My recent work in Theoretical Computer Science and Discrete Mathematics

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About Me

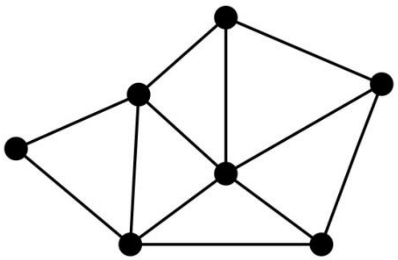
- By Training
  - Applied Mathematician & Theoretical Computer Scientist
- I do not work in any particular application area
  - My research is on developing general mathematical and algorithmic tools
  - Also, solving discrete mathematical problems that arise out of computer science

Some Topics

- Graph Algorithms
- Data Structures
- Probabilistic Geometry (if time)
- General tools for Improving Dynamic Programming
- Information Theory (Source Coding)
- ….

Graph Algorithms

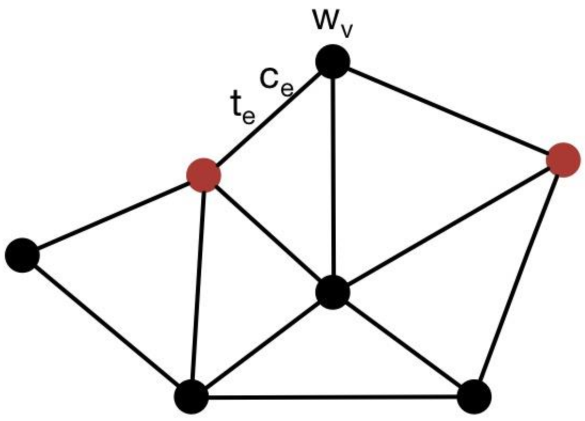
- Graphs model many types of relationships



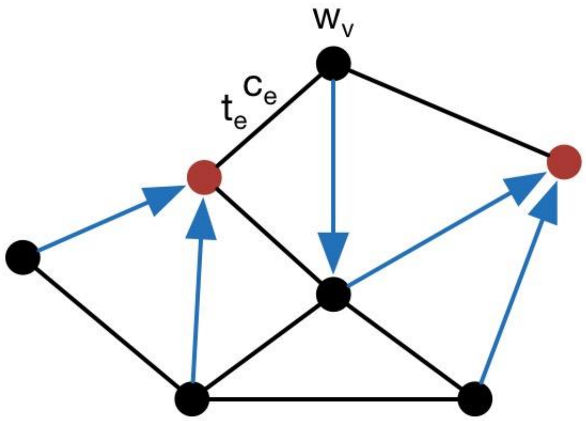
- Many "real" problems can be recast as graph problems and "solved" via graph algorithms
  - Problems in many different areas can be solved using the same graph algorithm, which does not "know" about the original problem settings
  - *Unreasonable effectiveness of Mathematics (E. Wigner)*
- My current graph work is in constructing *evacuation protocols*

Evacuation Protocols

- How quickly can people be evacuated from building in case of emergency?
  Model as dynamic flow graph
- Vertices **v = rooms**
  - Some are specified as exits (sinks)
  - Know **w_v = # of people in each v**
- Edges **e = hallways** with associated
  - **t_e = time to travel edge e**
  - **c_e = # people that can enter e each minute**



- If too many people are at vertex they need to wait to enter edge. This causes congestion and slows down evacuation.
- Want to place sign in each room v pointing "this way out"
  => Everybody in or arriving at v must leave by same edge.



- Problem is to choose evacuation edges that minimize evacuation time.
- More advanced version is to figure out placement of evacuation doors.

- Problem is NP-Hard in general.
- Research is on special graphs and approximation algorithms

