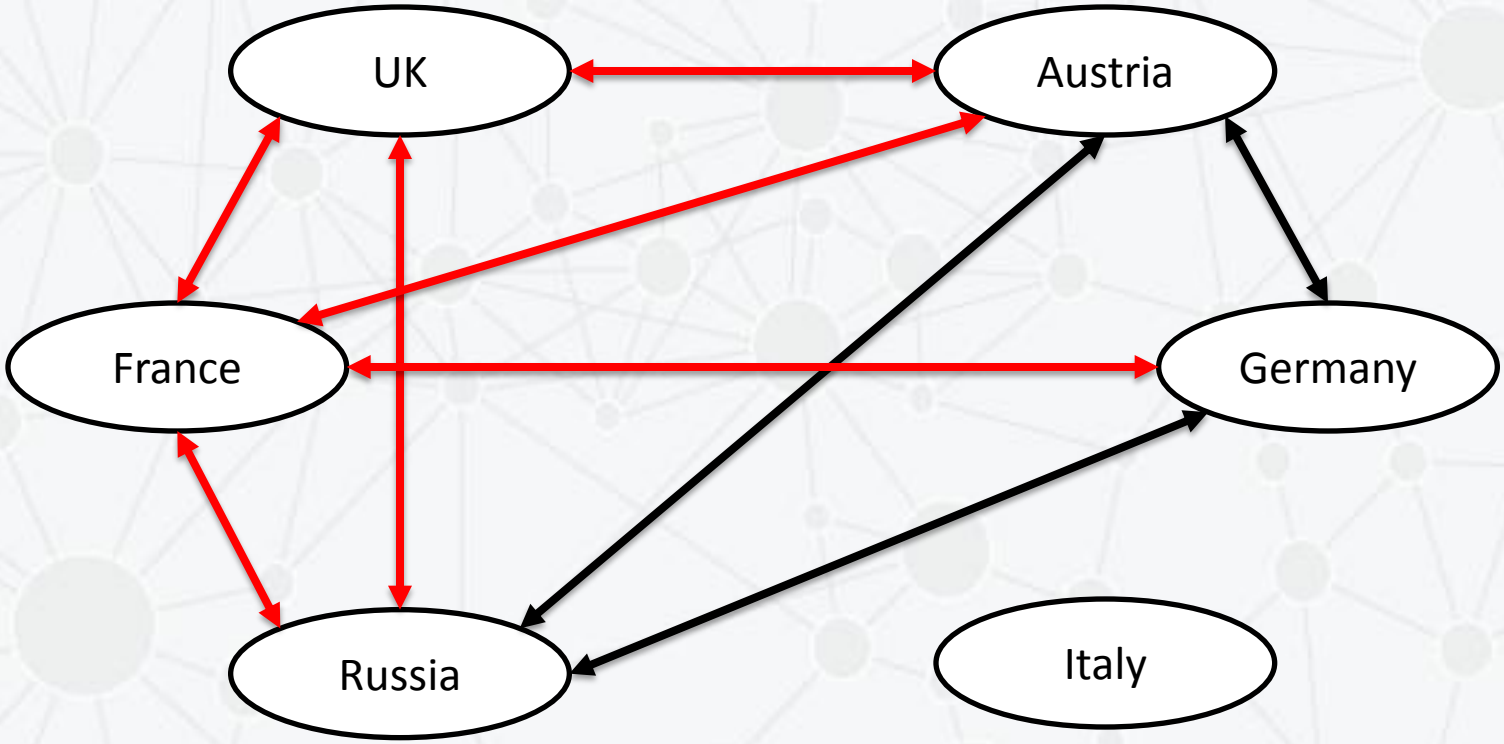
Structural Balance



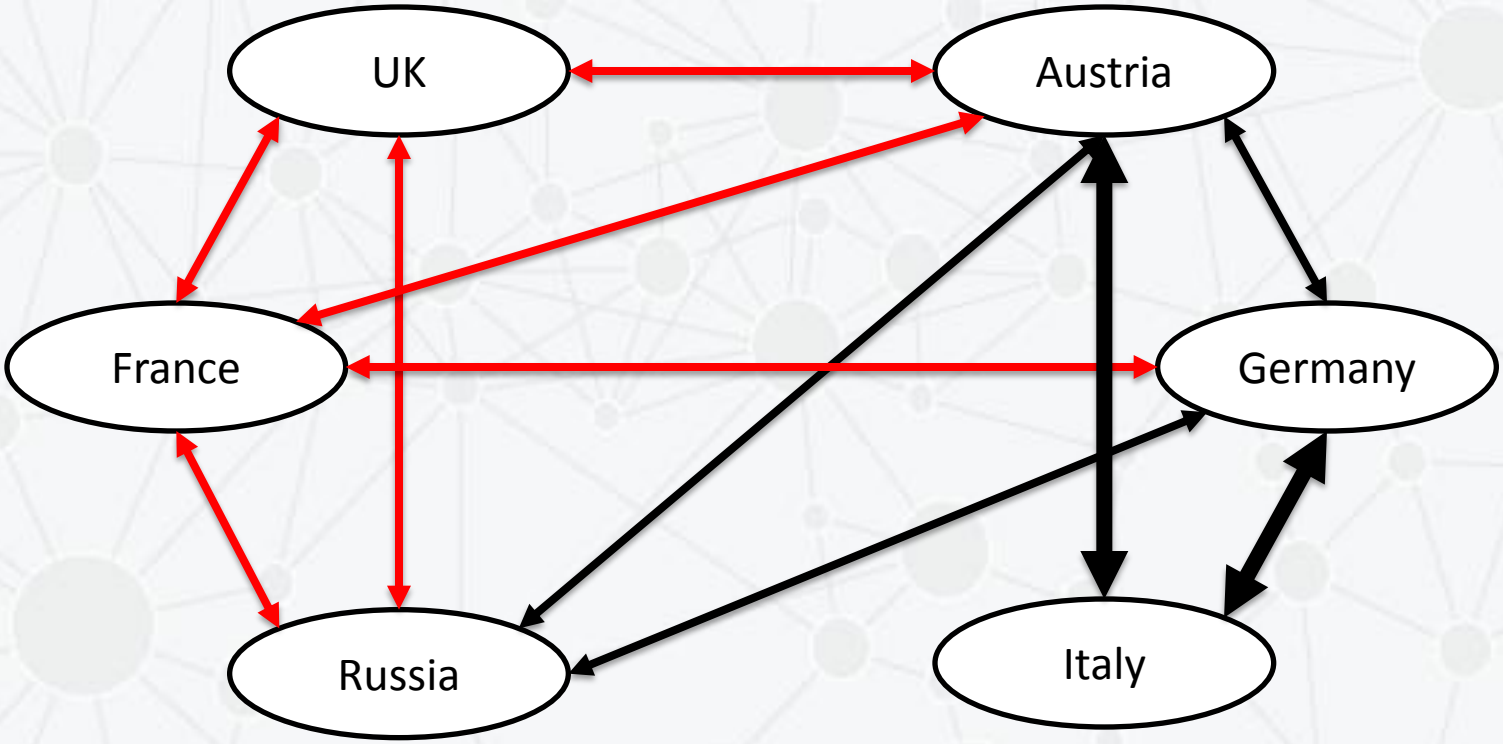
Structural Balance is a *key* predictive technique

And it’s domain-agnostic

Allies and Enemies



Allies and Enemies



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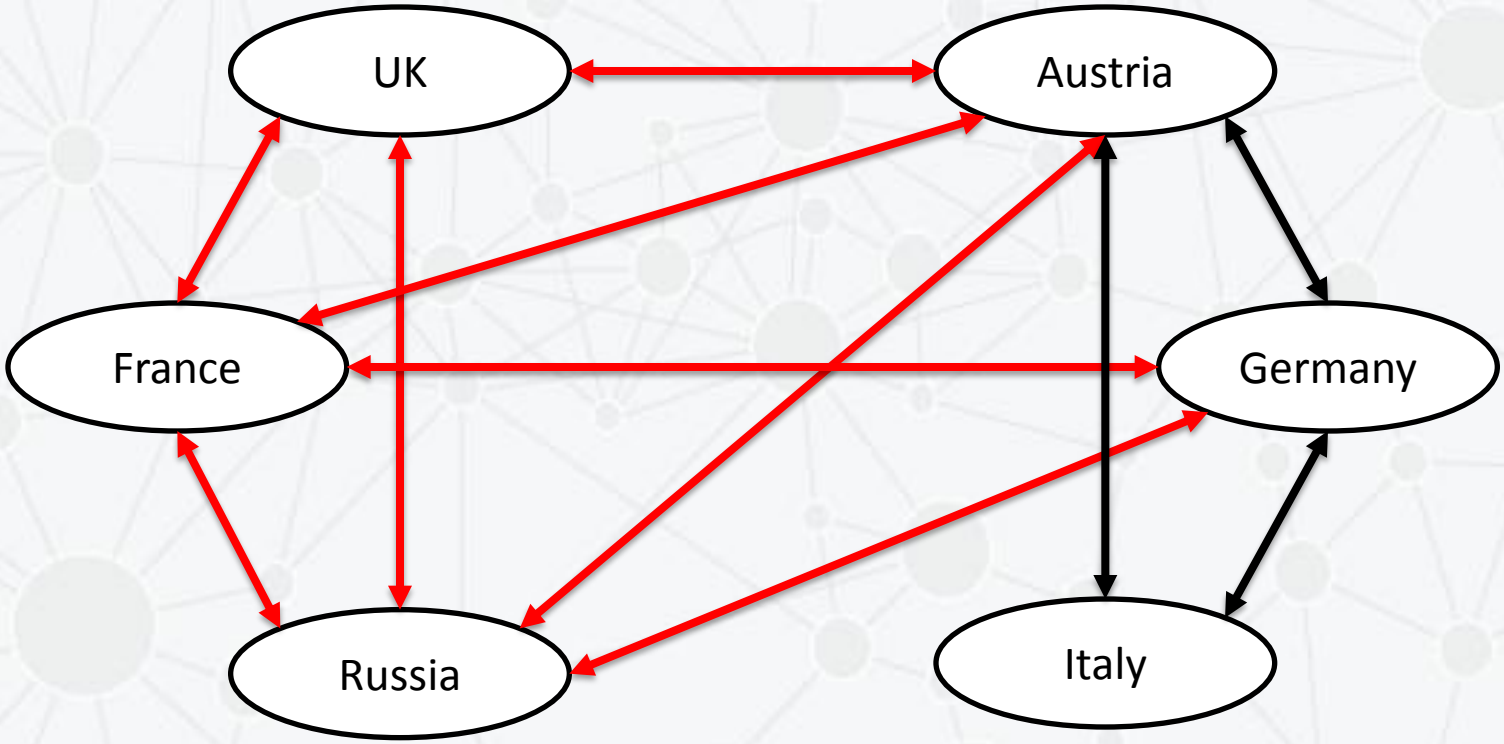

