DS 4300

Introduction to the Graph Data Model

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What is a Graph Database

- Data model based on the graph data structure
- Composed of nodes and edges
  - edges connect nodes
  - each is uniquely identified
  - each can contain properties (e.g. name, occupation, etc)
  - supports queries based on graph-oriented operations
    - traversals
    - shortest path
    - *lots of others*
  - Each node/edge uniquely identifiable
  - Own query language

Where do Graphs Show up?

- Social Networks
  - yes… things like Instagram,
  - but also… modeling social interactions in fields like psychology and sociology
- The Web
  - it is just a big graph of “pages” (nodes) connected by hyperlinks (edges)
- Chemical and biological data
  - systems biology, genetics, etc.
  - interaction relationships in chemistry

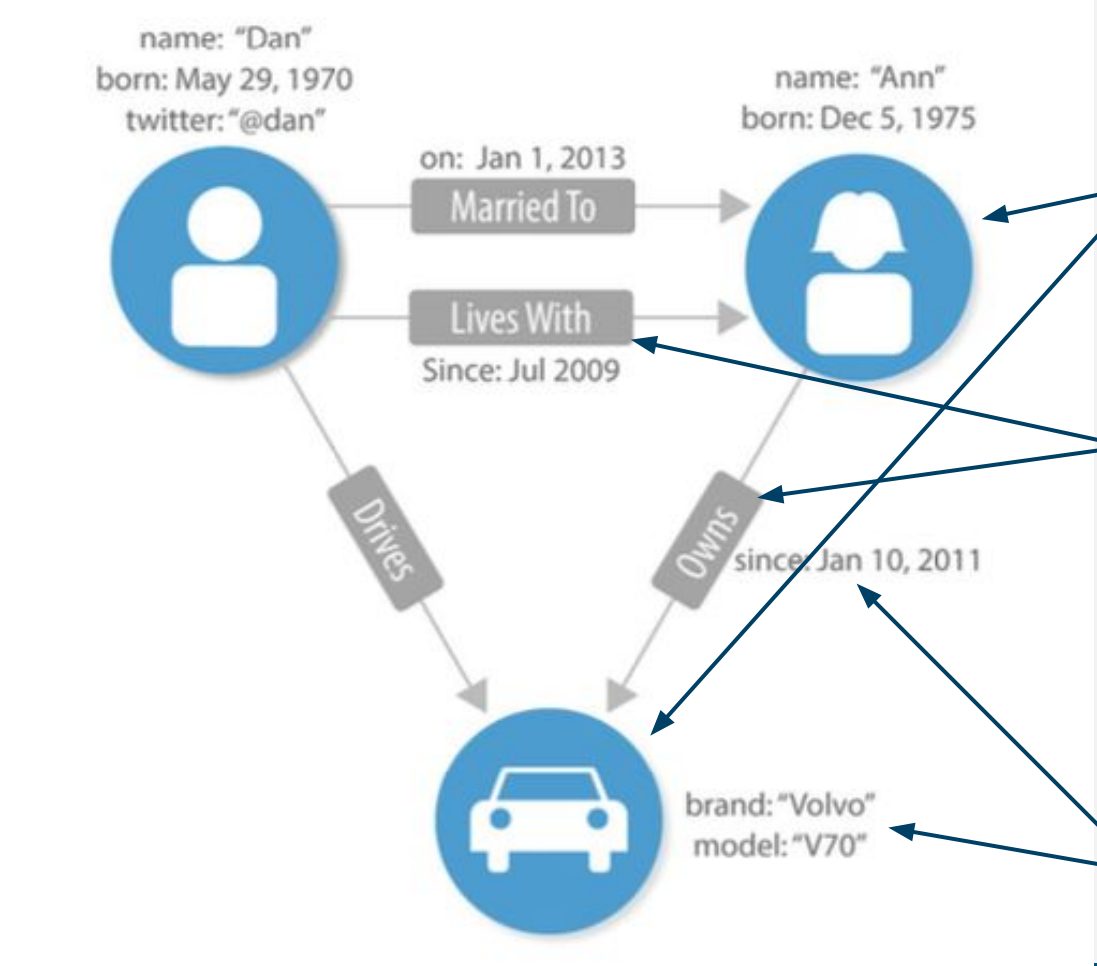
Basics of Graphs and Graph Theory

What is a graph?

