Orion: Shortest Path Estimation for Large Social Graphs

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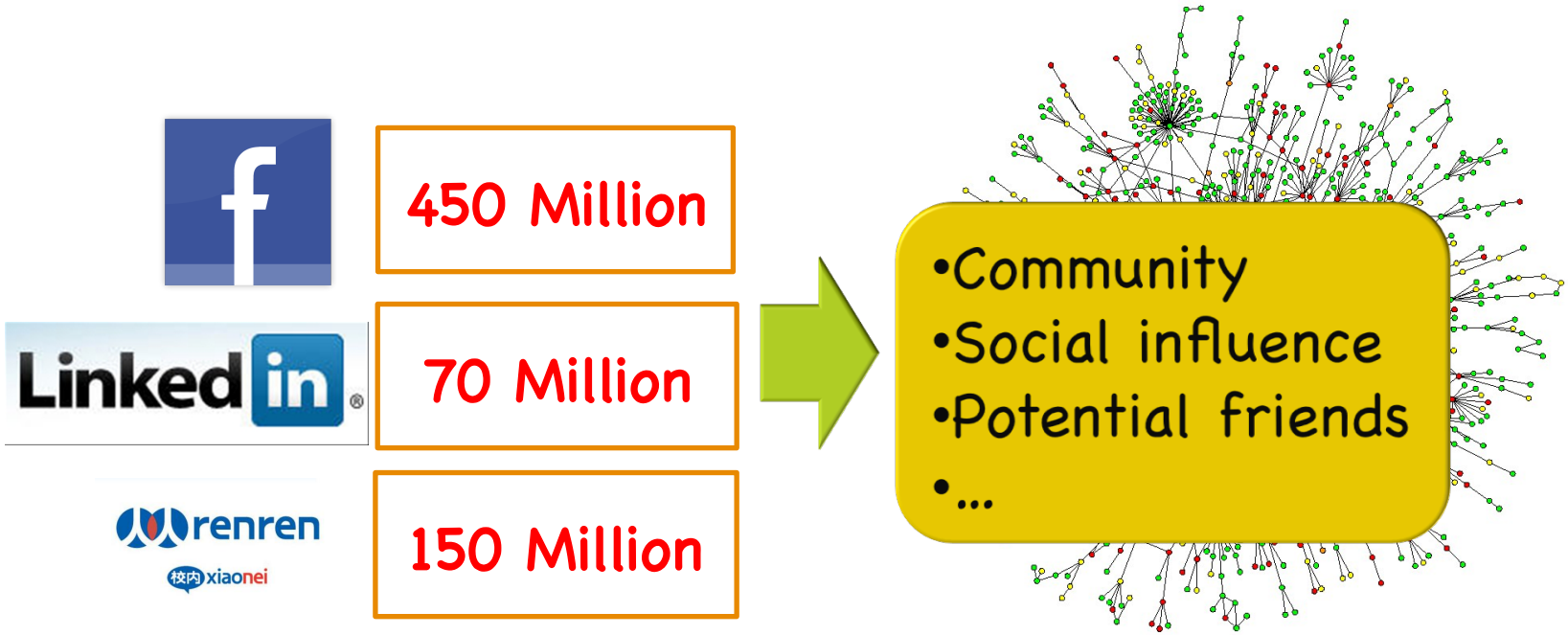
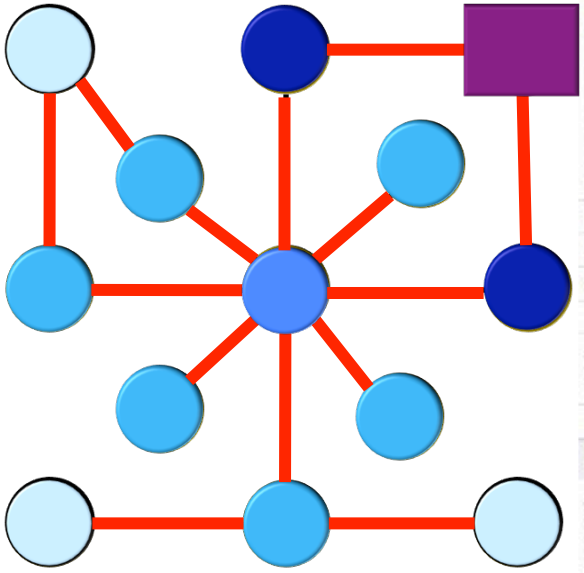
Super Large Social Graphs