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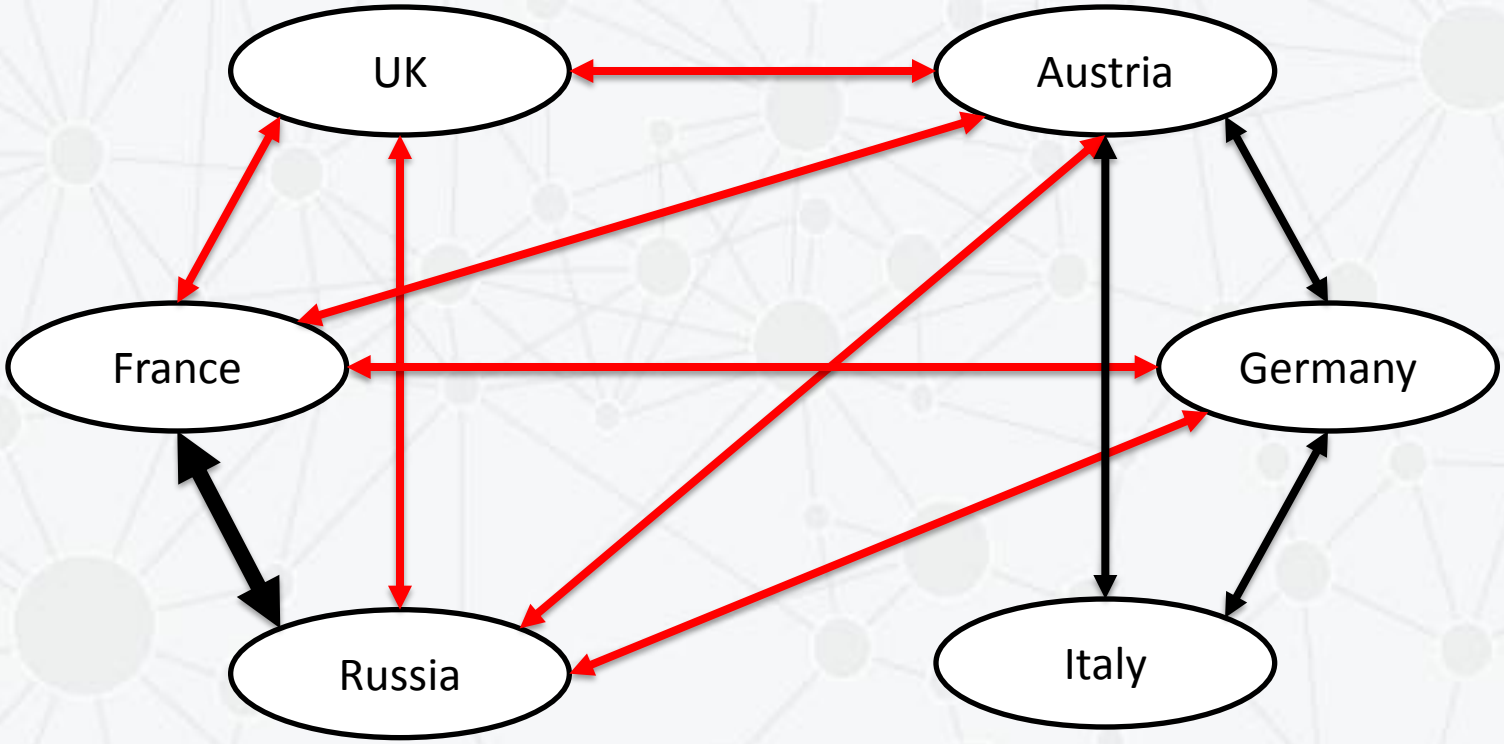

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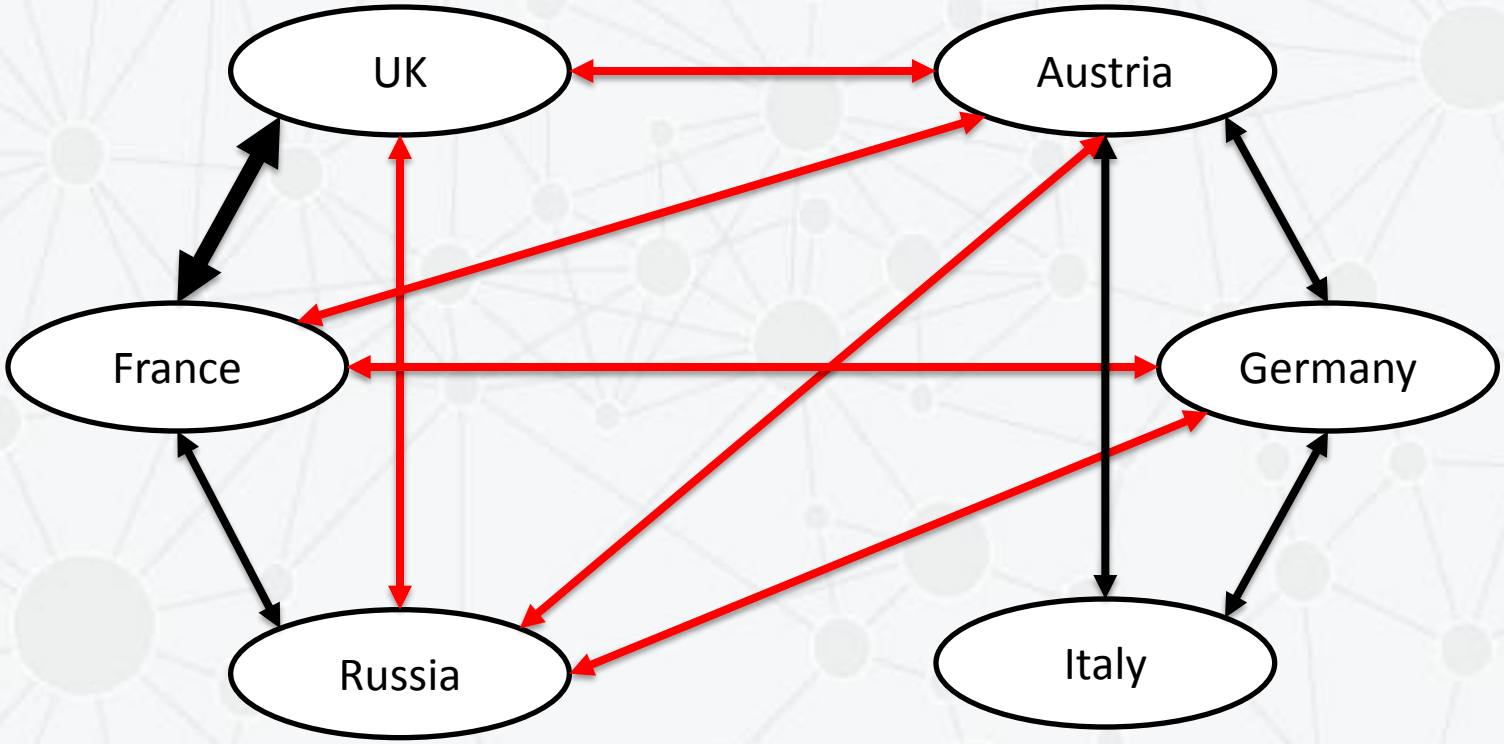
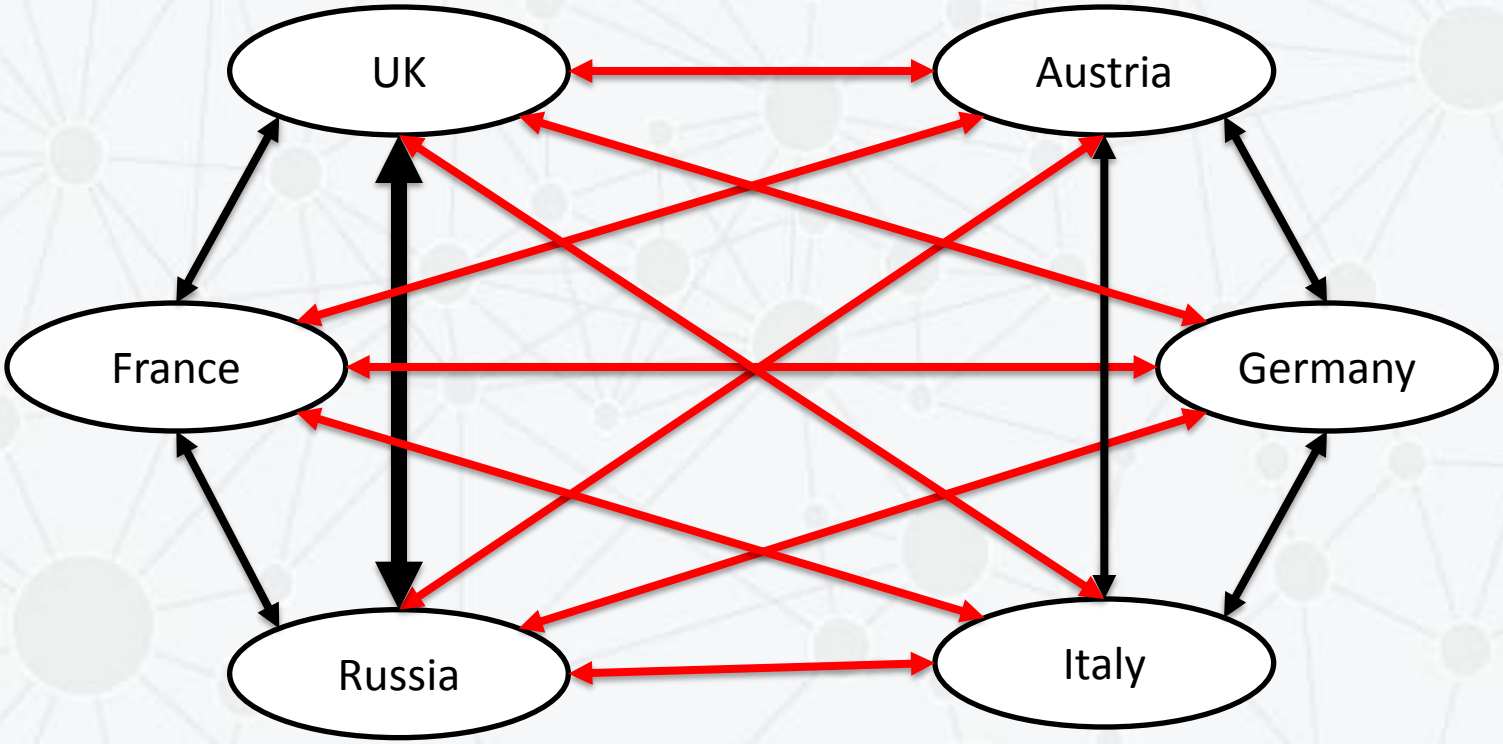
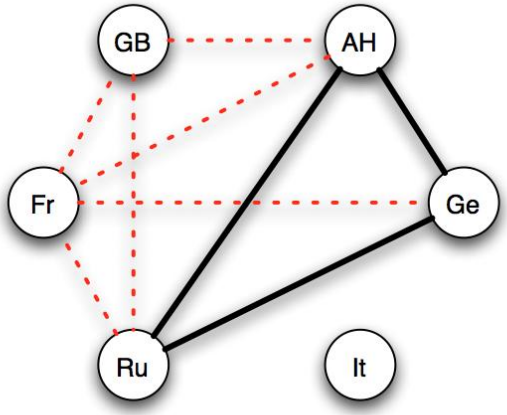


Allies and Enemies

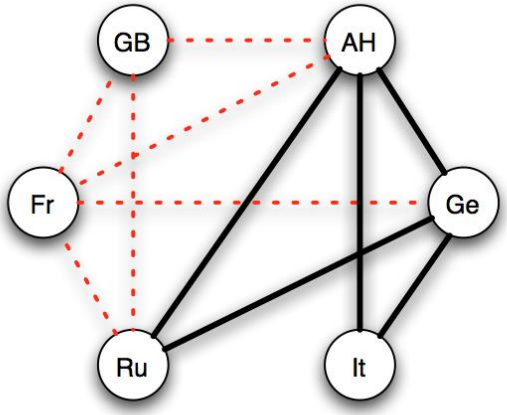


Predicting WWI

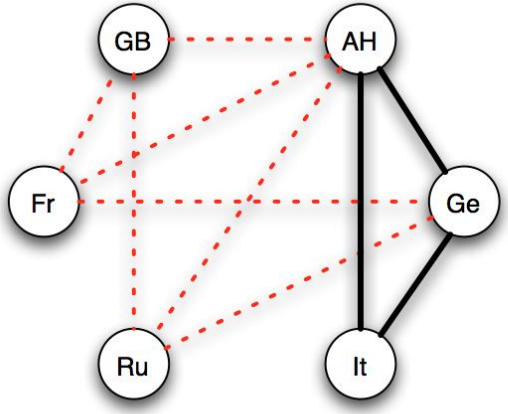
[Easley and Kleinberg]