Labeled Property Graph

- Composed of a set of node (vertex) objects and relationship (edge) objects
- Labels are used to mark a node as part of a group
- Properties are attributes (think KV pairs) and can exist on nodes and relationships
- Nodes with no associated relationships are OK. Edges not connected to nodes are not permitted.

Example



2 Labels:

- person
- car

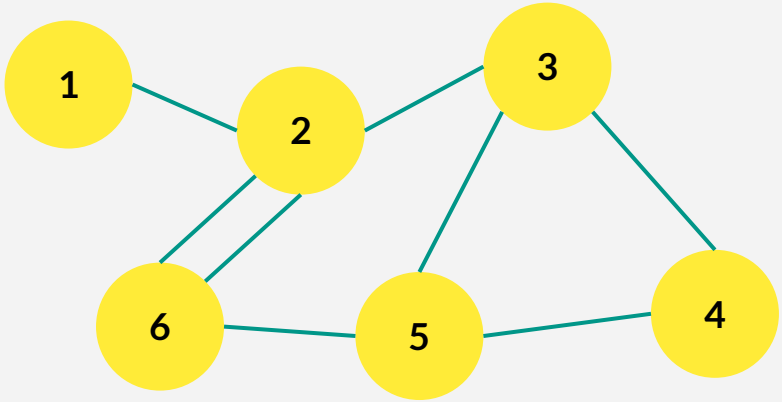
4 relationship types:

- Drives
- Owns
- Lives_with
- Married_to

Properties

Paths

A ***path*** is an ordered sequence of nodes connected by edges in which no nodes or edges are repeated.



Ex: $1 \rightarrow 2 \rightarrow 6 \rightarrow 5$

Not a path:
$1 \rightarrow 2 \rightarrow 6 \rightarrow 2 \rightarrow 3$

Flavors of Graphs

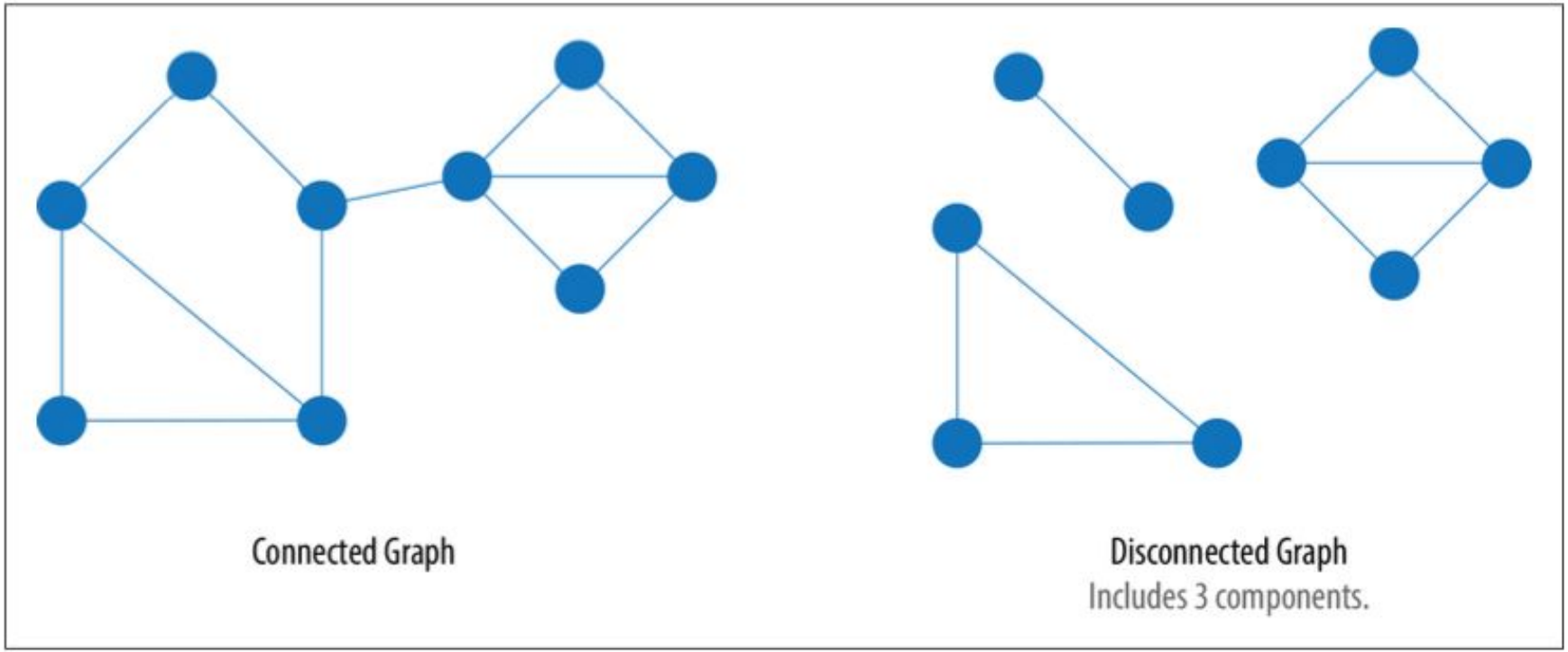
Connected (vs. Disconnected) – there is a path between any two nodes in the graph

