http://www.cs.unh.edu/~ruml/cs758
Coping with NP-Completeness

- find tractable special case
- run only on small inputs
- heuristic optimal algorithm that’s usually fast
- heuristic non-optimal algorithm that’s always fast
  - if bounded suboptimality: ‘approximation algorithm’
Approximation
\( \rho(n) \)-approximation iff cost \( C \) for optimal cost \( C^* \) is bounded as 
\[
\max\left( \frac{C}{C^*}, \frac{C^*}{C} \right) \leq \rho(n)
\]

*polynomial-time approximation scheme* (PTAS) if, given \( \epsilon \) as an input parameter, algorithm is a \((1 + \epsilon)\)-approximation algorithm and polynomial time in input size \( n \)

*fully-polynomial-time approximation scheme* (FPTAS) if running time is polynomial in \( n \) and \( 1/\epsilon \)
want to cover all edges using fewest number of vertices
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1. $C \leftarrow \emptyset, E' \leftarrow E$
2. while $E'$ is not empty
3. pick arbitrary edge $(u, v)$ from $E'$
4. add $u$ and $v$ to $C$
5. remove any other edges that touch $u$ or $v$ from $E'$
6. return $C$

clearly a cover and polytime. quality vs optimal?
Proof of 2-Approximation

For each \((u, v)\) edge picked, we choose both vertices. No subsequent edge we pick will be adjacent to these vertices. The optimal solution must contain at least one vertex from every edge we pick.

In other words, \(|C| = 2|\text{picked}|\) and \(|\text{picked}| \leq |C^*|\).

So \(|C| \leq 2|C^*|\).
Cheapest tour (Hamiltonian cycle) over all vertices. Distances satisfy the triangle inequality: \[ c(u, w) \leq c(u, v) + c(v, w). \]
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1. compute minimum spanning tree
2. construct tour by preorder walk of tree

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Proof of 2-Approximation:

1. cost of MST \( \leq \) optimal because deleting edge from an optimal tour is a spanning tree
2. if tour really followed edges of MST, would traverse each edge twice, ie, be twice the cost of MST
3. some edges are short-cuts over previously-visited vertices and hence shorter (by triangle inequality)
4. solution \( \leq \) twice MST \( \leq \) twice optimal
Coping with NPC Approximation
Approximation
Vertex Cover
Proof
Metric TSP

- asst 13
- asst 14
- exam review: Fri Dec 7
- final exam: Wed Dec 12, 3:30-5:30pm, N101
Non-approximability
Cheapest tour (Hamiltonian cycle) over all vertices. Distances can be anything.

If $P \neq NP$, no polytime $\rho$-approximation algorithm exists for TSP.
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Show via reduction from Hamiltonian cycle, ie, given $\rho$-approx alg for TSP, we could decide Hamiltonian cycle.

1. Given $G$, construct complete graph $G'$ for TSP using edges of cost 1 for edges in $E$ and cost $\rho|V| + 1$ for all others.
2. If graph contains Hamiltonian cycle, optimal tour has length $|V|$.
3. Any other tour has cost $\geq |V| - 1 + \rho|V| + 1 = |V| + \rho|V|$.
4. Approx alg must return Hamiltonian cycle if it exists. Therefore we can decide Hamiltonian cycle.
maximize the number of satisfied clauses

2-approximation:
maximize the number of satisfied clauses

2-approximation: all true or all false!

8/7-approximation:
maximize the number of satisfied clauses

2-approximation: all true or all false!

8/7-approximation: set each variable randomly! (either expected, or guaranteed with expected poly time)

The PCP theorem implies that there exists an \( \epsilon > 0 \) such that \((1 + \epsilon)\)-approximation of MAX-3SAT is NP-hard.
For example:

- What’s still confusing?
- What question didn’t you get to ask today?
- What would you like to hear more about?

Please write down your most pressing question about algorithms and put it in the box on your way out.

*Thanks!*