Data Structures

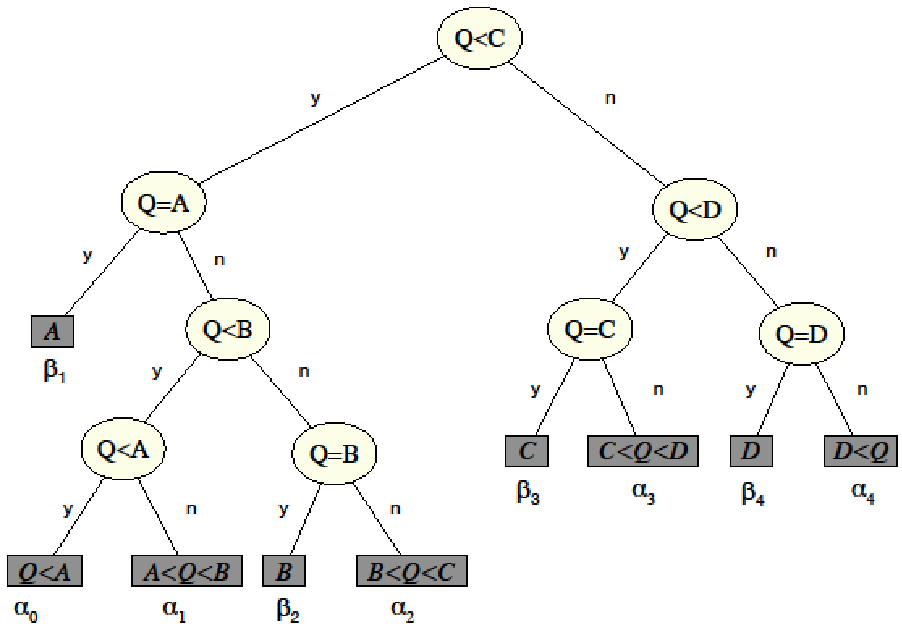
- How data is stored in a computer has profound impact on the efficiency of computing procedures

- The field of Data Structures constructs structures that are useful/efficient for different applications
  - *"useful/efficient" depends upon platform. What is workable for a desktop computer might not be appropriate in a small sensor node (that has limited memory, processing power and energy)*

- Currently working on constructing efficient search trees (old topic that keeps coming back)

Optimal Binary Comparison Trees

- <u>Problem:</u> Given set of search keys and empirical probabilities α, β of search succeeding or failing, construct a min-cost comparison (=, <) search tree. *Cost of tree is average time to search for query Q.*



- 40 year old open problem to find polynomial time construction algorithm. Currently have an O(n^4) one.

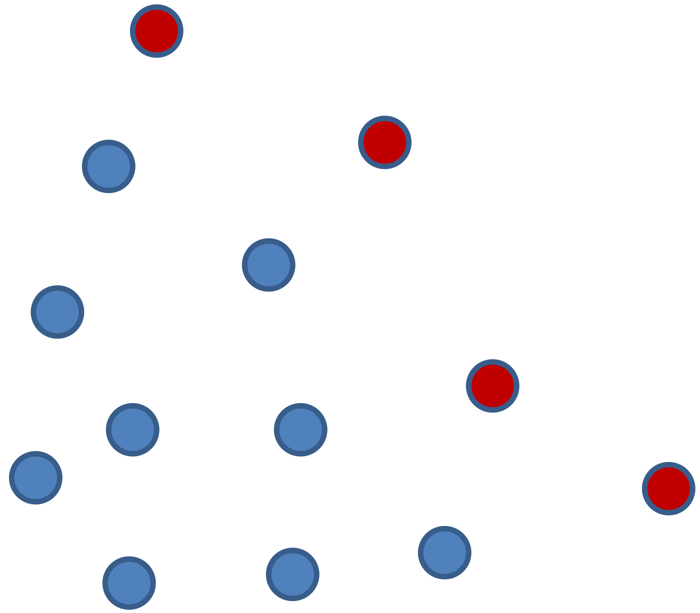
- O(n^4) is not particularly useful. Also have an O(n) time approximation algorithm that constructs tree with *almost min-cost* average query time

Probabilistic Geometry

- Analyzing properties of random points
  - Leads to better understanding of empirical running times of many (output dependent) algorithms
- Used in many application areas, e.g., ad-hoc networks, data base queries, auction theory, ….
- Currently working on maximal points

Maximal Points

- Points in a set are **maximal** if there is no other point in set that is bigger in all dimensions. (Diagram is 2D but idea extends and is useful in all dimensions).



- In data retrieval, maximal points known as *skyline queries*; in game theory, as *pareto optimums*.

- Problem is to study average # of maximal points occurring in a set of n random points

- Interesting because many algorithms are output dependent. Knowing average # permits calculating average run time of maxima finding algorithm (original analysis of skyline queries)

- Difficulty is that average # was only known for particular point distributions which might not model reality.
  My current research includes analyzing this # (and related values such as size of convex hull) for a much larger set of distributions

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