Weighted (vs. Unweighted) – edge has a weight property (important for some algorithms)

Directed (vs. Undirected) – relationships (edges) define a start and end node

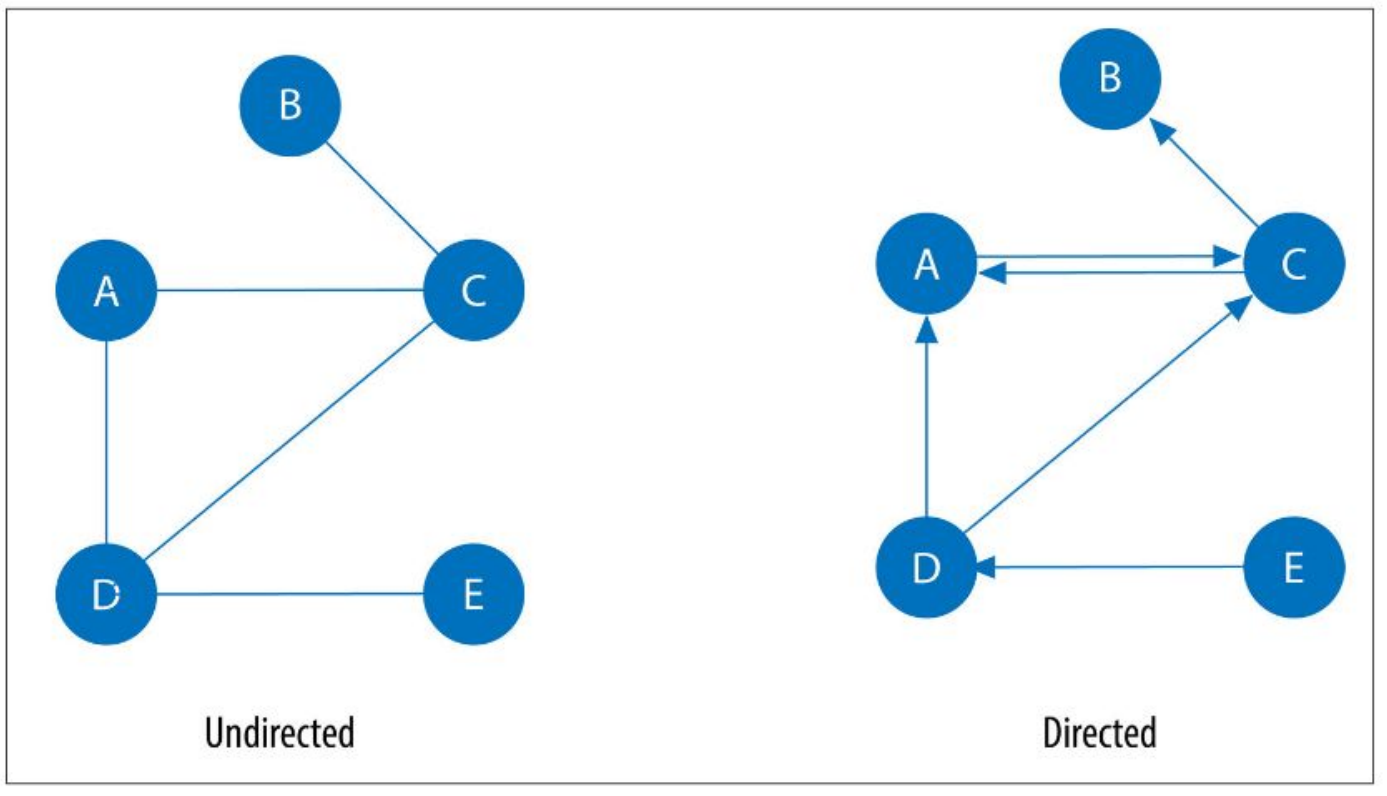
Acyclic (vs. Cyclic) – Graph contains no cycles

