Economics and Computation

CPSC 455/555 // Econ 425/563, Fall 2011

Time: Tu & Th, 2:30-3:45 pm

Room: AKW 200

http://zoo.cs.yale.edu/classes/cs455/fall11/

(Approximate) Topic Outline

- Routing and network formation
- Sponsored search
- Combinatorial auctions
- P2P systems
- Reputation management
- Information markets

Textbook

Algorithmic Game Theory, eds: N. Nisan, T. Roughgarden, E. Tardos, and V. Vazirani, Cambridge Univ. Press, 2007

available in the Yale bookstore

Schedule

Sept. 20: First HW Assignment Due
Oct. 11: Second HW Assignment Due
Oct. 13: First Exam (in class)
Oct. 21: Fall Semester Drop Date
Oct. 27: Third HW Assignment Due
Nov. 17: Fourth HW Assignment Due
Nov. 19 - 27: Thanksgiving Break
Nov. 29: Fifth HW Assignment Due
Dec. 1: Second Exam (in class)

Requirements

- Reading assignments
- 5 Written HW Assignments, each worth 10% of the course grade
- 2 In-Class Exams, each worth 25% of the course grade
- <u>No</u> final exam during exam week

Rules and Guidelines

- Deadlines are firm.
- Late penalty: 5% per day.
- Announcements and assignments will be posted on the class webpage (as well as conveyed in class).
- No "collaboration" on homeworks unless you are told otherwise.
- Pick up your graded homeworks and exams promptly, and tell the TA promptly if one is missing.

Instructor: Joan Feigenbaum

Office: AKW 512

Office Hours: Thursdays 11:30 am - 12:30 pm
and by appointment

Phone: 203-432-6432

Assistant: Judi Paige
(judi.paige@yale.edu, 203-436-1267,
AKW 507a, 8:30 am – 4:30 pm M-F)

Note: Do not send email to Professor Feigenbaum, who suffers from RSI. Contact her through Ms. Paige or the TA.

TA: David Costanzo

Office: AKW 301

Office Hours: Weds, 2:30 - 3:30 pm
and by appointment

Email: David.Costanzo@yale.edu

If you're undecided, check out:

- J. Feigenbaum, D. Parkes, and D. Pennock, "Computational Challenges in Electronic Commerce," *Communications of the ACM*, 52(1), 2009, pp. 70-74.

- H. Varian, "Designing the Perfect Auction," *Communications of the ACM*, 51(8), 2008, pp. 9-11.

- Textbook, chapter 9
  (introduction to "mechanism design," for computer scientists)

- Textbook, chapter 14
  (incentive issues in distributed computation, particularly interdomain routing in the Internet)

Questions?

Two Views of Multi-agent Systems

CS

Focus is on
Computational &
Communication
Efficiency

Agents are
Correct,
Faulty, or
Adversarial

ECON

Focus is on
Incentives

Agents are
Strategic

Internet Computation

- Both incentives and computational and communication efficiency matter.

- "Ownership, operation, and use by numerous independent self-interested parties give the Internet the characteristics of an economy as well as those of a computer."