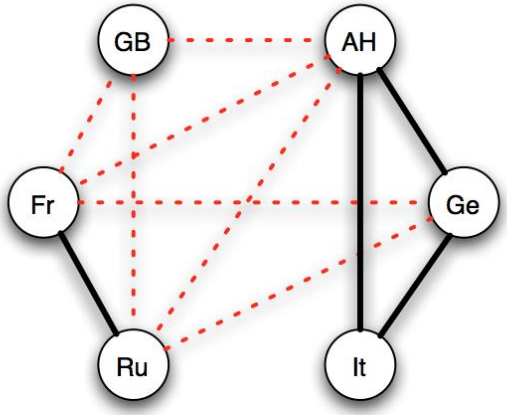
(a) *Three Emperors' League 1872–81*



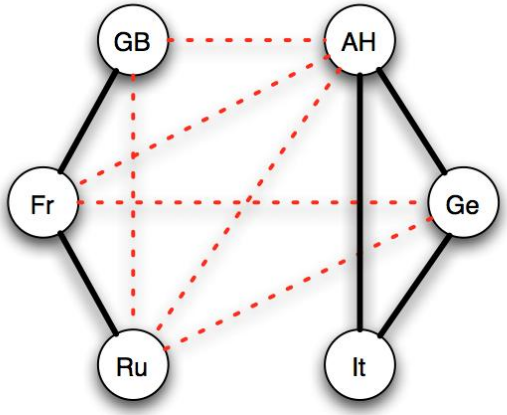
(b) *Triple Alliance 1882*



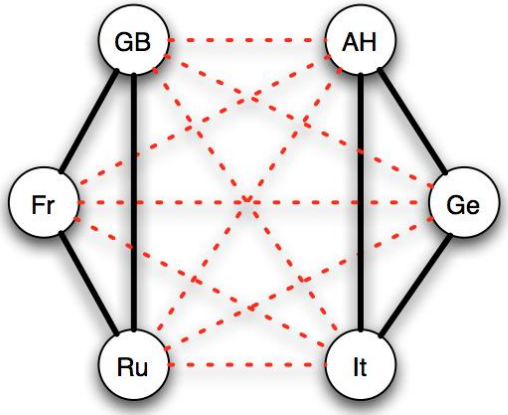
(c) *German-Russian Lapse 1890*



(d) *French-Russian Alliance 1891–94*



(e) *Entente Cordiale 1904*



(f) *British Russian Alliance 1907*

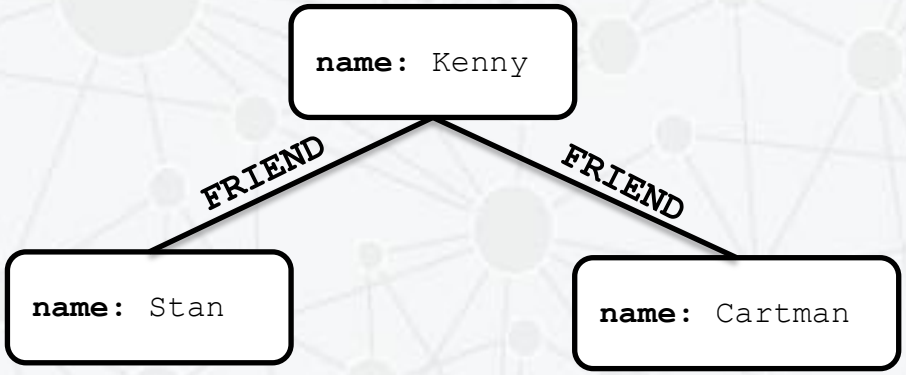
Strong Triadic Closure

It if a node has strong relationships to two neighbours, then these neighbours must have at least a weak relationship between them.

[Wikipedia]

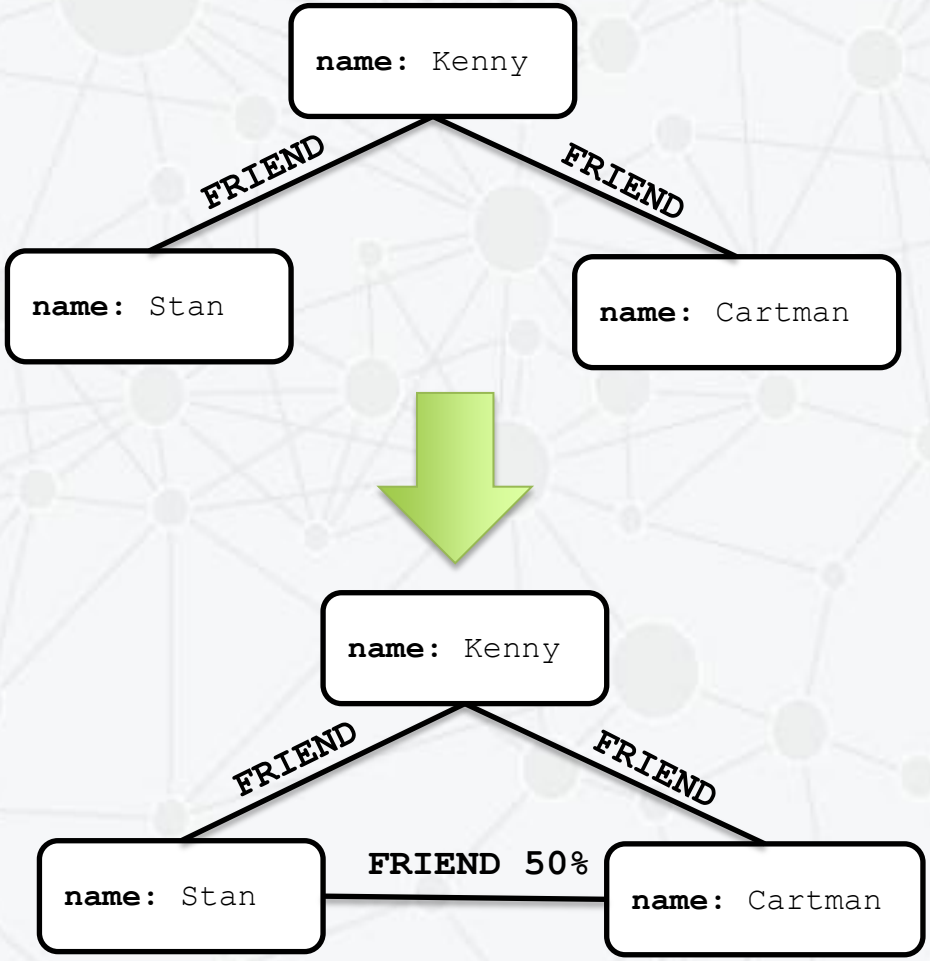
Triadic Closure

(weak relationship)



Triadic Closure

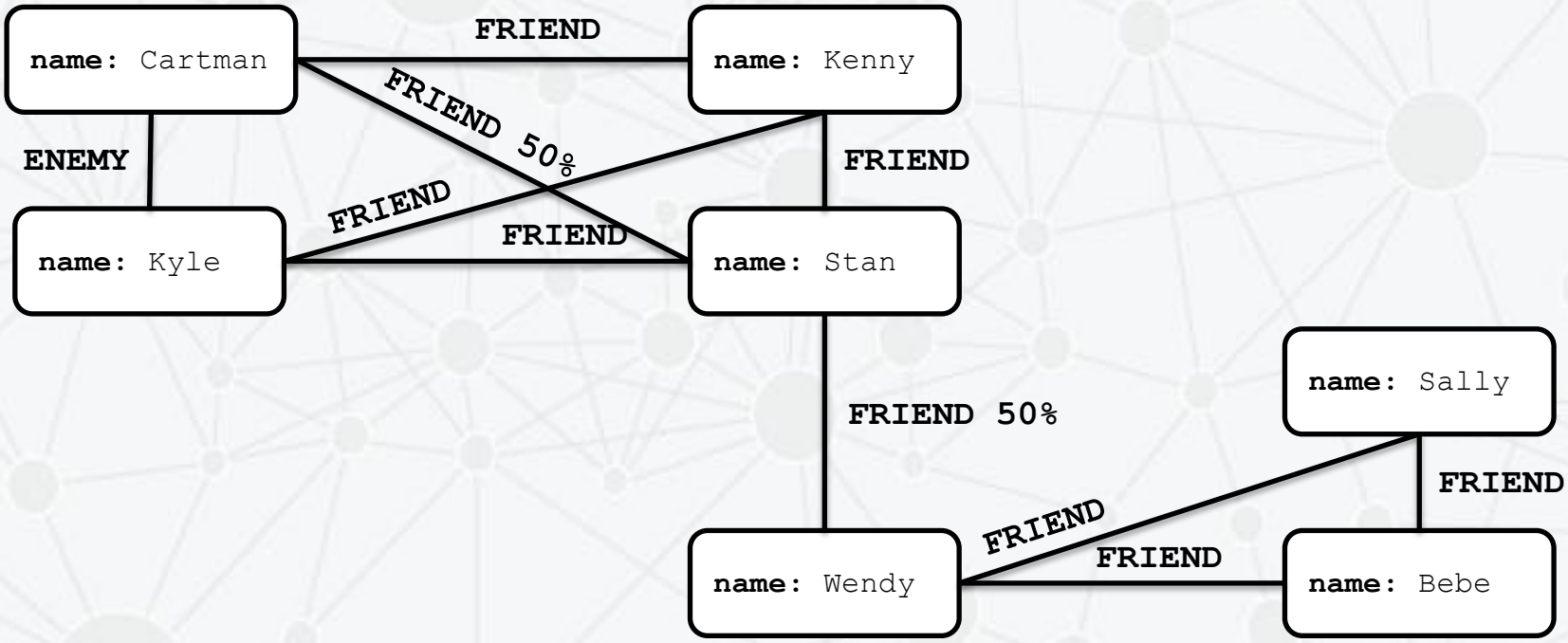
(weak relationship)



Weak relationships

- Relationships can have “strength” as well as intent
  - Think: weighting on a relationship in a property graph
- Weak links play another super-important structural role in graph theory
  - They bridge neighbourhoods