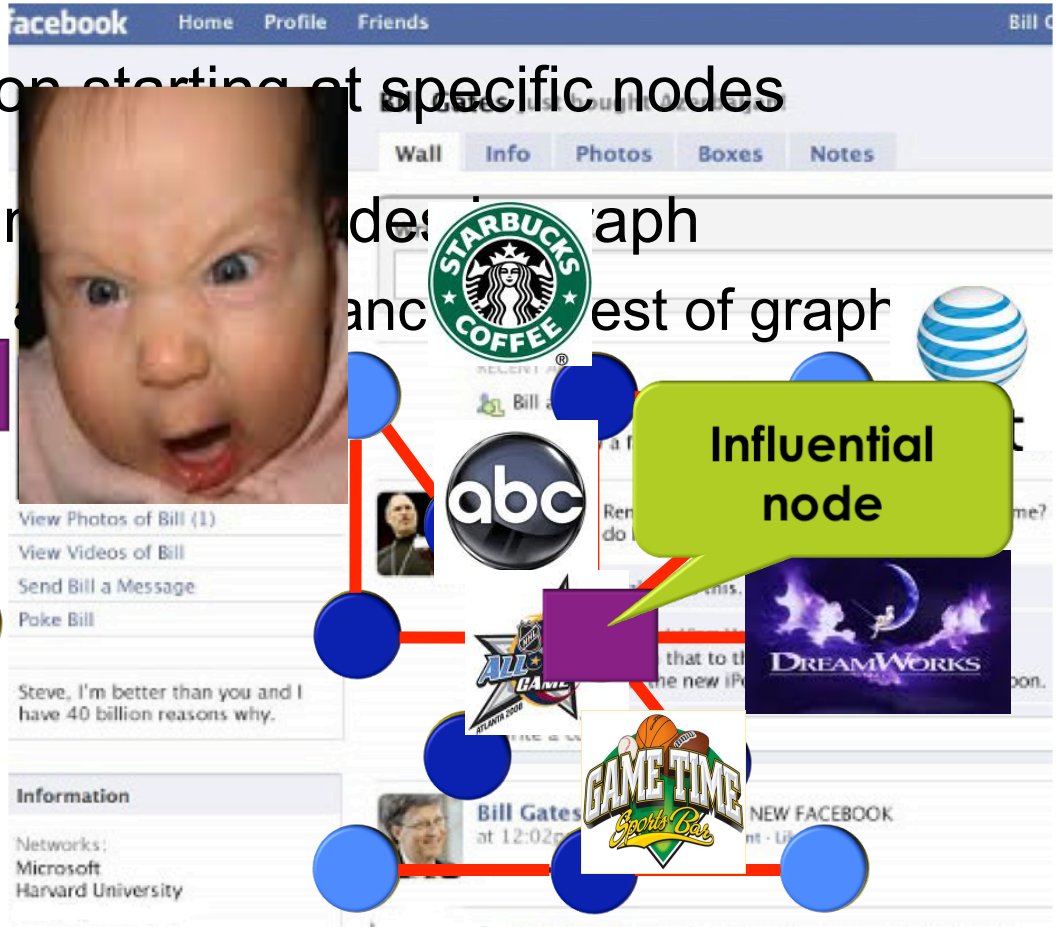
Maximizing Social Influence

- Product advertisement in OSN
  - Bill Gates "likes" Windows Mobile 7

- Propagate information starting at specific nodes
- Goal: find the most in… …des in …aph
  - Nodes with shorter … …anc… …est of graph