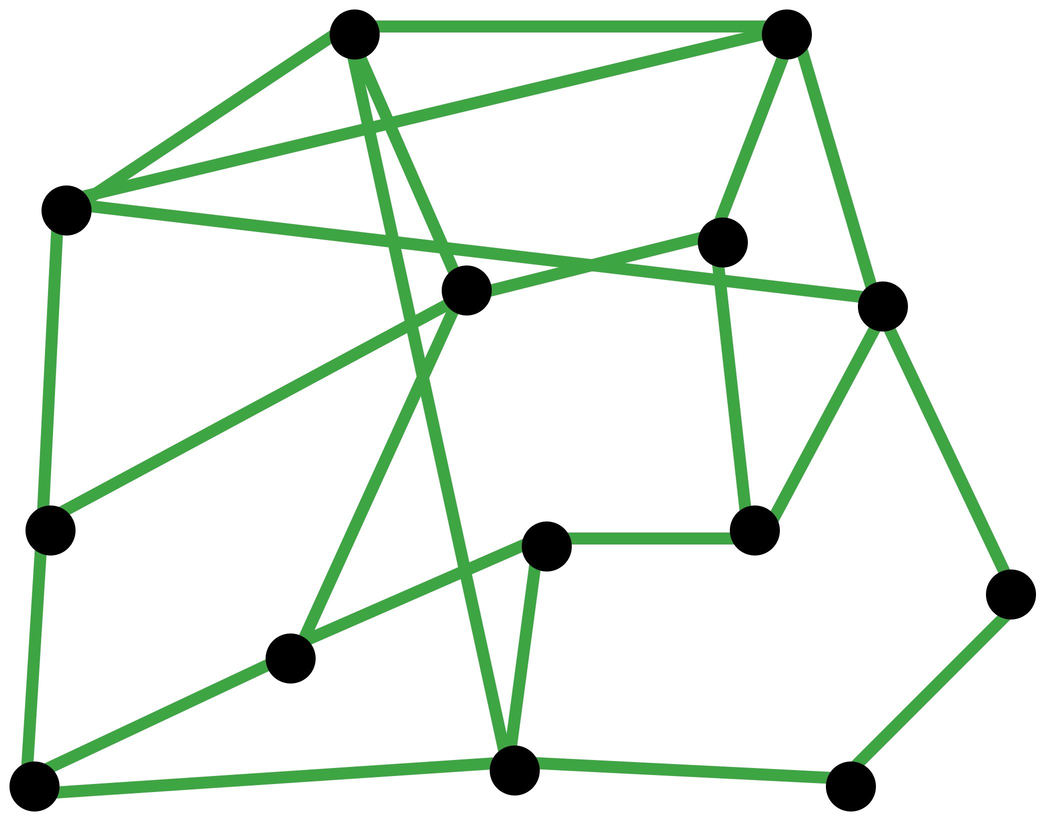
$\Rightarrow$ Twelve-year explosion of research in "Econ-CS"

Computational Complexity Themes

- "Easy" vs. "Hard"
- Reductions (Equivalence)
- Approximation
- Randomness, average case
- Communication, distrib. comp.