Local Bridges

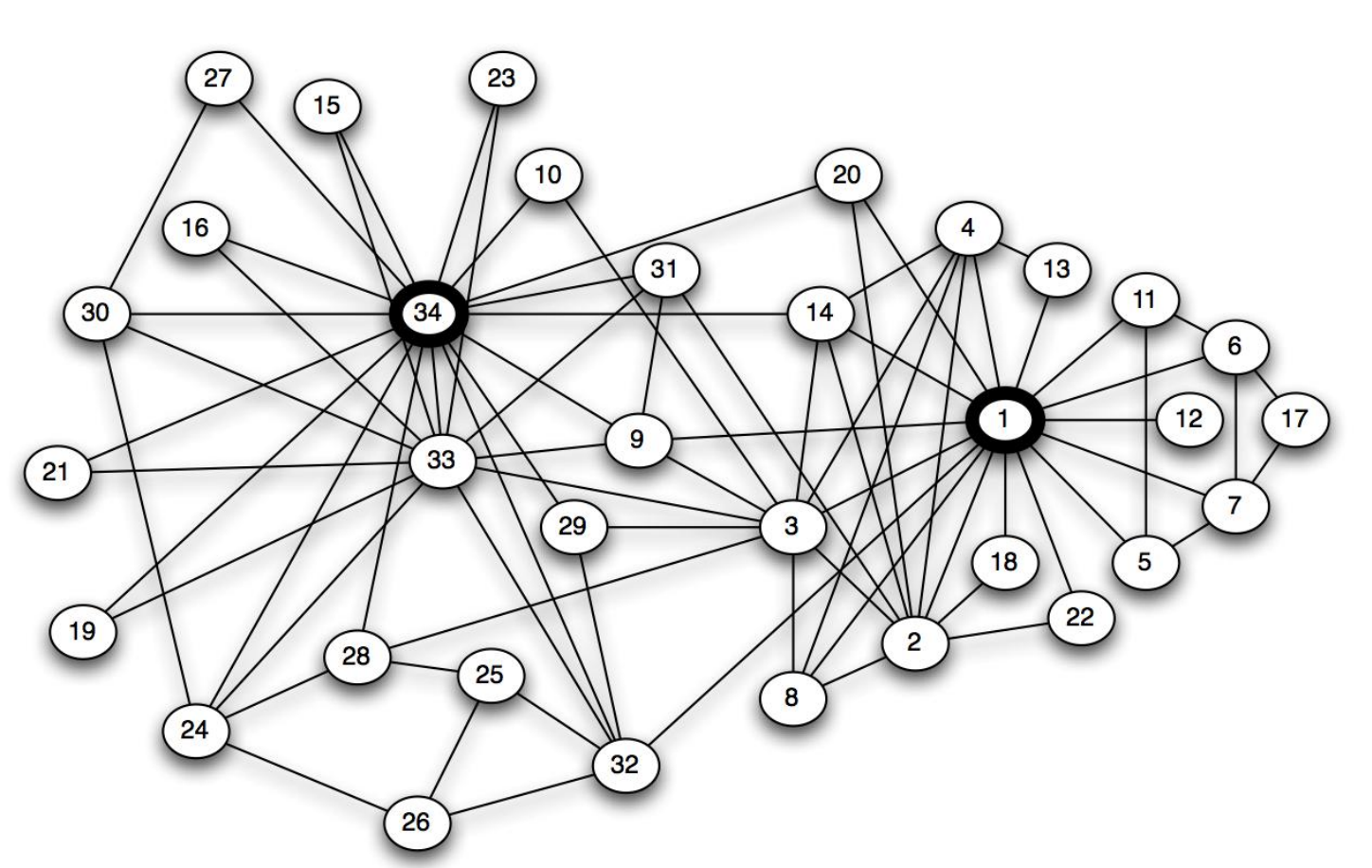


Local Bridge Property

*"If a node **A** in a network satisfies the Strong Triadic Closure Property and is involved in at least two strong relationships, then any local bridge it is involved in must be a weak relationship."*

[Easley and Kleinberg]

University Karate Club

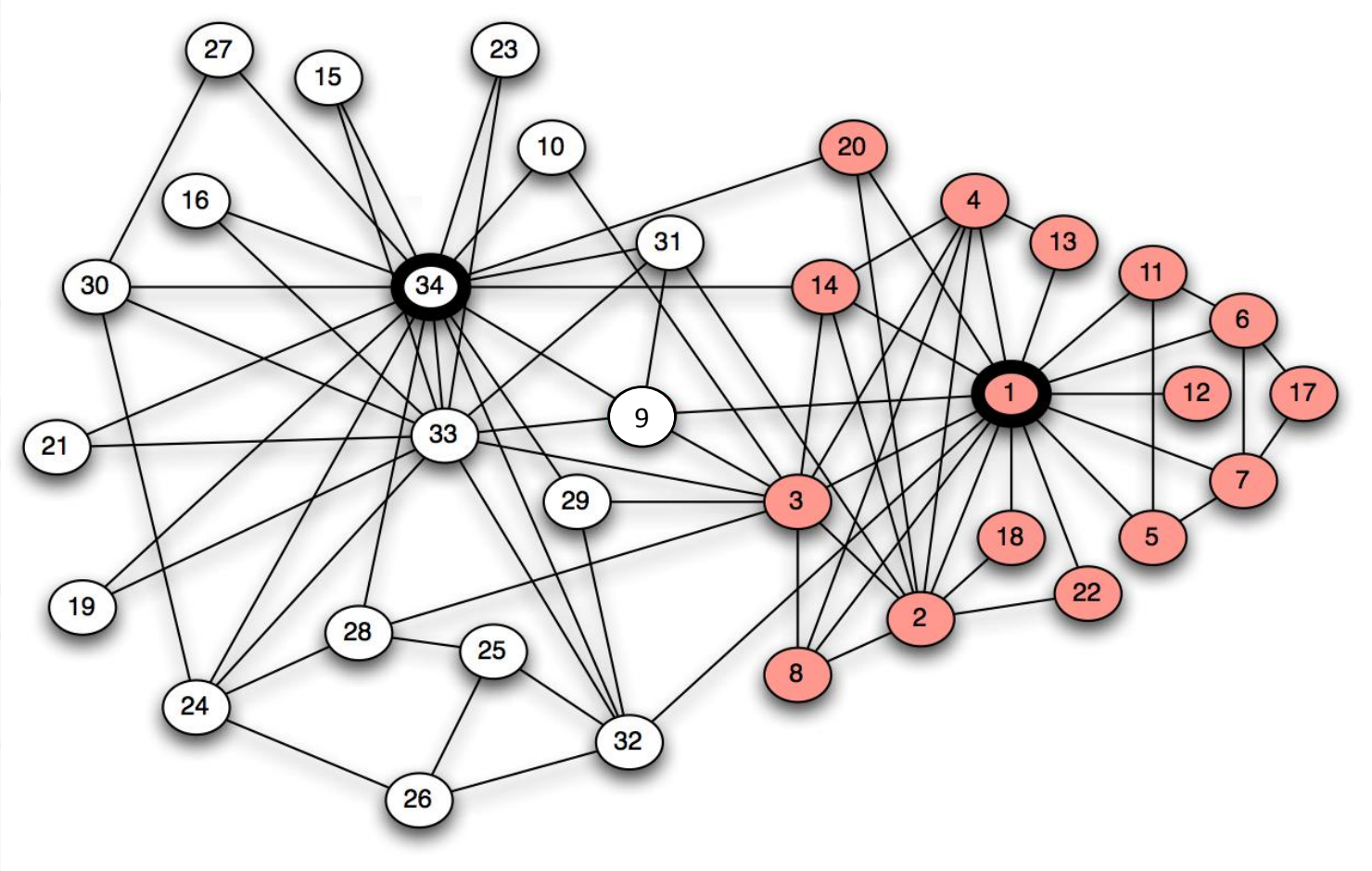


Graph Partitioning

- (NP) Hard problem
  - Recursively remove the spanning links between dense regions
  - Or recursively merge nodes into ever larger “subgraph” nodes
  - Choose your algorithm carefully – some are better than others for a given domain
- Can use to (almost exactly) predict the break up of the karate club!

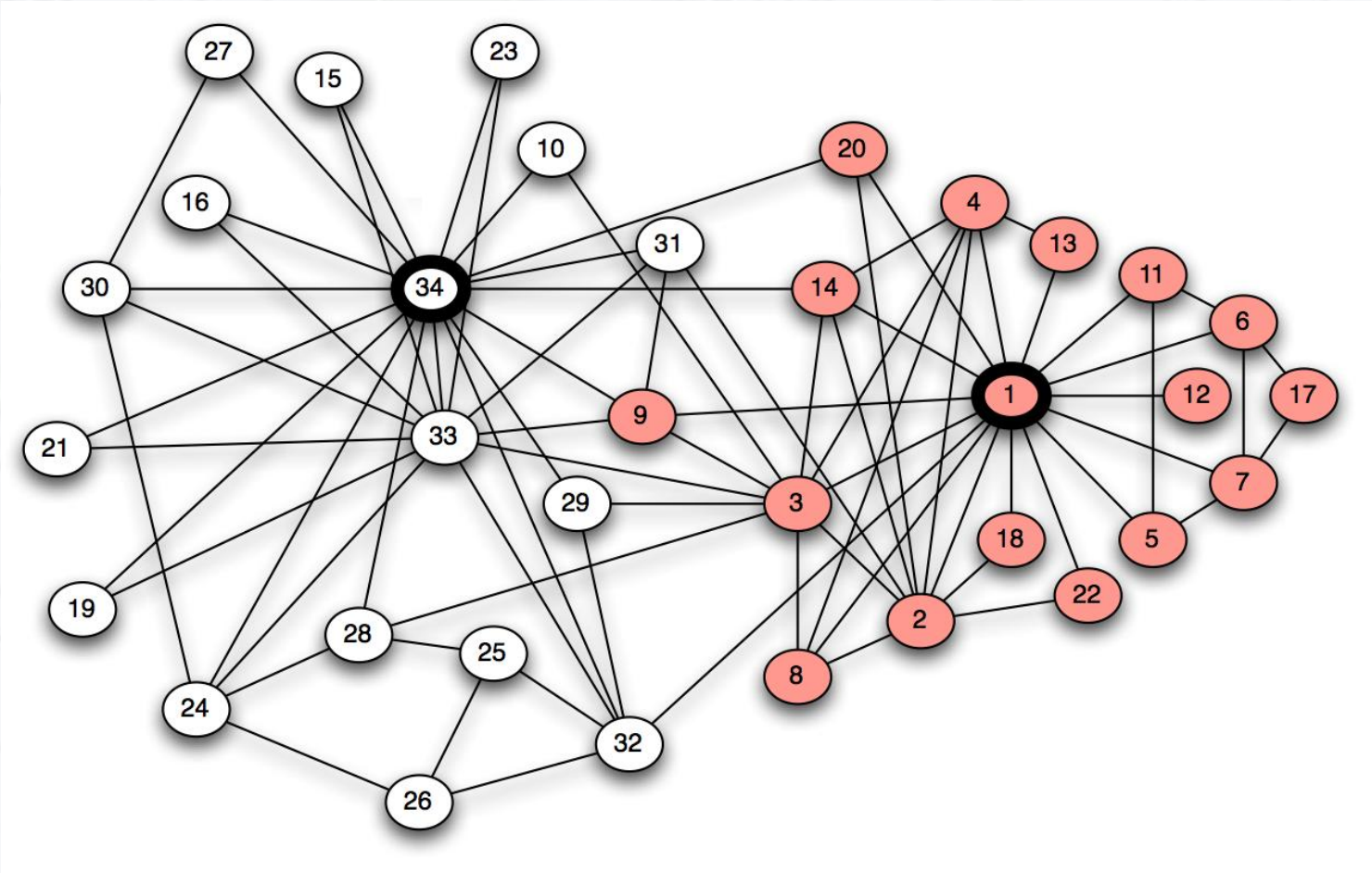
University Karate Clubs

(predicted by Graph Theory)



