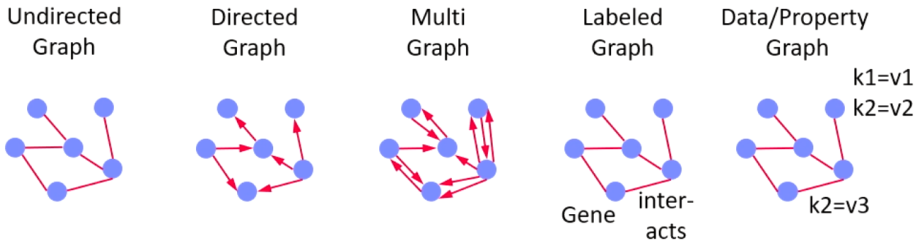
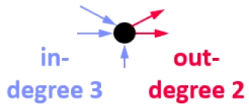
Terminology

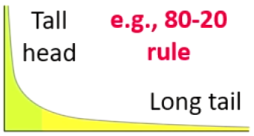
- for further details see [[Graphs KR]]
- recap:
  - **Terminology**
    - Graph G = (V, E) of vertices V (set of nodes) and edges E (set of links between nodes)
    - **Different types of graphs**



  - **Terminology, cont.**
    - **Path:** Sequence of edges and vertices (**walk:** allows repeated edges/vertices)
    - **Cycle:** Closed walk, i.e., a walk that starts and ends at the same vertex
    - **Clique:** Subgraph of vertices where every two distinct vertices are adjacent
  - **Metrics**
    - **Degree** (in/out-degree): number of incoming/outgoing edges of that vertex
    - **Diameter:** Maximum distance of pairs of vertices (longest shortest-path)



  - **Power Law Distribution**
    - Degree of most real graphs follows a power law distribution



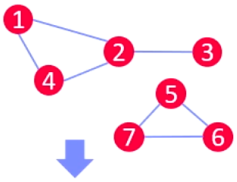
Vertex-Centric Processing

Programming Model

- Represent graph as collection of vertices w/ edge (adjacency) lists
- Implement algorithms via Vertex API
- Terminate if all vertices halted / no more msgs

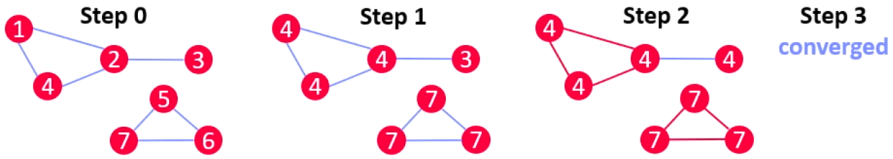
```
public abstract class Vertex {
  public String getID();
  public long superstep();
  public VertexValue getValue();

  public compute(Iterator<Message> msgs);
  public sendMsgTo(String v, Message msg);
  public void voteToHalt();
}
```

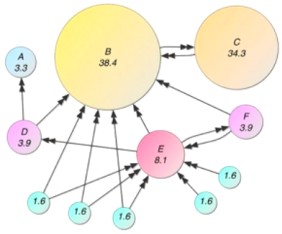


2 [1, 3, 4]
7 [5, 6]
4 [1, 2]
1 [1, 2, 4]
5 [6, 7]
3 [2]
6 [5, 7]

- **Example1: Connected Components**
  - Determine connected components of a graph (subgraphs of connected nodes)
  - Propagate max(current, msgs) if != current to neighbors, terminate if no msgs



- **Example 2: Page Rank**
  - Ranking of webpages by importance / impact
  - **#1:** Initialize vertices to 1/numVertices()
  - **#2:** In each super step
    - Compute current vertex value:
      `value = 0.15/numVertices()+0.85*sum(msg)`
    - Send to all neighbors:
      `value/numOutgoingEdges()`



[**Credit:** https://en.wikipedia.org/wiki/PageRank]

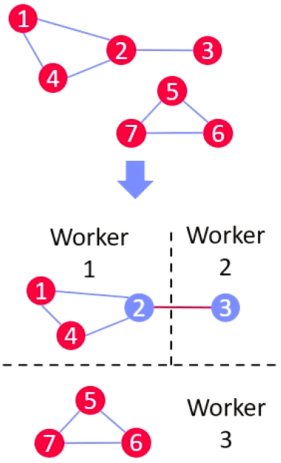
Graph-Centric Processing

Motivation

- Exploit graph structure for algorithm-specific optimizations
  (number of network messages, scheduling overhead for super steps)
- **Large diameter / average vertex degree**

Programming Model

- Partition graph into subgraphs (block/graph)
- Implement algorithm directly against subgraphs (internal and boundary nodes)
- Exchange messages in super steps only between boundary nodes ➔ faster convergence

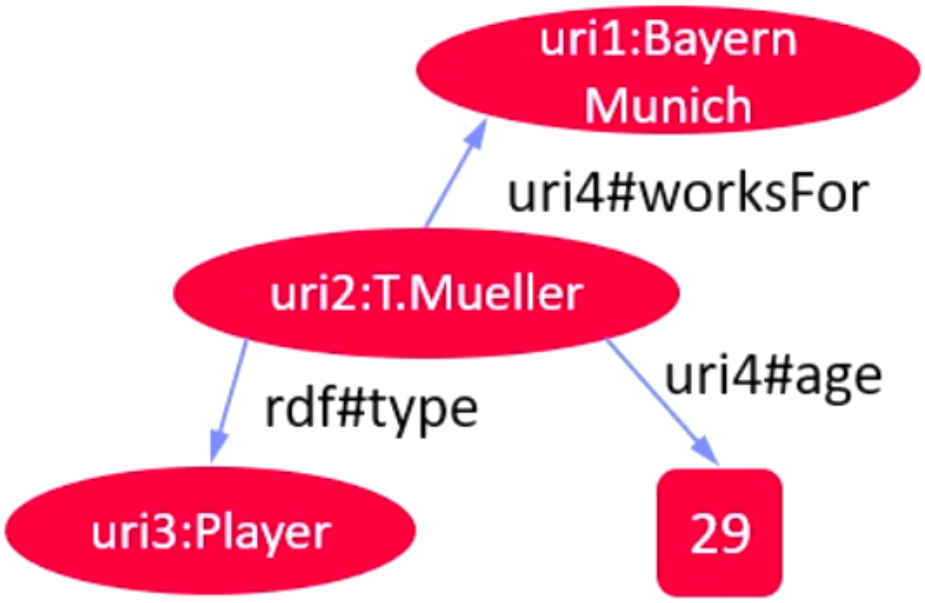


[Yuanyuan Tian, Andrey Balmin, Severin Andreas Corsten, Shirish Tatikonda, John McPherson: From "Think Like a Vertex" to "Think Like a Graph". **PVLDB 2013**]

[Da Yan, James Cheng, Yi Lu, Wilfred Ng: Blogel: A Block-Centric Framework for Distributed Computation on Real-World Graphs. **PVLDB 2014**]

Ressource Description Framework

- RDF Data
  - data and meta data description as triples
    - (subject, predicate, object)
  - e.g. URIs or Literals



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- RDF graphs are directed, labeled multigraph
- querying data

Querying RDF Data

- SPARQL (SPARQL Protocol And RDF Query Language)
- Subgraph matching

```
SELECT ?person
WHERE {
  ?person rdf:type uri3:Player ;
          uri4:worksFor uri1:”Bayern Munich” .
}
```

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[[Data Models]]