Connected vs. Disconnected

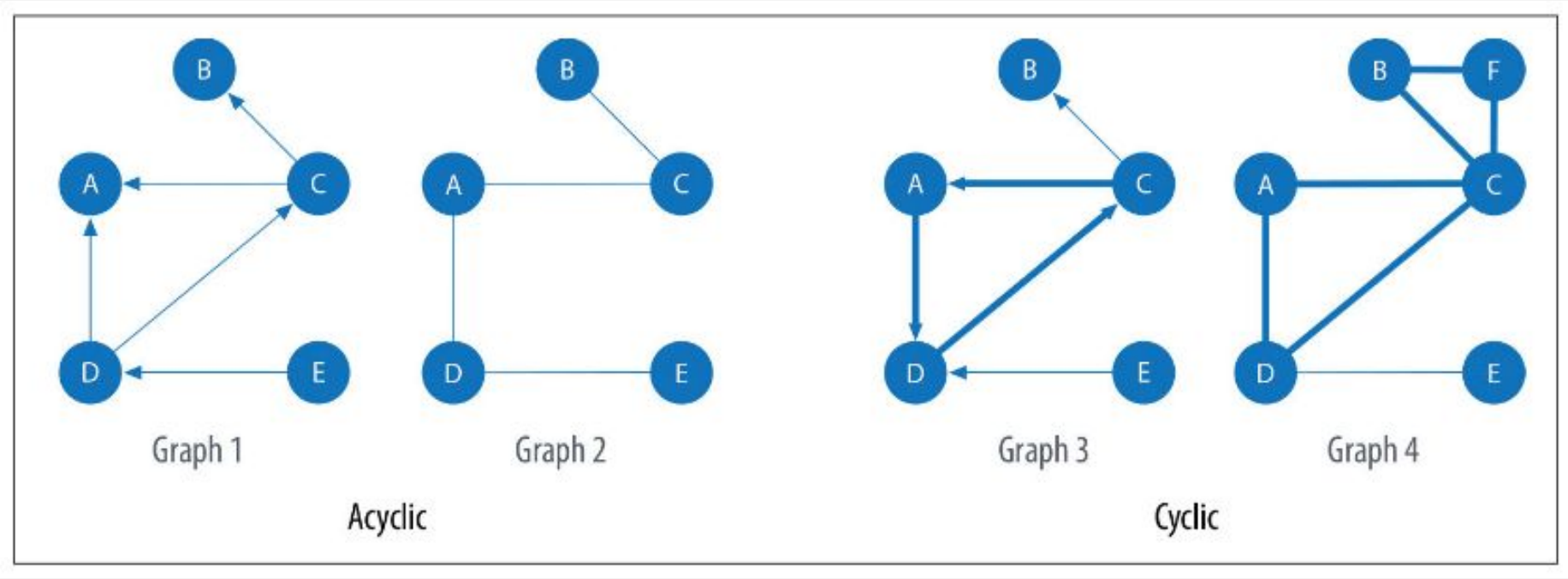


Weighted vs. Unweighted

Directed vs. Undirected

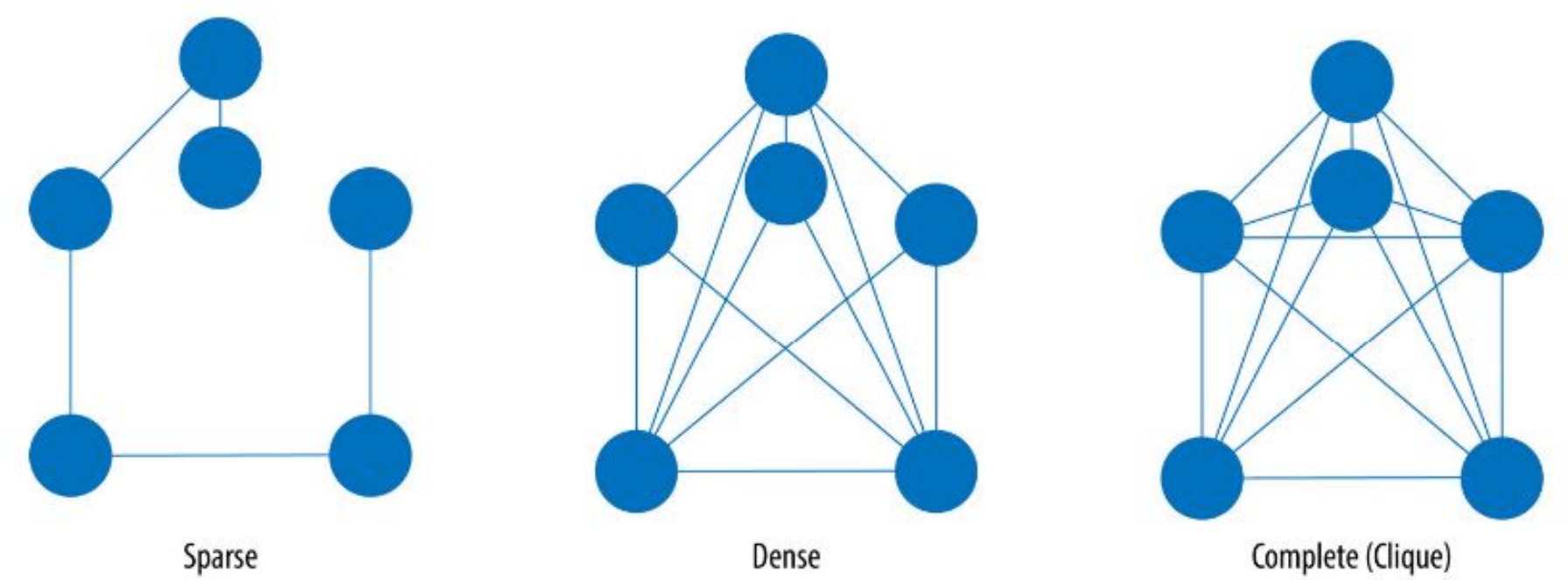


Cyclic vs Acyclic



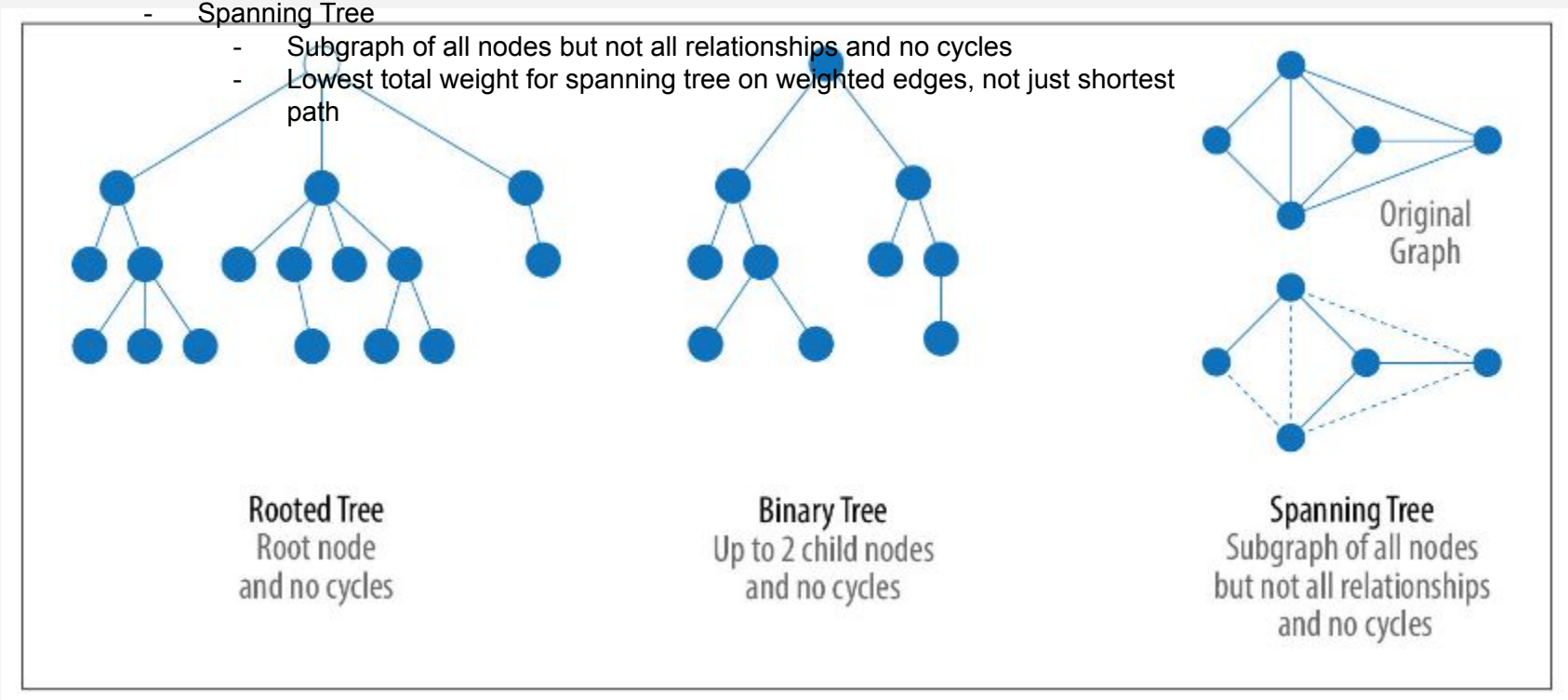
Sparse vs. Dense

Adjacency list for sparse data, matrix for dense
Undirected graphs only need half the adjacency matrix



Trees

- Rooted tree
  - Root node and no cycles