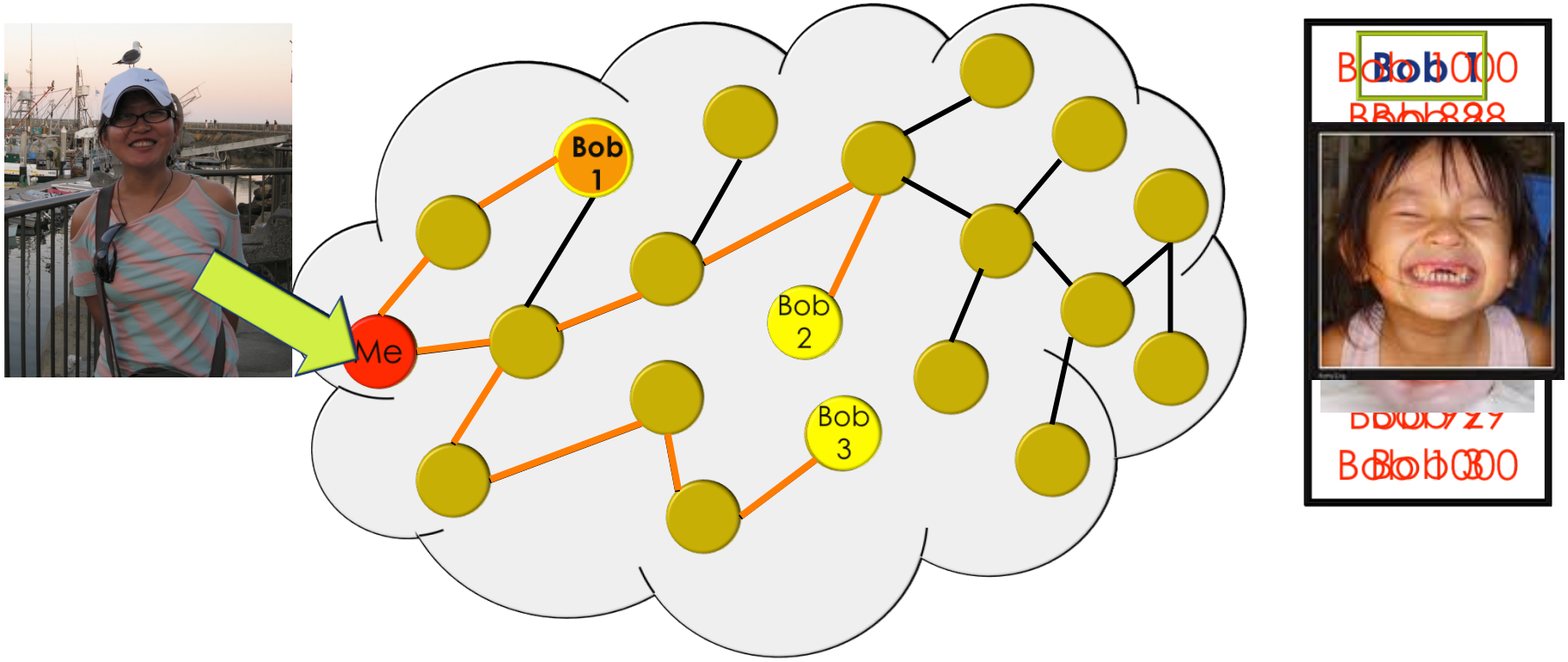
Start @ random node



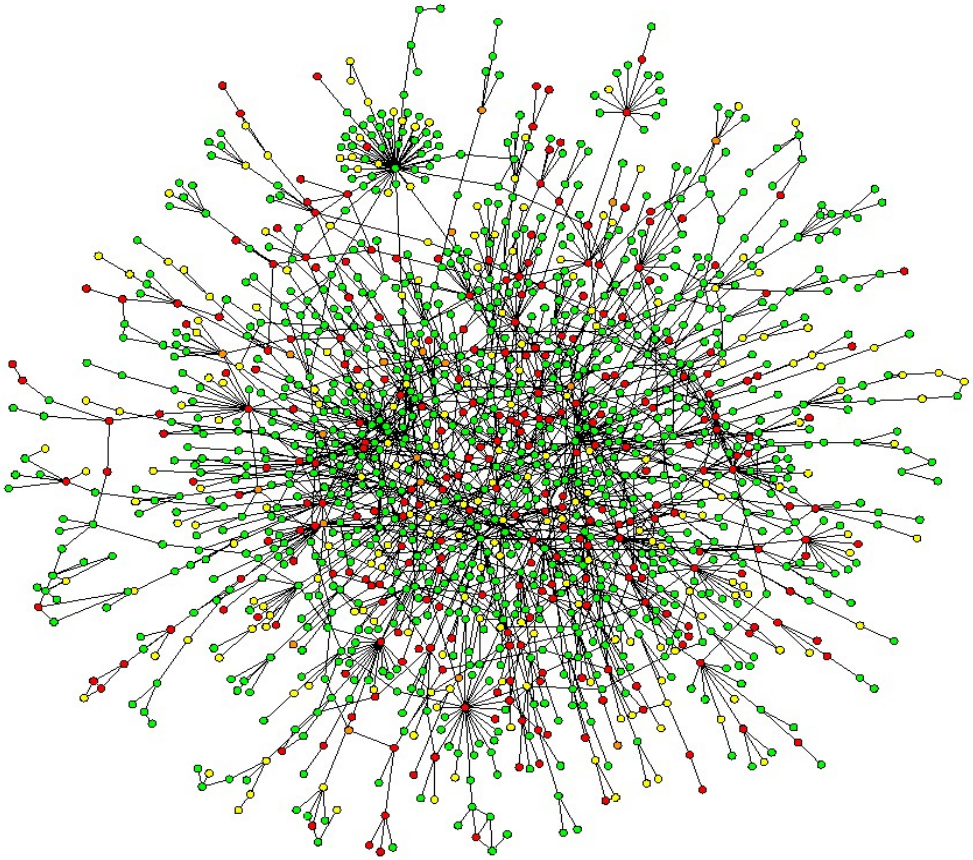
Start @ influential node

Ranked Social Search

- Search for specific friends in social network
  - Rank search results based on the social distances