University Karate Clubs

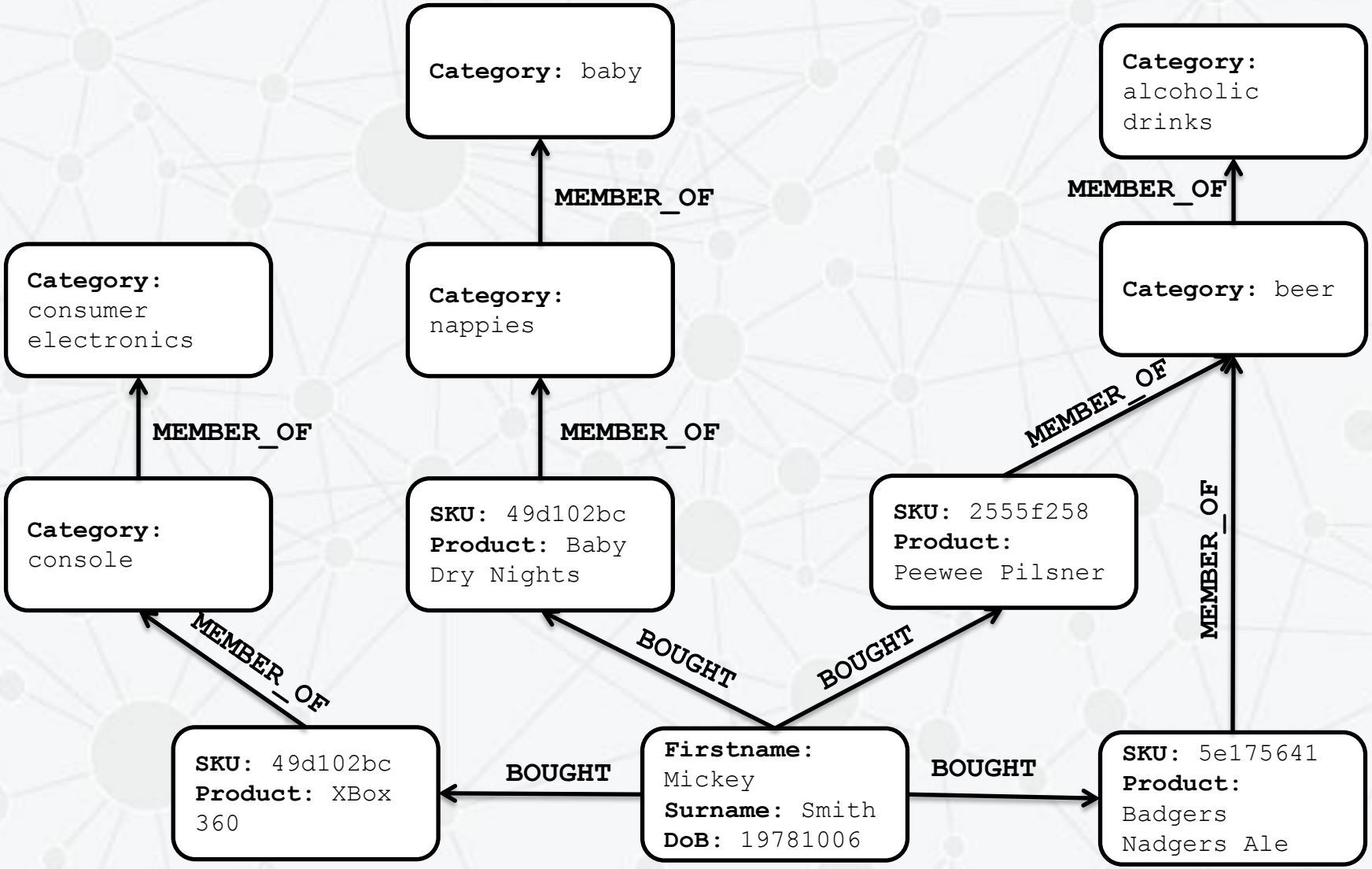
(what actually happened!)




john
crane
Ltd

Cypher

- Declarative graph pattern matching language
  - "SQL for graphs"
  - A humane tool pioneered by a tamed SQL DBA
- A pattern graph matching language
  - Find me stuff like…

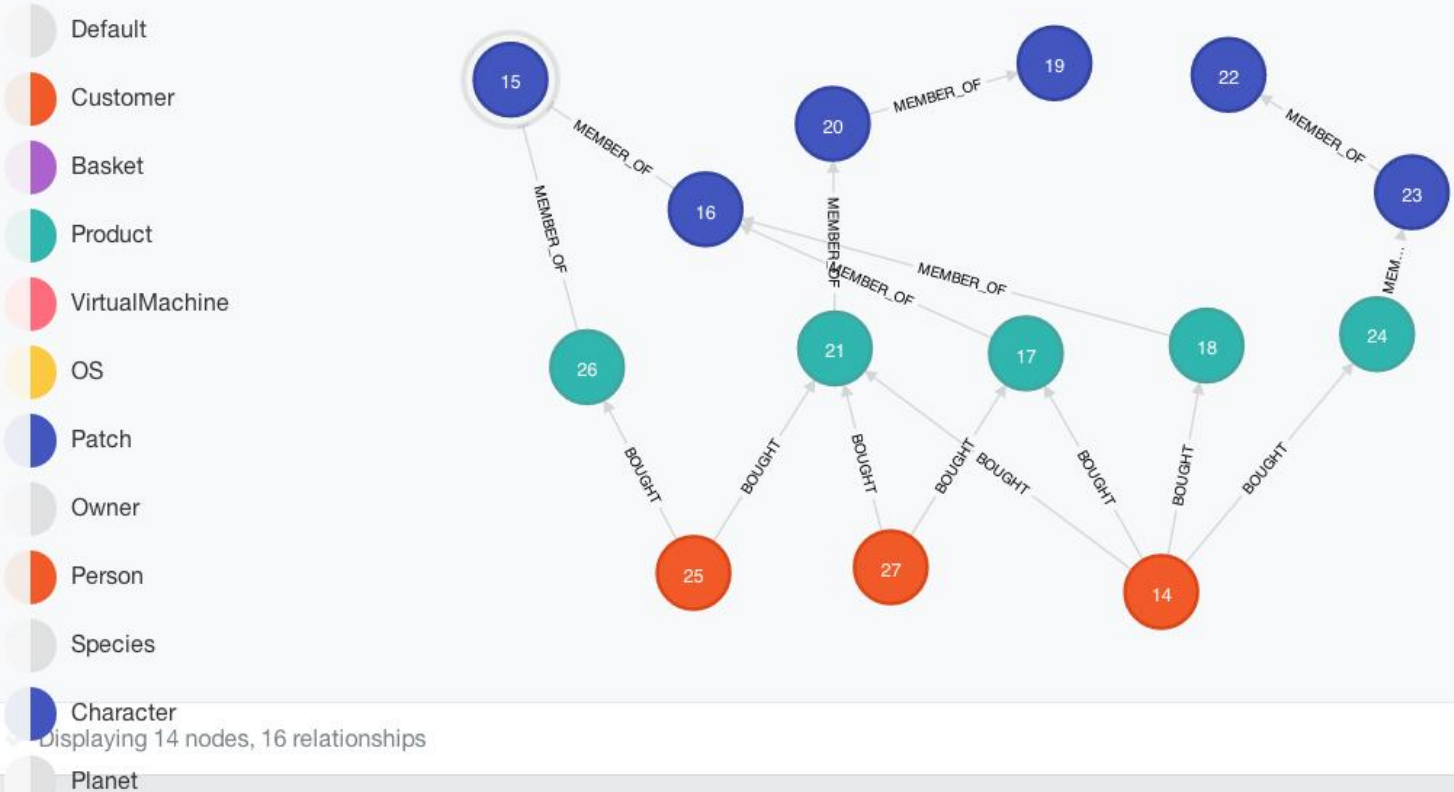

Category: baby
MEMBER_OF
Category: alcoholic drinks
MEMBER_OF
Category: consumer electronics
Category: nappies
Category: beer
MEMBER_OF
MEMBER_OF
MEMBER_OF
Category: console
SKU: 49d102bc Product: Baby Dry Nights
SKU: 2555f258 Product: Peewee Pilsner
MEMBER_OF
BOUGHT
BOUGHT
MEMBER_OF
SKU: 49d102bc Product: XBox 360
BOUGHT
Firstname: Mickey Surname: Smith DoB: 19781006
BOUGHT
SKU: 5e175641 Product: Badgers Nadgers Ale