- Binary tree
  - Up to 2 child nodes and no cycles
- Spanning Tree
  - Subgraph of all nodes but not all relationships and no cycles
  - Lowest total weight for spanning tree on weighted edges, not just shortest path



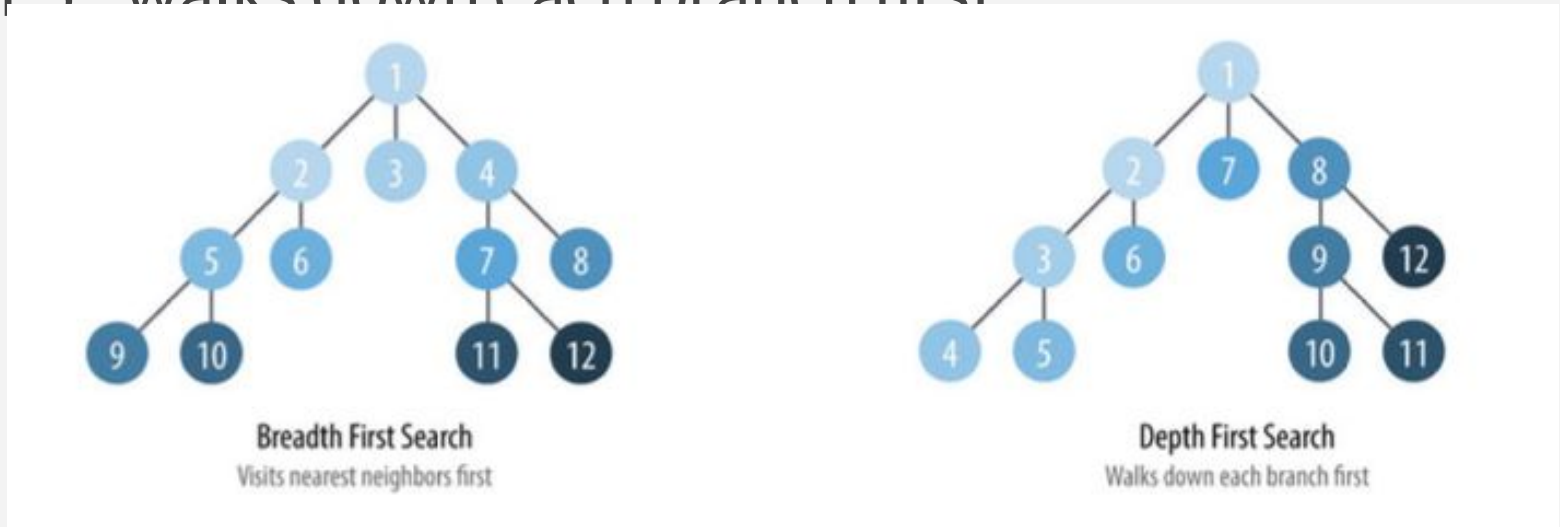
Types of Graph Algorithms - Pathfinding

- **Pathfinding**
  - finding the shortest path between two nodes, if one exists, is probably the most common operation
  - “shortest” means fewest edges or lowest weight
  - Average Shortest Path can be used to monitor efficiency and resiliency of networks.
  - Minimum spanning tree, cycle detection, max/min flow… are other types of pathfinding
  - Fewest edges for unweighted, lowest weight for weighted
  - Good for identifying resiliency and bottlenecks