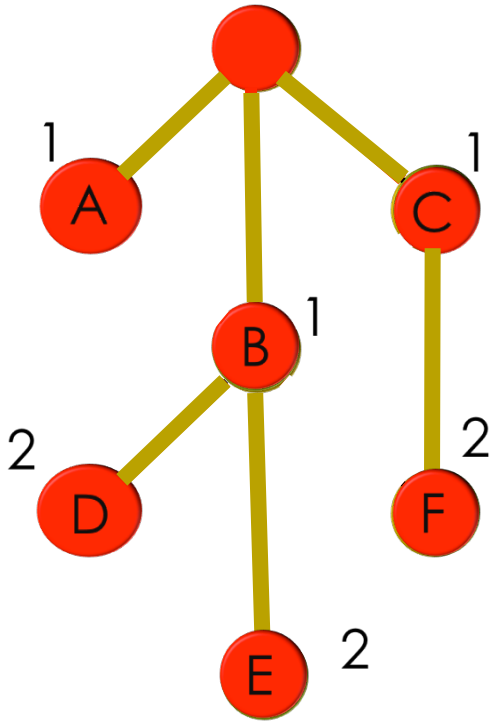
Node distance computation is hard!!



Node Distance Algorithms

For a graph with *n* nodes and *m* edges

Algorithm
Breadth-First Search (BFS)
Dijkstra
Floyd-Warshall



Problem of Node Distance Algorithms

Node distance algorithms
do not scale!

43 Million nodes

+

1 Billion edges

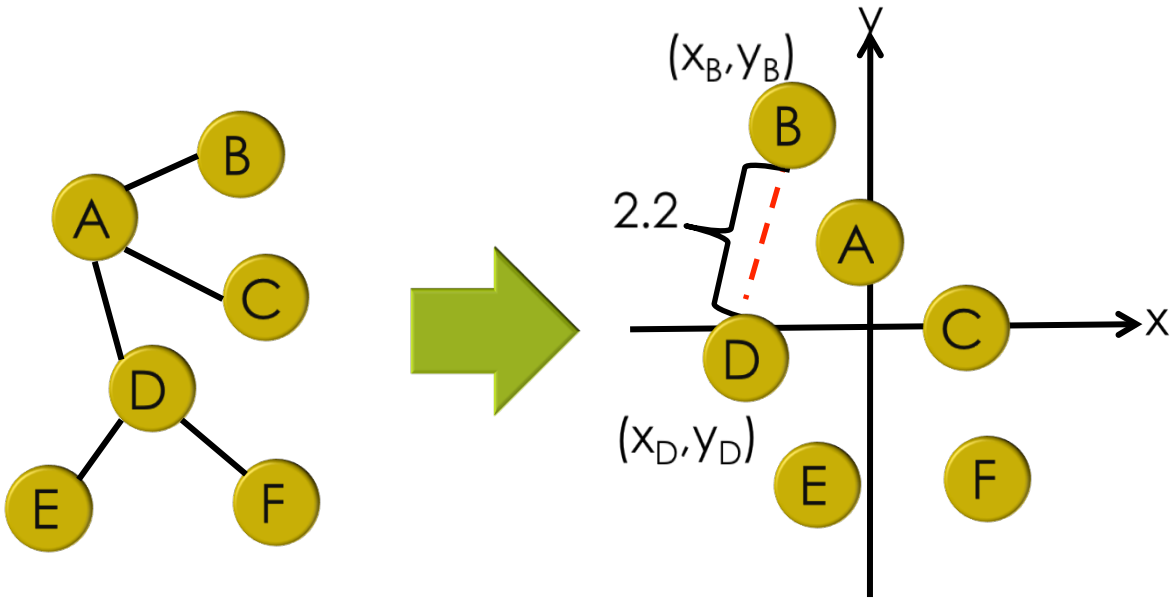
A More Scalable Solution?

- Design a scalable system for large graphs
  - Real-time queries are important
  - Desired query time: O(1)
  - Do preprocessing

- How to achieve O(1) query time?
  - Represent node distance in a graph as distance between two nodes in Euclidean Space
- Map all graph nodes into Euclidean Space
  - A Graph Coordinate System

Orion

- A Graph Coordinate System
  - **Embedding: "Capture"** node distances using Euclidean positions
  - Estimate node distances using coordinates in **constant time**



Outline

- Motivation
- Designing Orion
- Experimental Results
- Using Orion in Graph Applications
- Conclusion