Neo4j data/graph.db

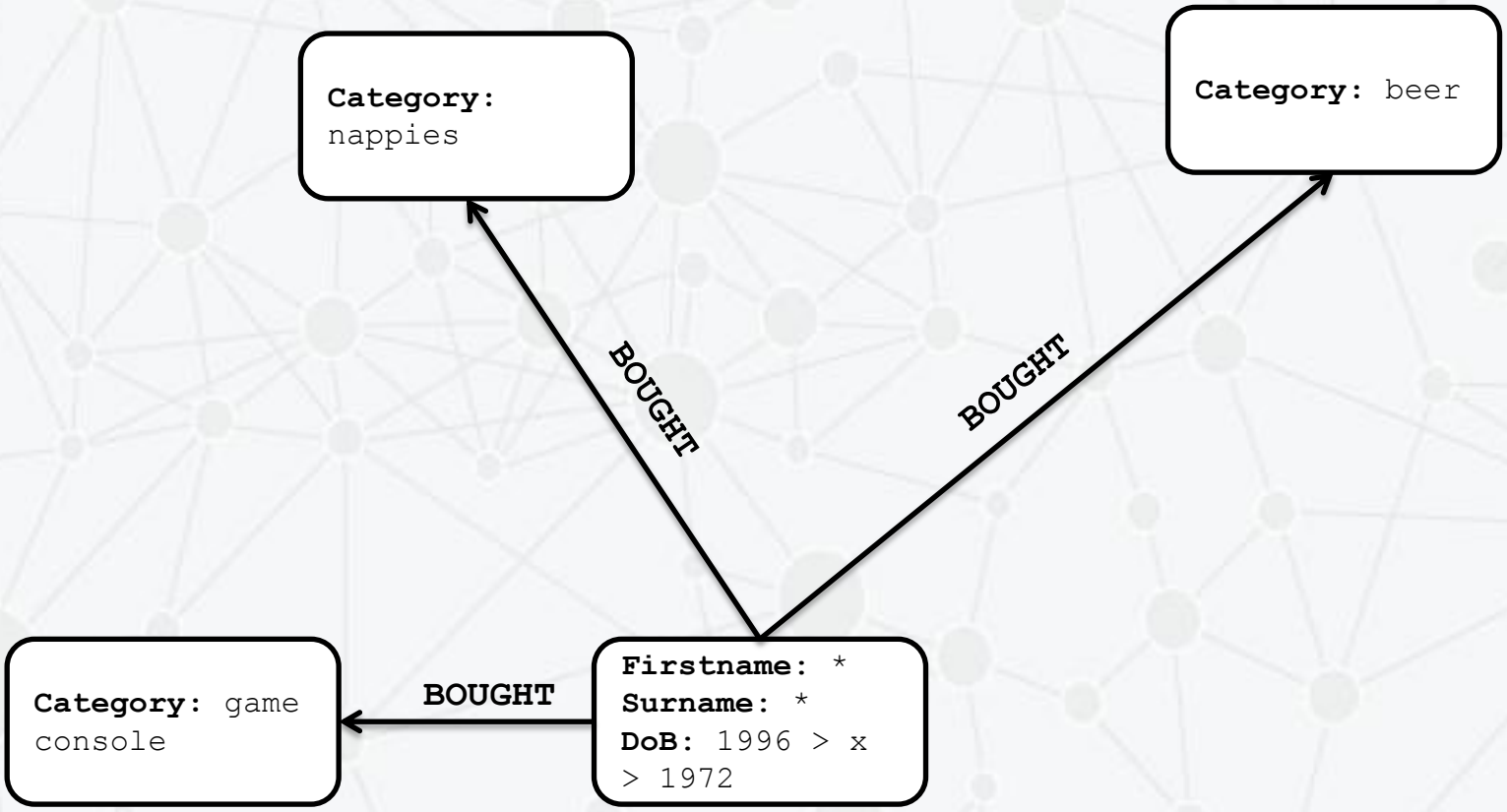
localhost:7474/browser/

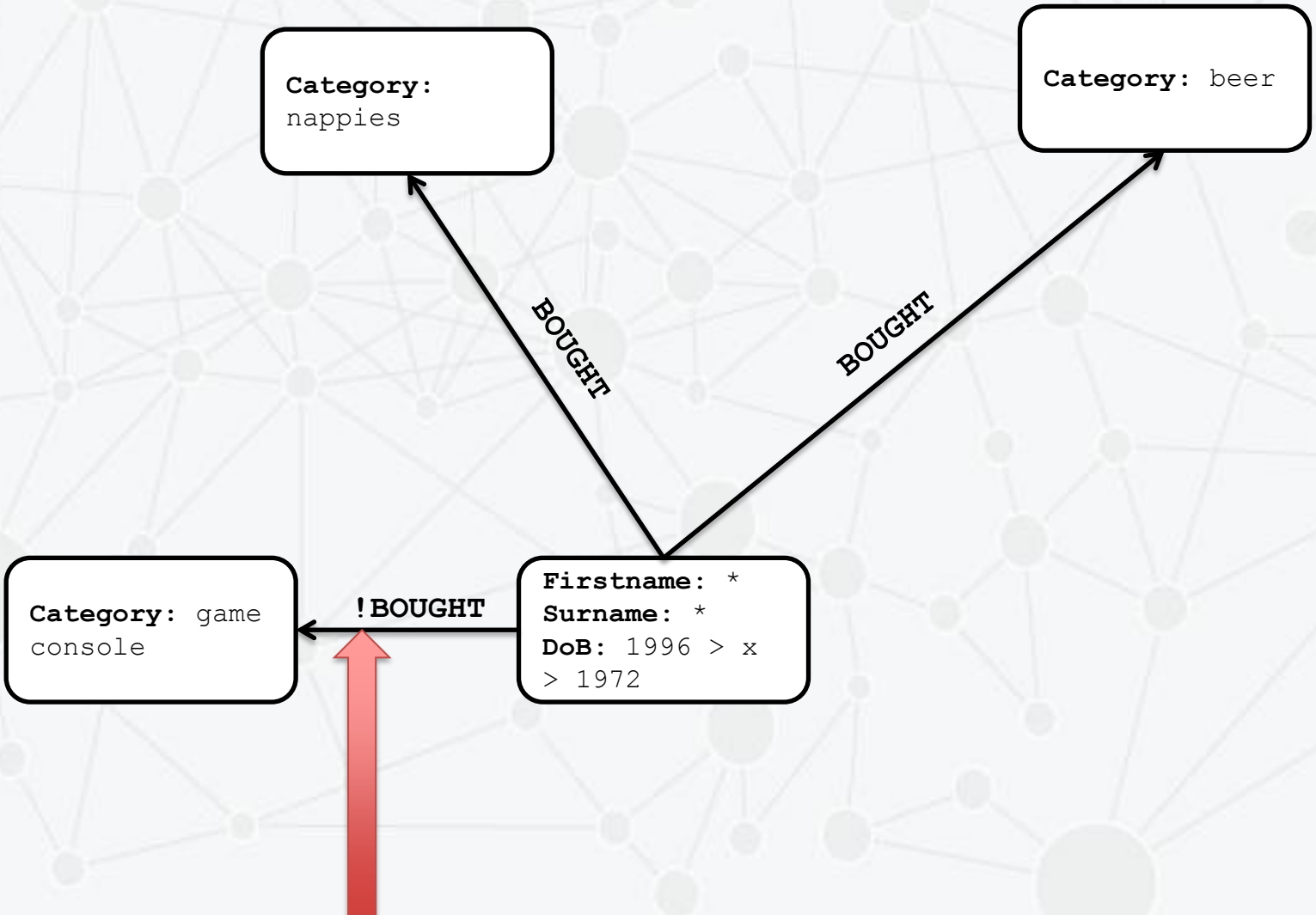
```
1 CREATE (daddy1:Person { name: 'Mickey Smith', dob: 19781006 })
2
3 CREATE (alcohol:Category { category : 'alcoholic drinks'})
4 CREATE (beer:Category { category : 'beer'})
5 CREATE beer-[:MEMBER_OF]->alcohol
6
```

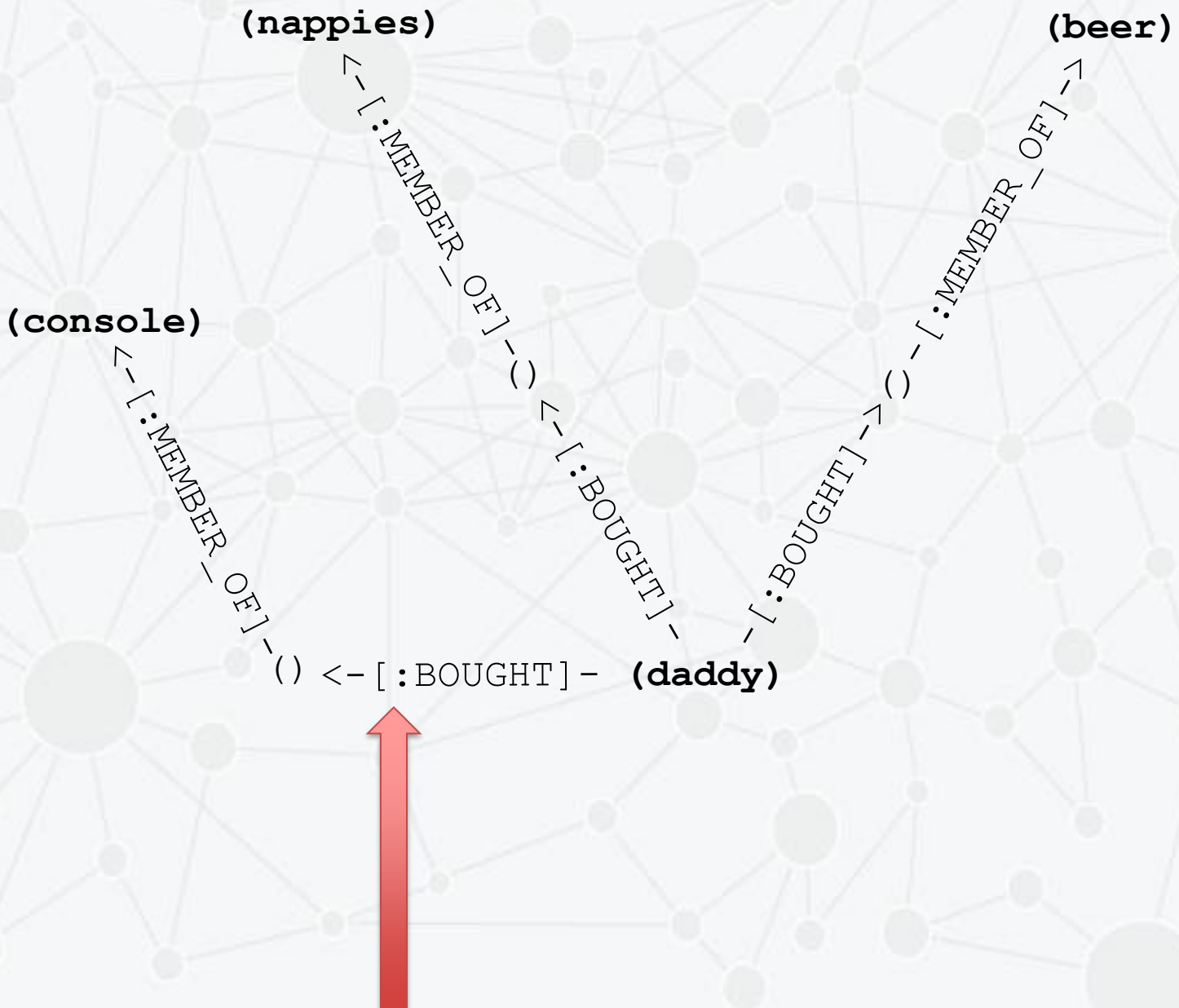
CYPHER MATCH n RETURN n



Displaying 14 nodes, 16 relationships


Category: nappies
Category: beer
BOUGHT
BOUGHT
Category: game console
BOUGHT
Firstname: *
Surname: *
DoB: 1996 > x > 1972


Category: nappies
Category: beer
BOUGHT
BOUGHT
Category: game console
!BOUGHT
Firstname: *
Surname: *
DoB: 1996 > x > 1972


(nappies)
(beer)
(console)
-[:MEMBER_OF]->
-[:MEMBER_OF]->
-[:MEMBER_OF]->
()
-[:BOUGHT]->
()
-[:BOUGHT]->
-[:MEMBER_OF]->
() <-[:BOUGHT]- (daddy)

Flatten the graph

```
(d)-[:BOUGHT]->()-[:MEMBER_OF]->(n)
(d)-[:BOUGHT]->()-[:MEMBER_OF]->(b)


(d)-[:BOUGHT]->()-[:MEMBER_OF]->(c)
```

Include any labels

```
(d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(n:Category)
(d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(b:Category)
```

```
(d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(c:Category)
```

Add a MATCH clause

```
MATCH (d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(n:Category),
      (d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(b:Category)
```

Constrain the Pattern

```
MATCH (d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(n:Category),
      (d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(b:Category),
      (c:Category)

WHERE NOT((d)-[:BOUGHT]->()-[:MEMBER_OF]->(c))
```