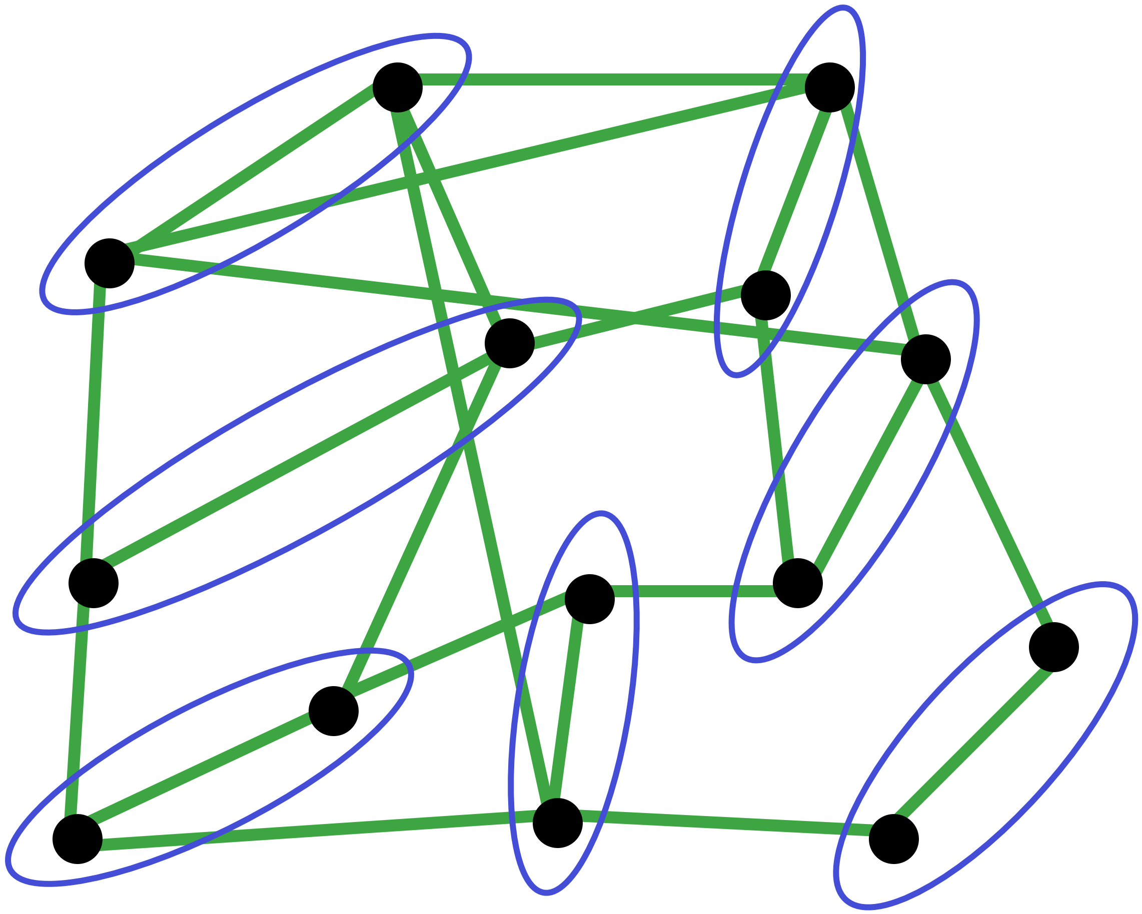
Poly-Time Solvable

- Nontrivial Example : Matching



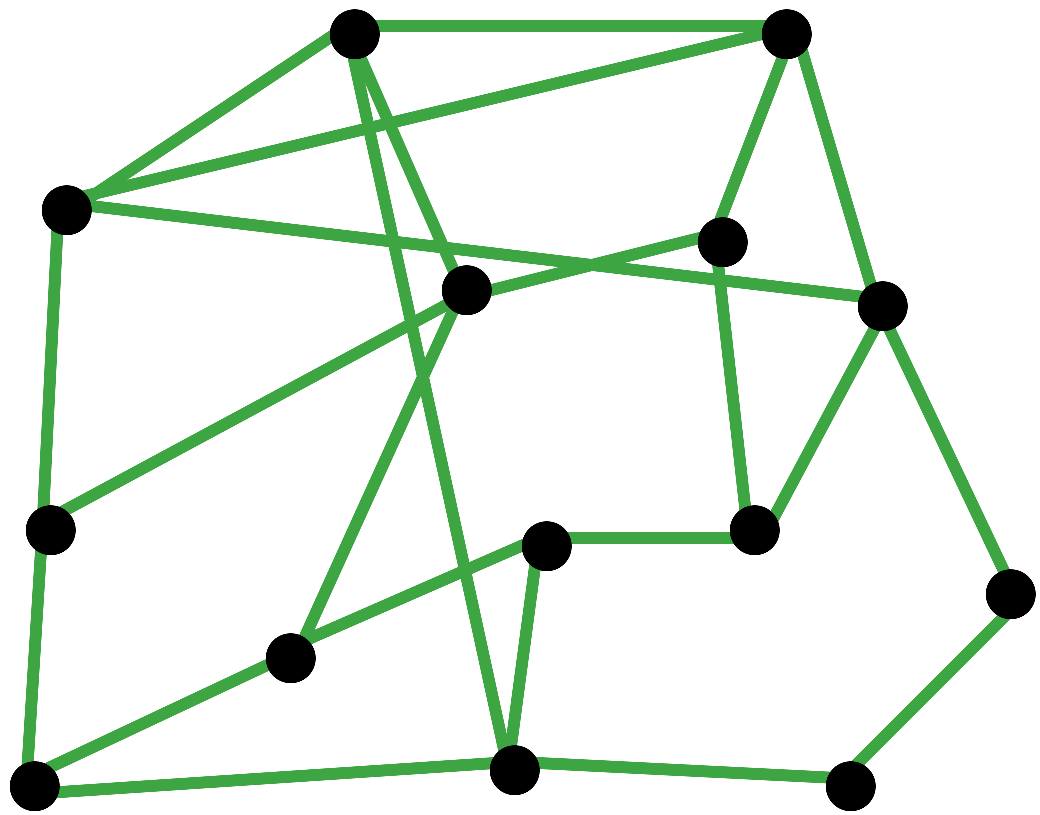
Poly-Time Solvable

- Nontrivial Example : Matching



Poly-Time Verifiable

- Trivial Example : Hamiltonian Cycle