Design Goals of Orion

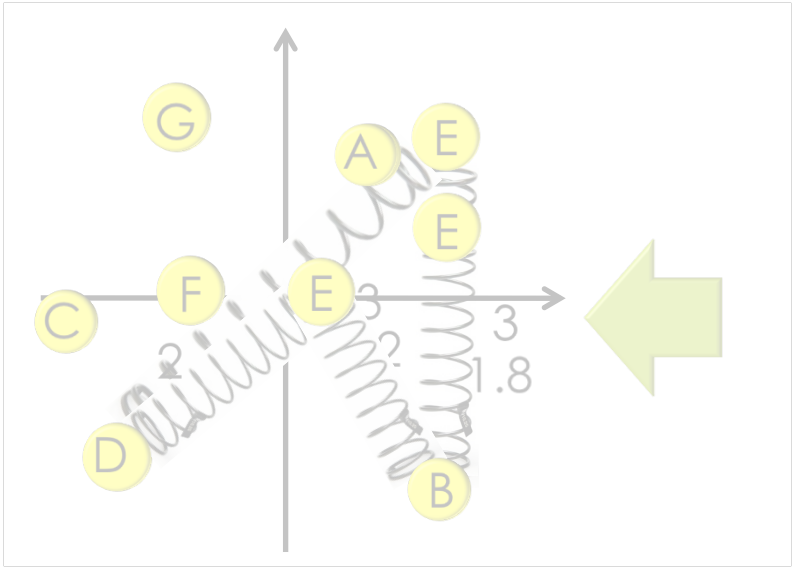
- **Scalability (preprocessing time)**
  - Preprocessing time scales linearly w/ graph size
  - Minimize number of BFS operations
- **Accuracy**
  - Distance estimates approximate ground truth
- **Fast convergence**
  - Individual node calibration should not oscillate

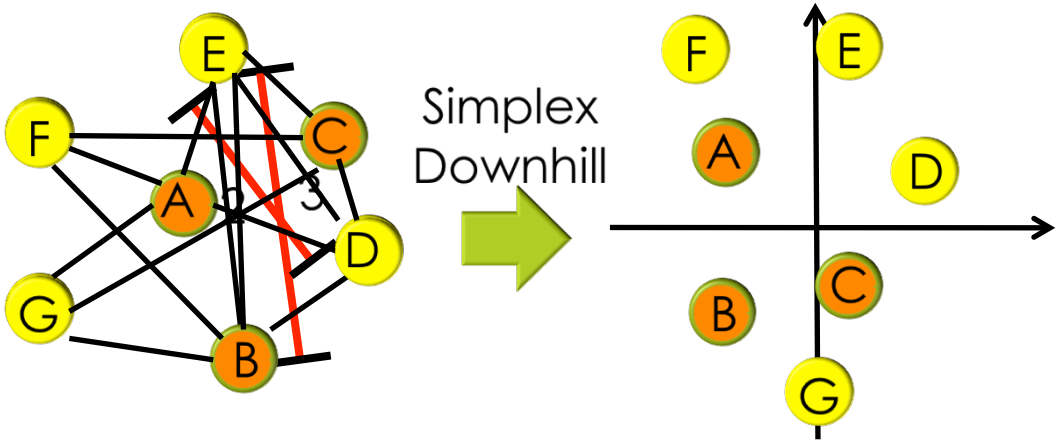
Approaches for Embedding

Our Choice

- Physical spring system
  - Each node needs to do BFS
  - Huge n
  - Multiple
  - Slow convergence
- Landmark-based approach
  - Distances to fixed number
  - onstant number of BFS
  - te once each node
  - Fast convergence