Add property constraints

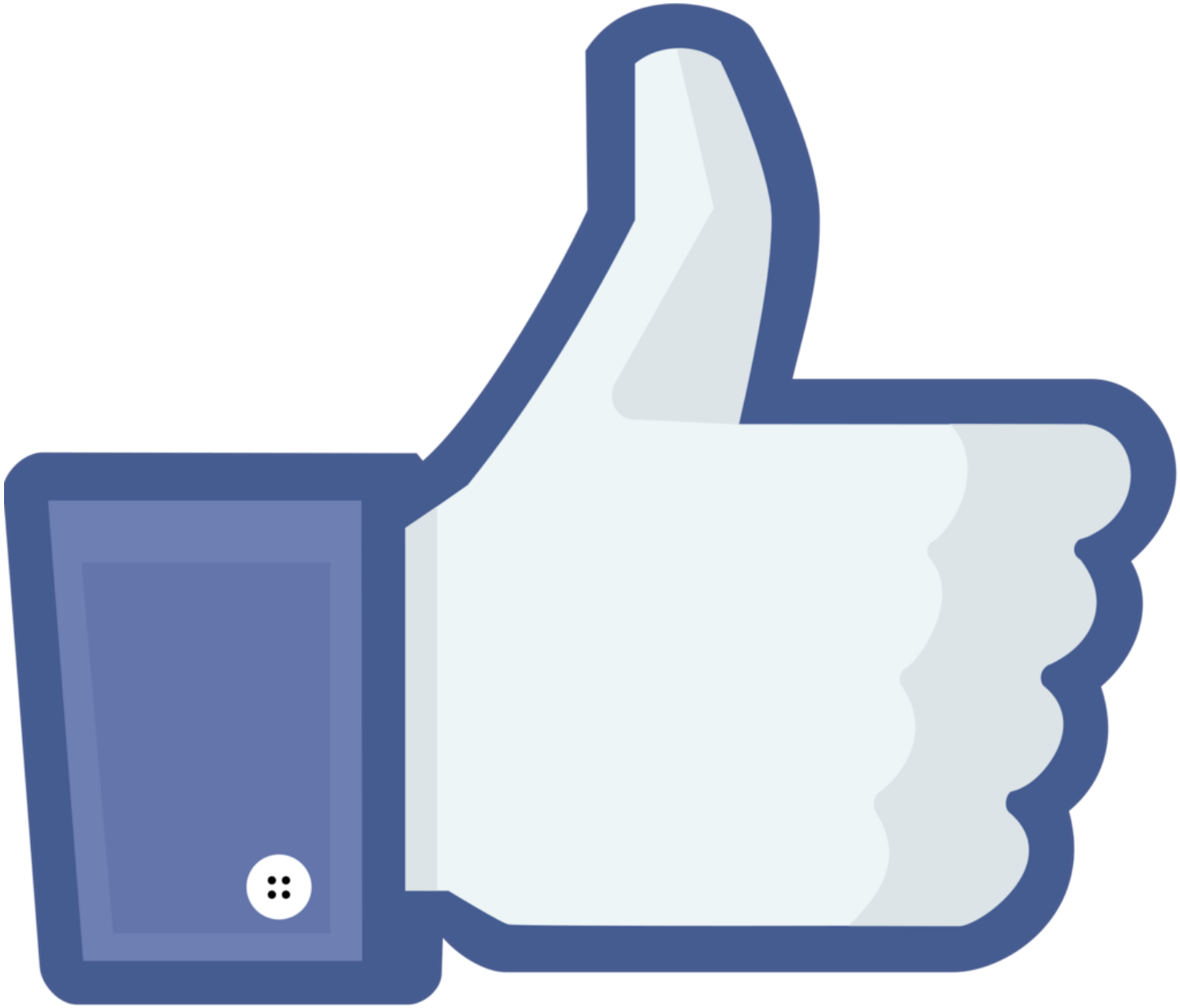
```
MATCH (d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(n:Category),
      (d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(b:Category),
      (c:Category)

WHERE n.category = "nappies" AND
      b.category = "beer" AND
      c.category = "console" AND
      NOT((d)-[:BOUGHT]->()-[:MEMBER_OF]->(c))
```

Profit!

```
MATCH (d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(n:Category),
      (d:Person)-[:BOUGHT]->()-[:MEMBER_OF]->(b:Category),
      (c:Category)

WHERE n.category = "nappies" AND
      b.category = "beer" AND
      c.category = "console" AND
      NOT((d)-[:BOUGHT]->()-[:MEMBER_OF]->(c))

RETURN DISTINCT d AS daddy
```

Results

```
==> +-----------------------------------------------+
==> | daddy                                         |
==> +-----------------------------------------------+
==> | Node[15]{name:"Rory Williams",dob:19880121} |
==> +-----------------------------------------------+
==> 1 row
==> 0 ms
==>
neo4j-sh (0)$
```

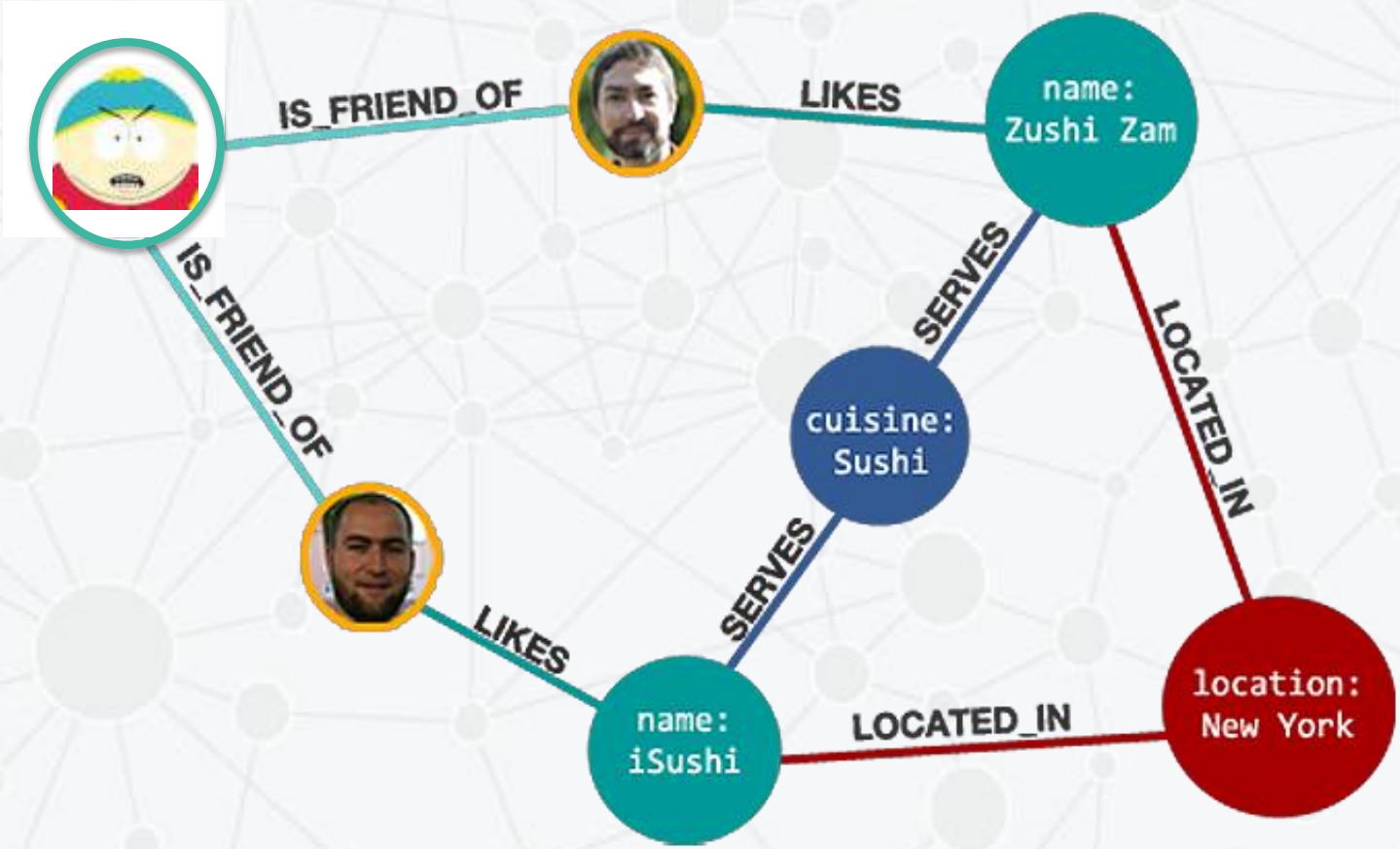


Facebook Graph Search

Which sushi restaurants in NYC do my friends like?

See http://maxdemarzi.com/

Graph Structure



Cypher query is easy!

```
MATCH (me)
        -[:IS_FRIEND_OF]->()
        -[:LIKES]->(restaurant)
        -[:LOCATED_IN]->(city),
       (restaurant)-[:SERVES]->(cuisine)

WHERE me.name = 'Jim' AND
      city.location='New York' AND
      cuisine.cuisine='Sushi'

RETURN restaurant
```