BFS vs DFS

BFS - visits nearest neighbors first

DFS - walks down each branch first



Shortest Path

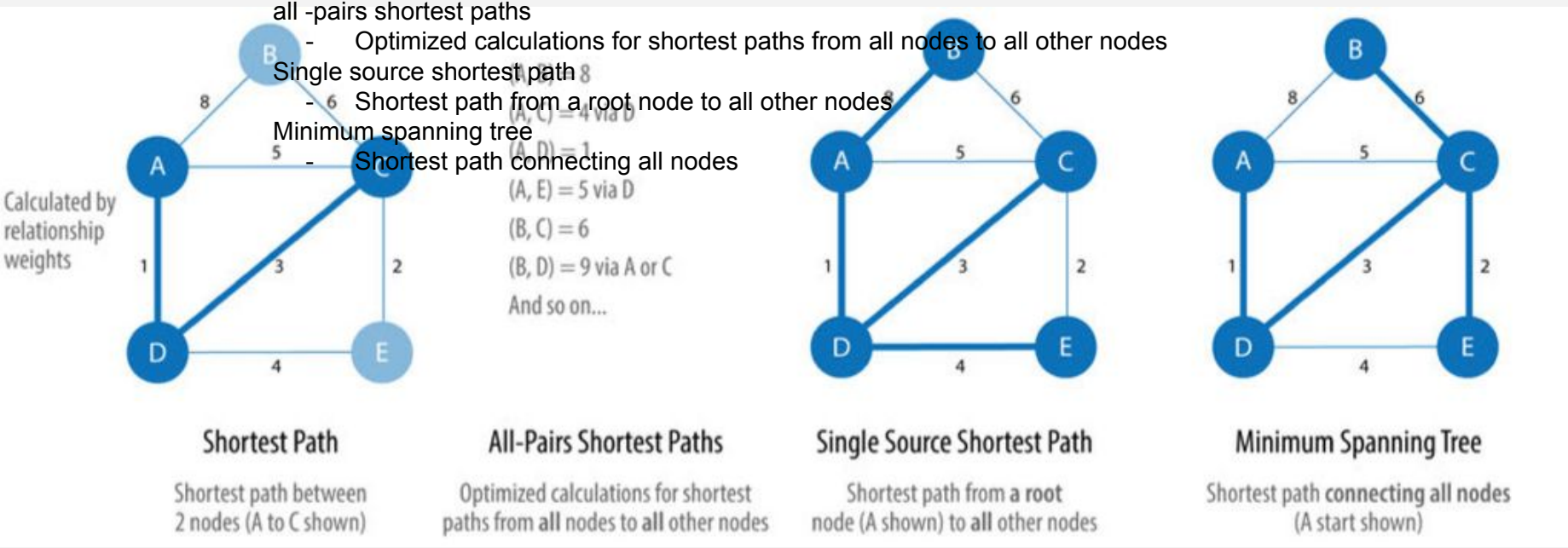
Spanning tree - sum of edge weights minimized

Shortest path
- Shortest path between 2 nodes, calculated by relationship weights

all -pairs shortest paths
- Optimized calculations for shortest paths from all nodes to all other nodes

Single source shortest path
- Shortest path from a root node to all other nodes

Minimum spanning tree
- Shortest path connecting all nodes



Types of Graph Algorithms - Centrality & Community Detection

- **Centrality**
  - determining which nodes are “more important” in a network compared to other nodes
  - EX: Social Network Influencers?
- **Community Detection**
  - evaluate clustering or partitioning of nodes of a graph and tendency to strengthen or break apart