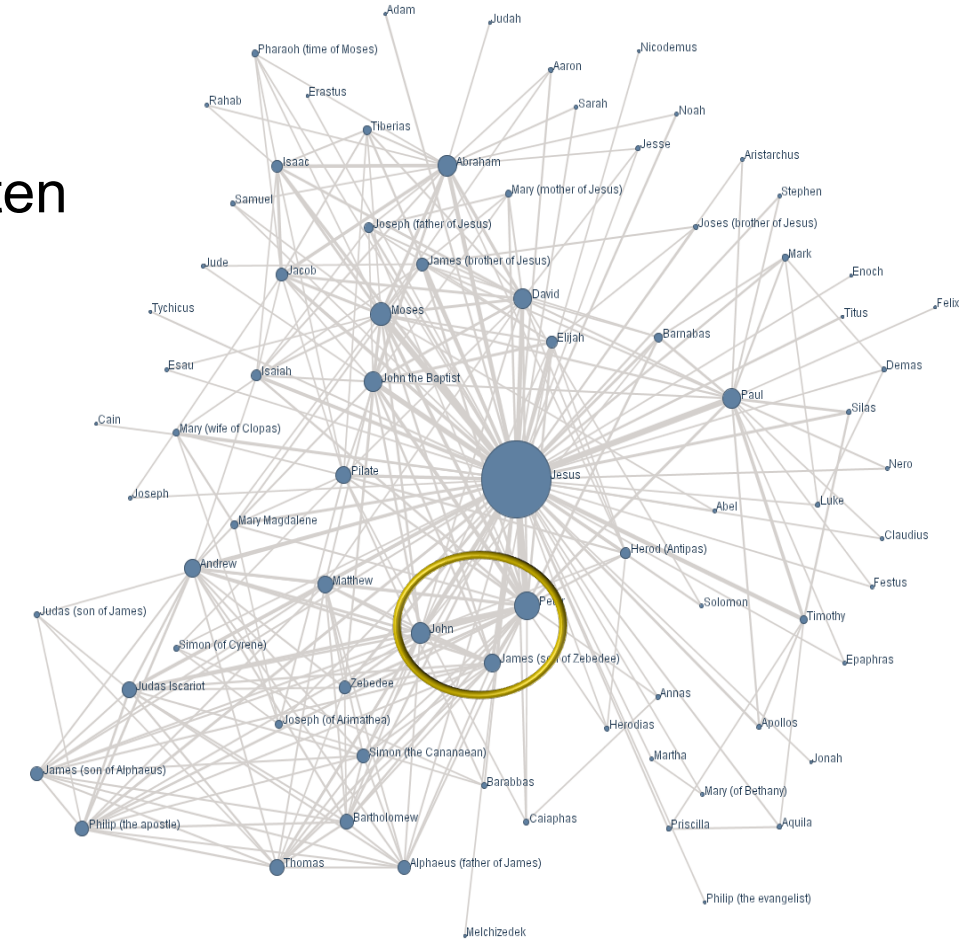
- How to select landmarks?
- How to position landmarks?





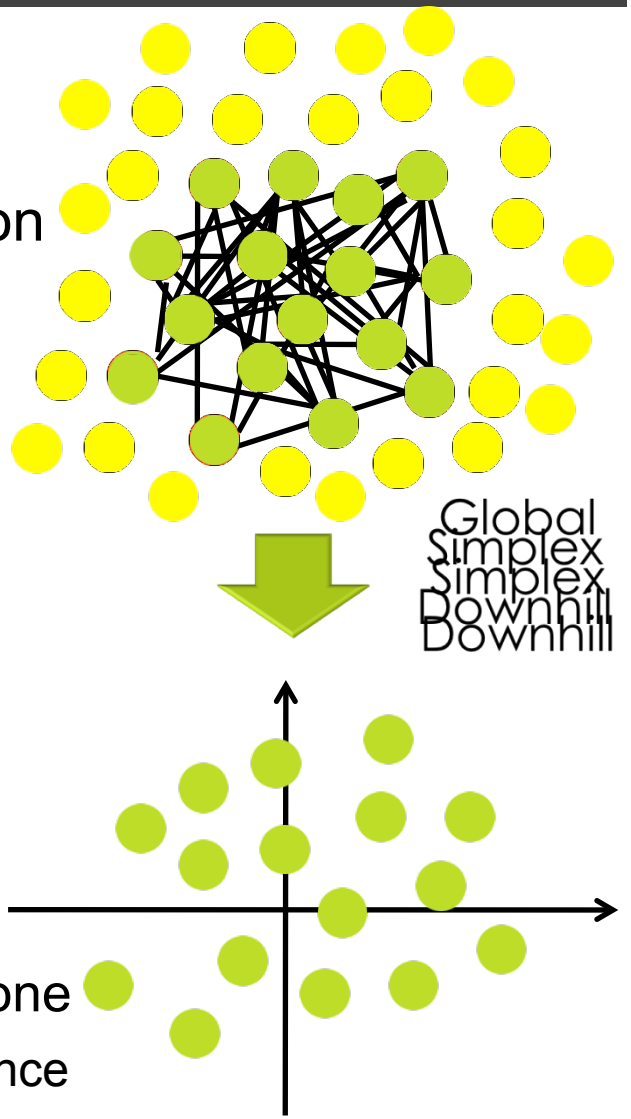
How to Select Landmarks?

- Intuition: highest degree nodes as landmarks
  - "Backbone" of social graph
- Landmark separation
  - Highest degree nodes often connected to each other
  - Need to avoid clusters of landmarks



How to Position Landmarks?