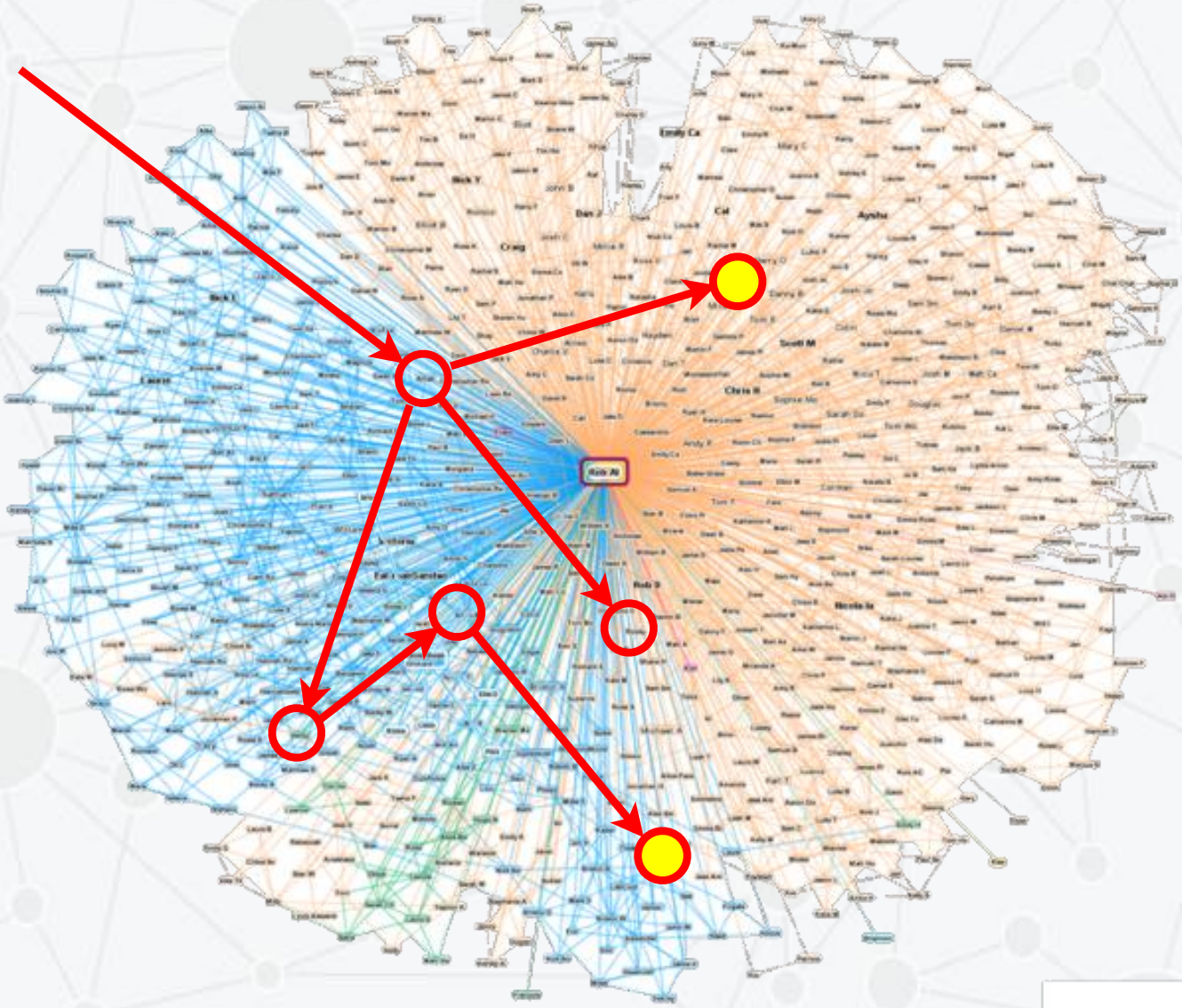
And richer with labels

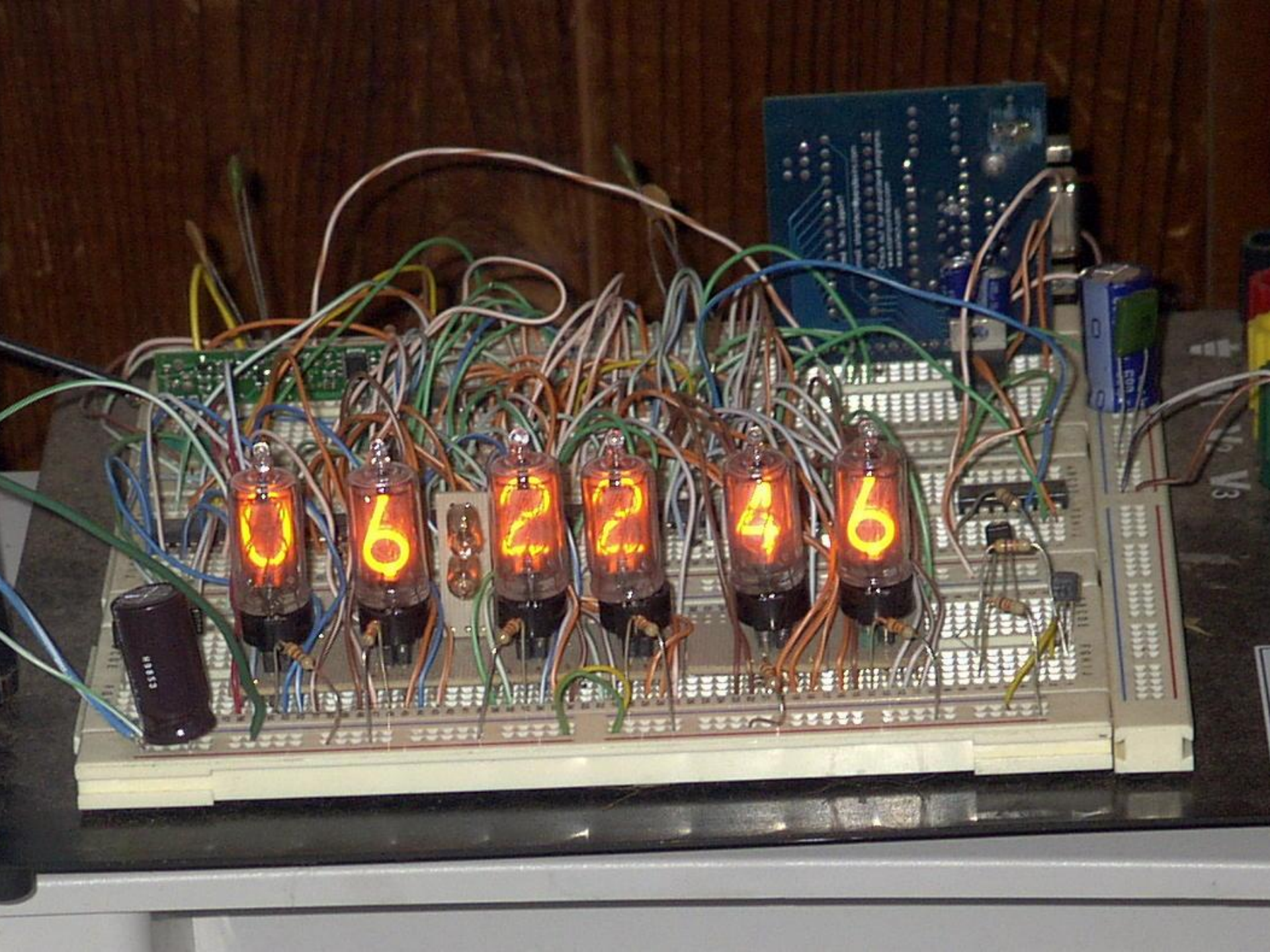
```
MATCH (me:Person)
        -[:IS_FRIEND_OF]->(:Person)
        -[:LIKES]->(restaurant:Restaurant)
        -[:LOCATED_IN]->(city:Place),
       (restaurant)-[:SERVES]->(cuisine:Cuisine)

WHERE me.name = 'Jim' AND
      city.location='New York' AND
      cuisine.cuisine='Sushi'

RETURN restaurant
```

And clearer with compact MATCH…

```
MATCH (:Person {name: 'Jim'})
  -[:IS_FRIEND_OF]->(:Person)
  -[:LIKES]->(restaurant:Restaurant)
  -[:LOCATED_IN]->(:Place {location: 'New York'}),
  (restaurant)-[:SERVES]->(:Cuisine {cuisine: 'Sushi'})

RETURN restaurant
```

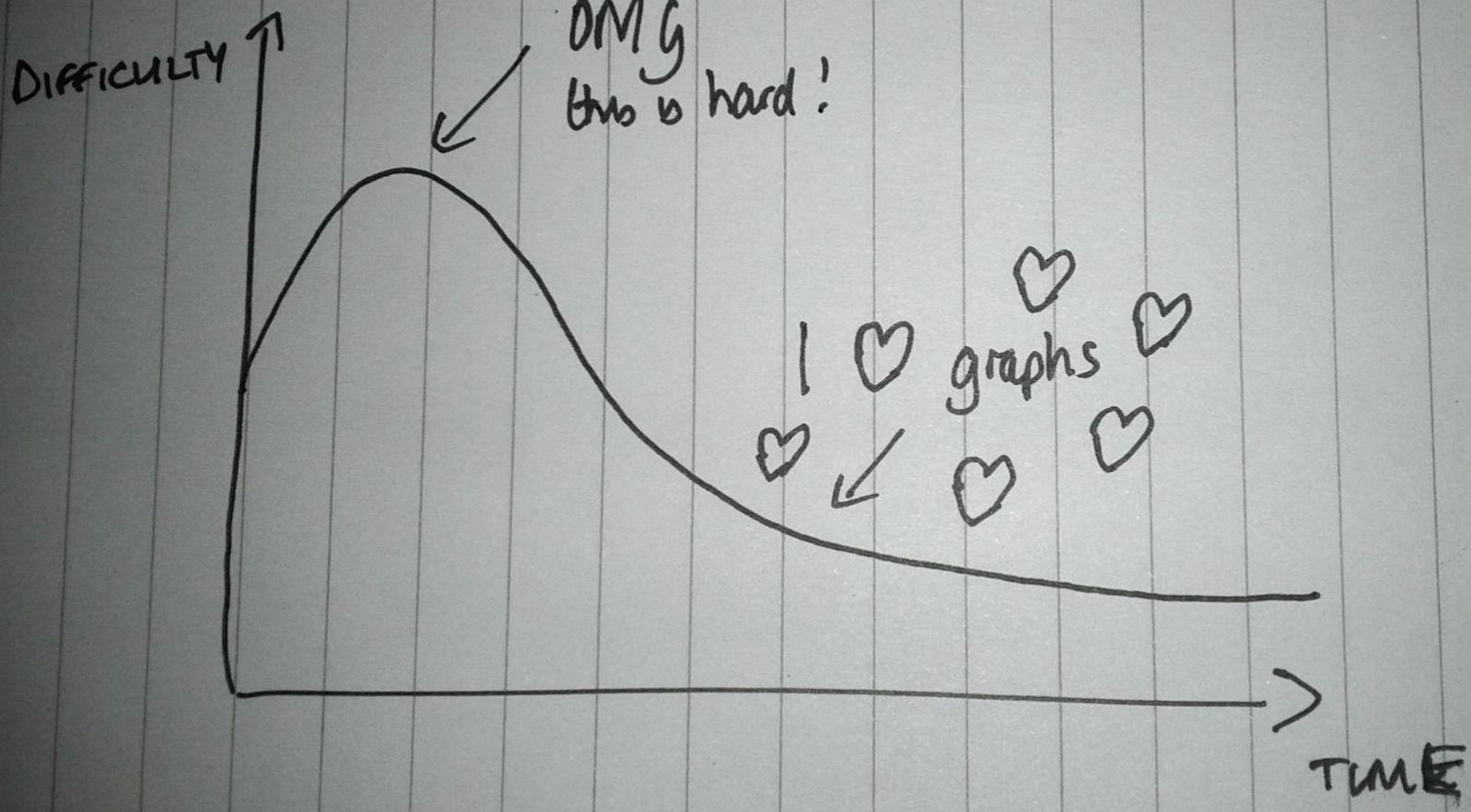
Search structure



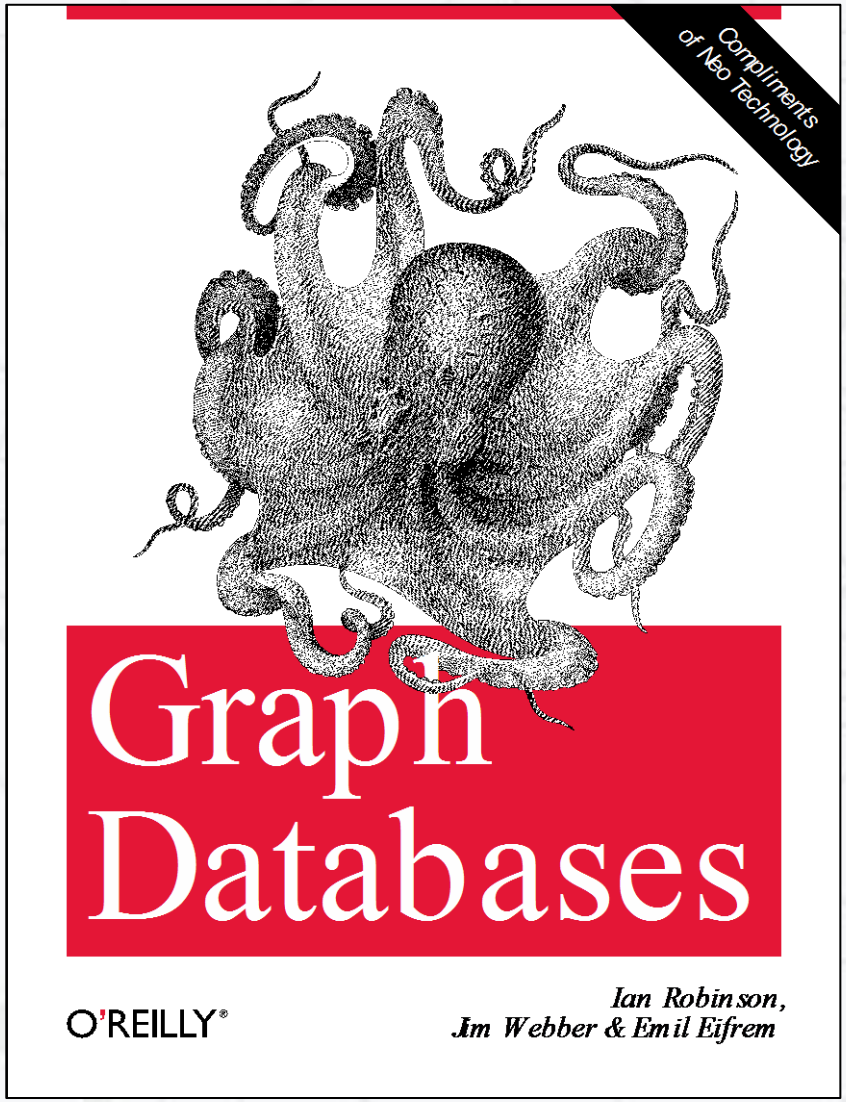

0 6 2 2 4 6

What's Neo4j good for?

- Data centre management
- Supply chain/provenance
- Recommendations
- Business intelligence
- Social computing
- MDM
- Web of things
- Time series/event data
- Product/engineering catalogue
- Web analytics, user journeys
- Scientific computing
- Spatial
- Geo/Seismic/Meteorological
- Bio/Pharma
- And many, many more…



credit: @markhneedham



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Don’t forget the Neo4j Stockholm Meetups!

Neo4j

Thanks for listening

@jimwebber