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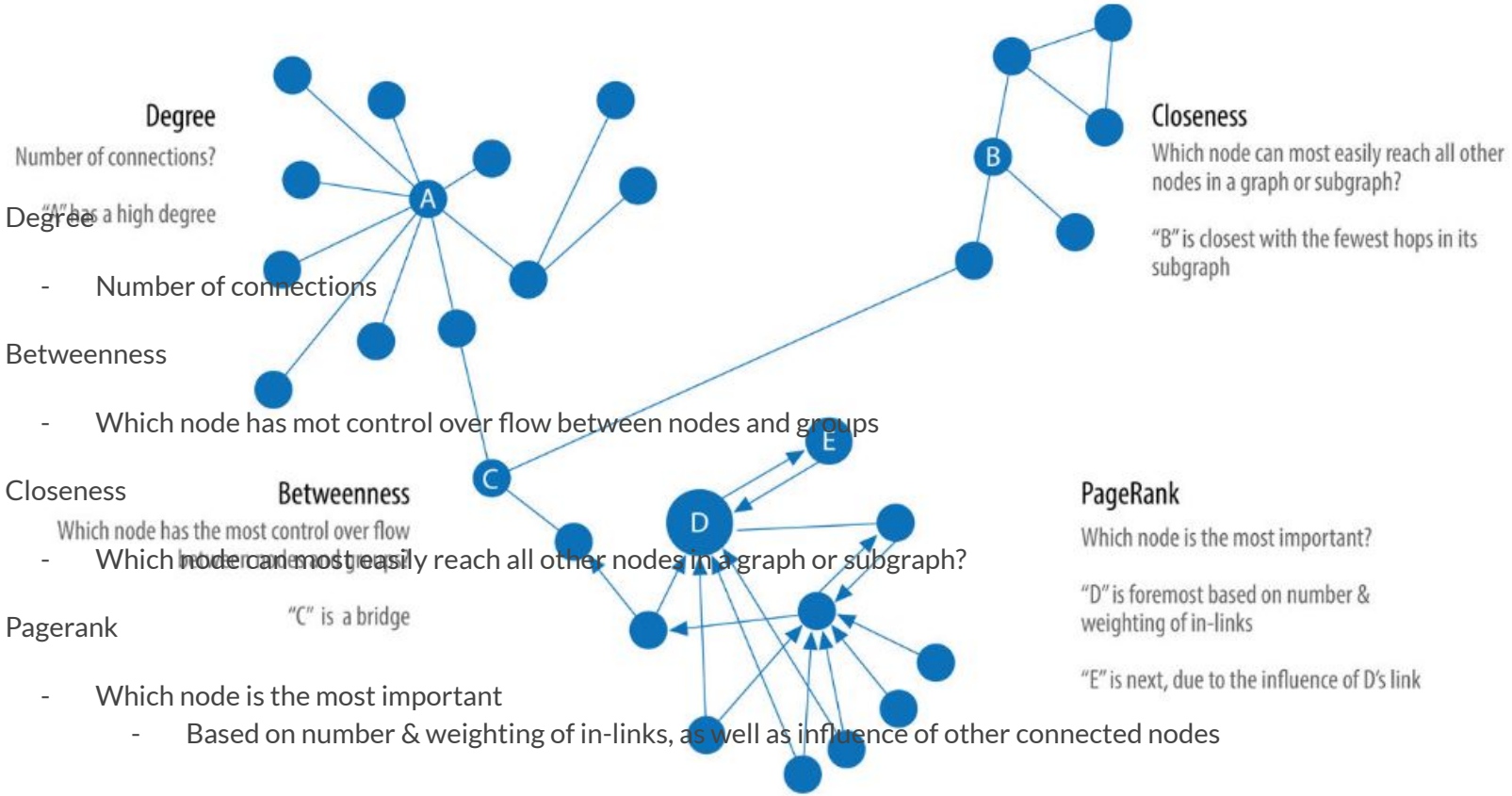

Degree

- Number of connections

Betweenness

- Which node has mot control over flow between nodes and groups

Closeness

- Which node can most easily reach all other nodes in a graph or subgraph?

Pagerank

- Which node is the most important
  - Based on number & weighting of in-links, as well as influence of other connected nodes

PageRank: SEO initially focused on how many pages pointed to the searched page (could be inflated by creating dummy websites): optimized into how many pages point to those pages (layered approach)

Some Famous Graph Algorithms

- **Dijkstra's Algorithm** - single-source shortest path algo for positively weighted graphs
- **A* Algorithm** - Similar to Dijkstra's with added feature of using a heuristic to guide traversal
- **PageRank** - measures the importance of each node within a graph based on the number of incoming relationships and the importance of the nodes from those incoming relationships

Neo4j

- A Graph Database System that supports both transactional and analytical processing of graph-based data
- Relatively new class of no-sql DBs
- Considered schema optional (one can be imposed)
- Supports various types of indexing
- ACID compliant
- Supports distributed computing
- Similar: Microsoft CosmoDB, Amazon Neptune

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