- Naïve solution: Global Simplex Downhill
  - $O(k^2D)$ for k landmarks in D-dimension space
  - However, k can be large for large graphs
- Incremental approach
  - Divide k landmarks into two groups
    - Small initial group L_k (16)
  - Two step computation
    - Initial group: global simplex downhill
    - Remaining landmarks added one by one
      - Use initial landmarks to calibrate distance



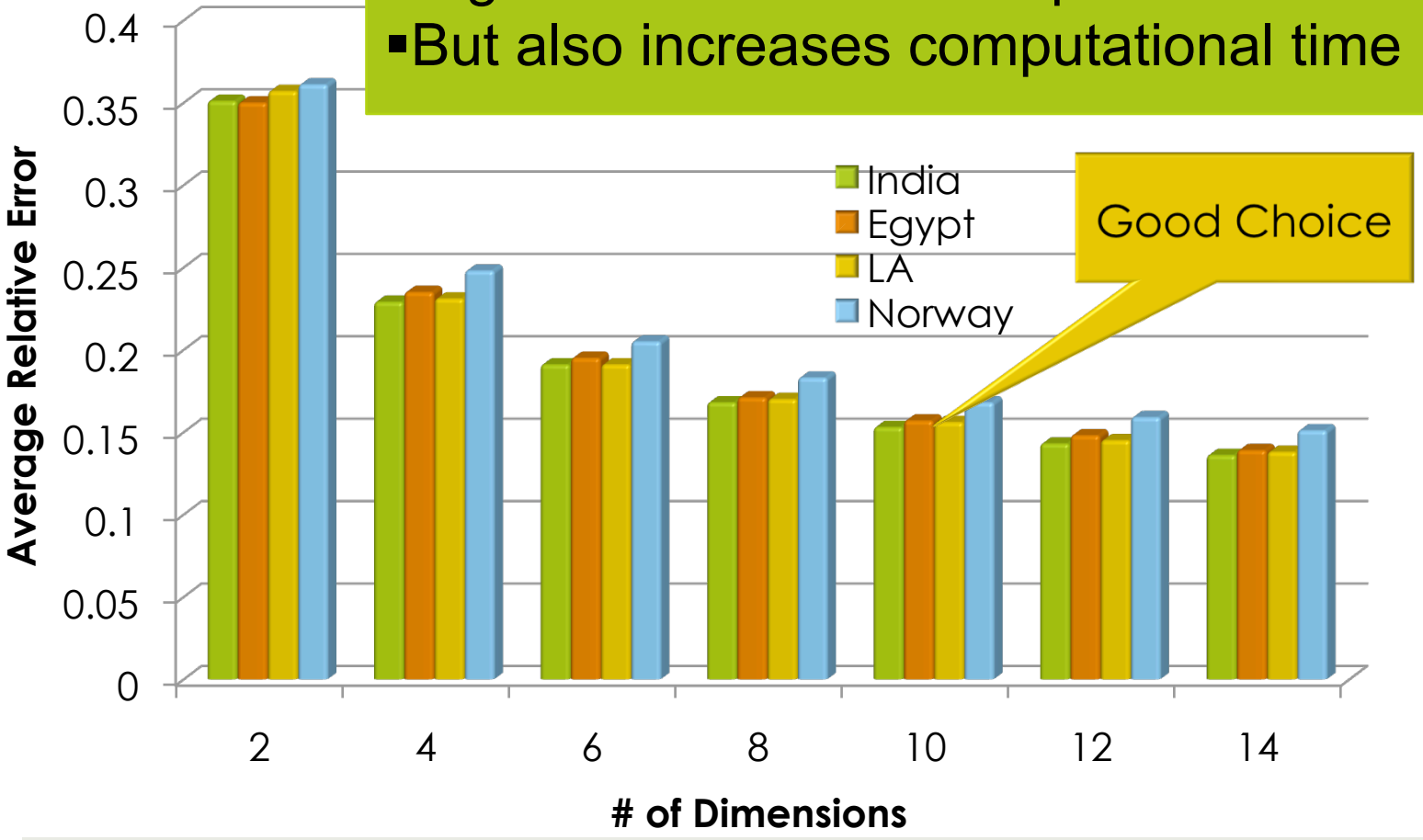
Experimental Setup

- Datasets
  - Four datasets from Facebook regional networks
- Evaluation Metrics
  - Relative Error: $E = \frac{|d^m - d^p|}{d^m}$
    - d^m: actual distance
      d^p: estimated distance computed by Orion
  - Computational Time

Network	Nodes	Edges	Avg. Path Len.
Norway	293K	5,589K	4.2
Egypt	246K	1,618K	5.0
Los Angeles	275K	2,115K	5.1
India	363K	1,556K	6.1

Dimensionality of Coordinates

- Error **< 0.2** when dimension > 6
- Higher dimensions → improved accuracy
- But also increases computational time



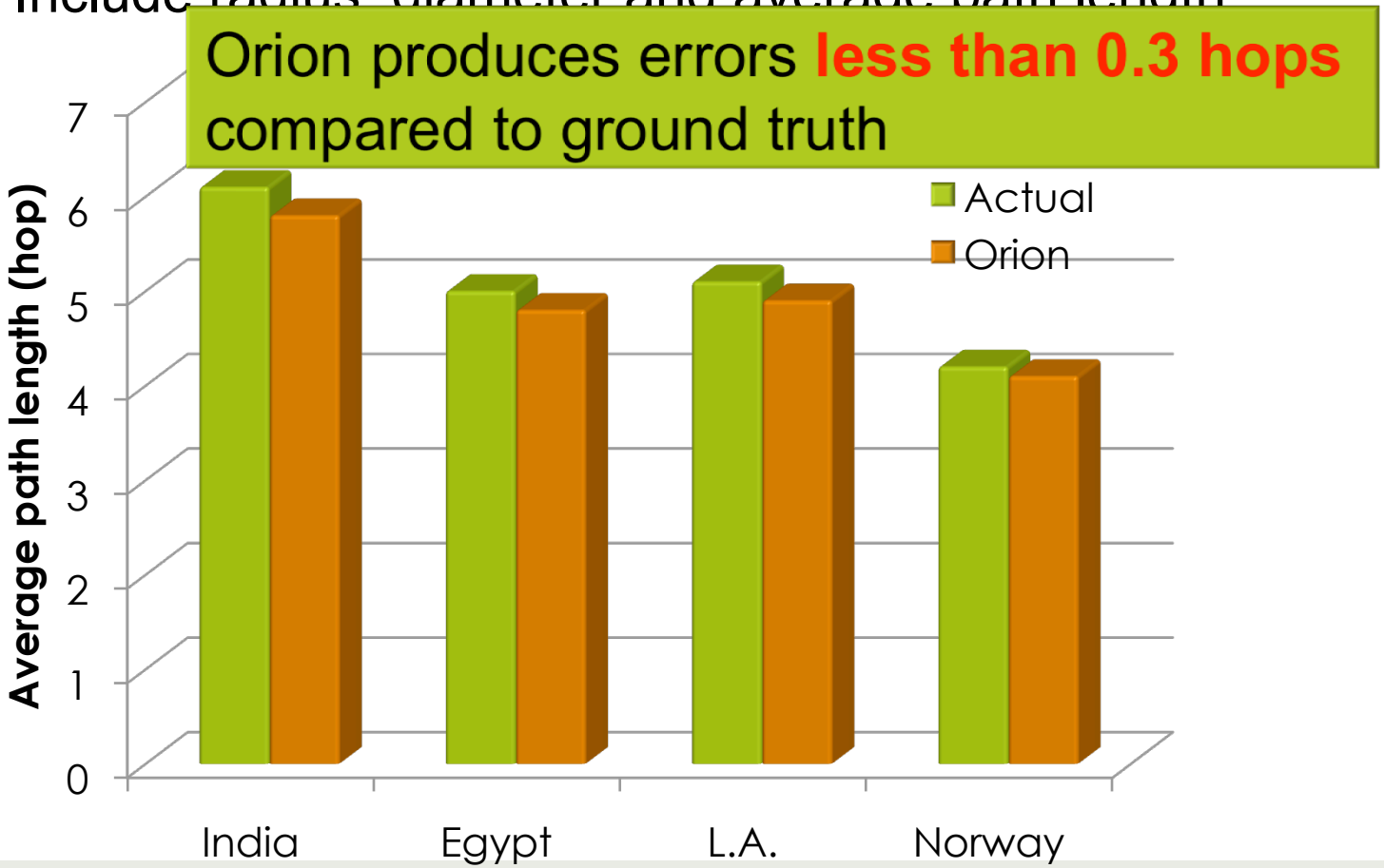
Computational Time

Time	India	Egypt	L.A.	Norway
Orion Preprocessing	9493s	6156s	6967s	7506s
Orion Response	0.0000002s	0.00000002s	0.00000018s	0.00000019s
BFS Response	1.028s	0.75s	1.027s	1.44s

- Orion Preprocessing: to compute coordinates for all nodes
  - One-time cost
  - 2 hours for 300K node graph on 1 cheap commodity server
  - Time scales linearly with graph size
    - Easily parallelized across clusters
- Average time per node-distance query
  - Orion is 7 orders of magnitude faster than BFS

Application: Node Separation Metrics

- Node separation metrics
  - Common tool to analyze graphs
  - Include radius, diameter and average path length



Conclusion

- We propose **Orion**, a scalable graph coordinate system for node distance computation
- Time complexity is low
  - Preprocessing: 2 hours for a 300K node graph
    - Can be parallelized across machine clusters
  - Query Response: 0.2μs to estimate node distances for per query
- Orion can accurately support node-distance based applications

Future / Ongoing Work

- Dynamics in social graphs
  - Investigate the impact of graph dynamics on node distances
  - Use heuristics to incrementally update graph embeddings at run time
- Weighted graphs
  - Examine the use of graph coordinate systems on applications on weighted graphs

Thank You. Questions?