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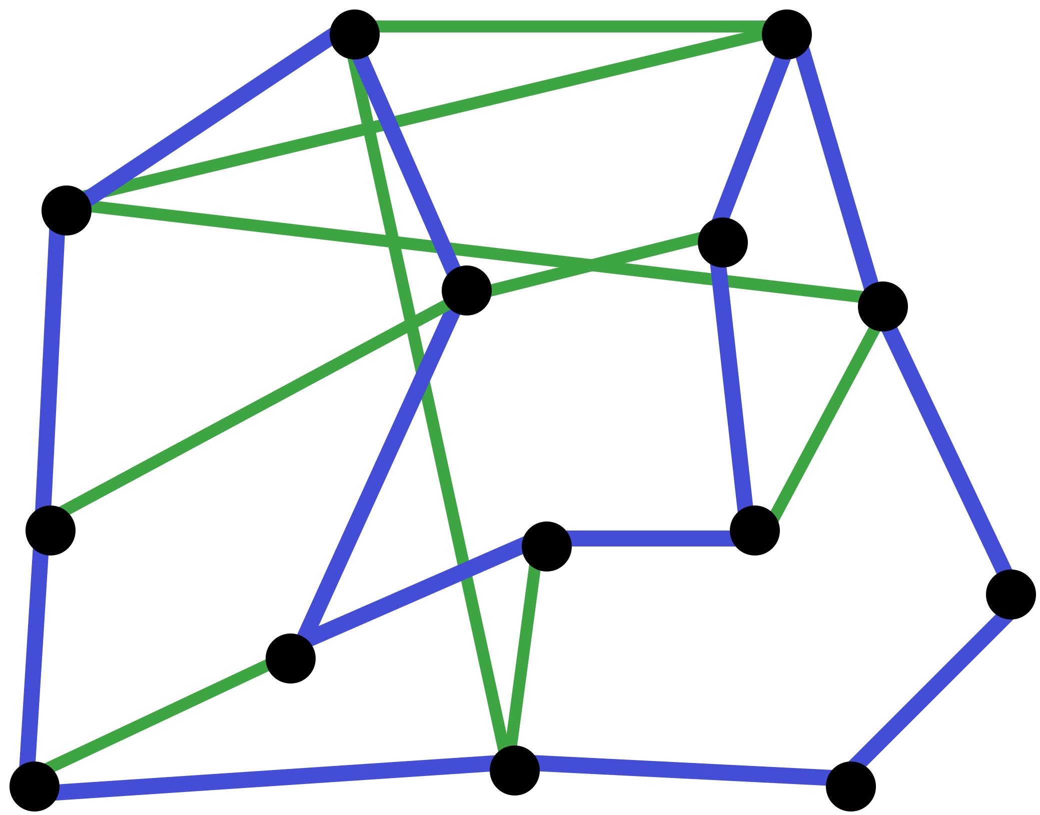


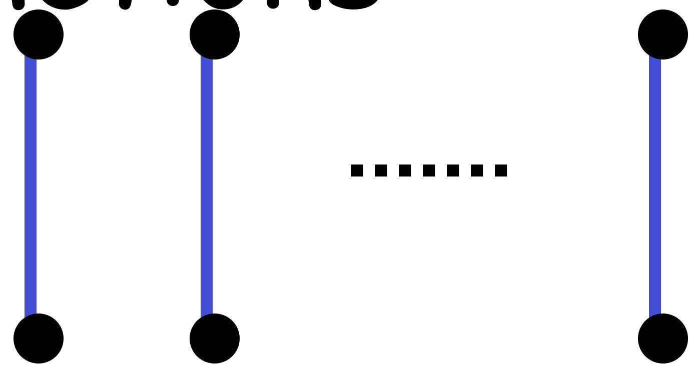
- Is it Easier to Verify a Proof than to Find one?

- Fundamental Conjecture of Computational Complexity:

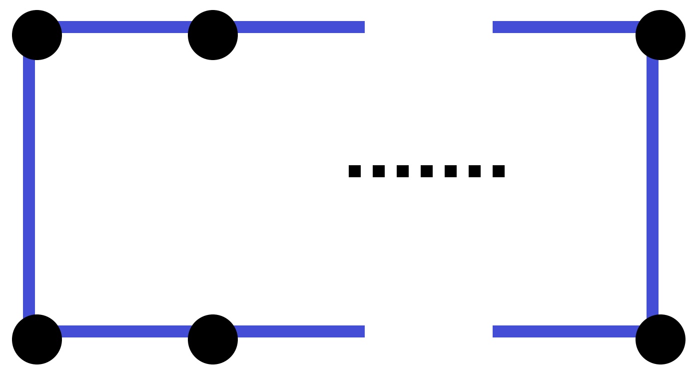
$$P \neq NP$$

Distinctions

- Matching:



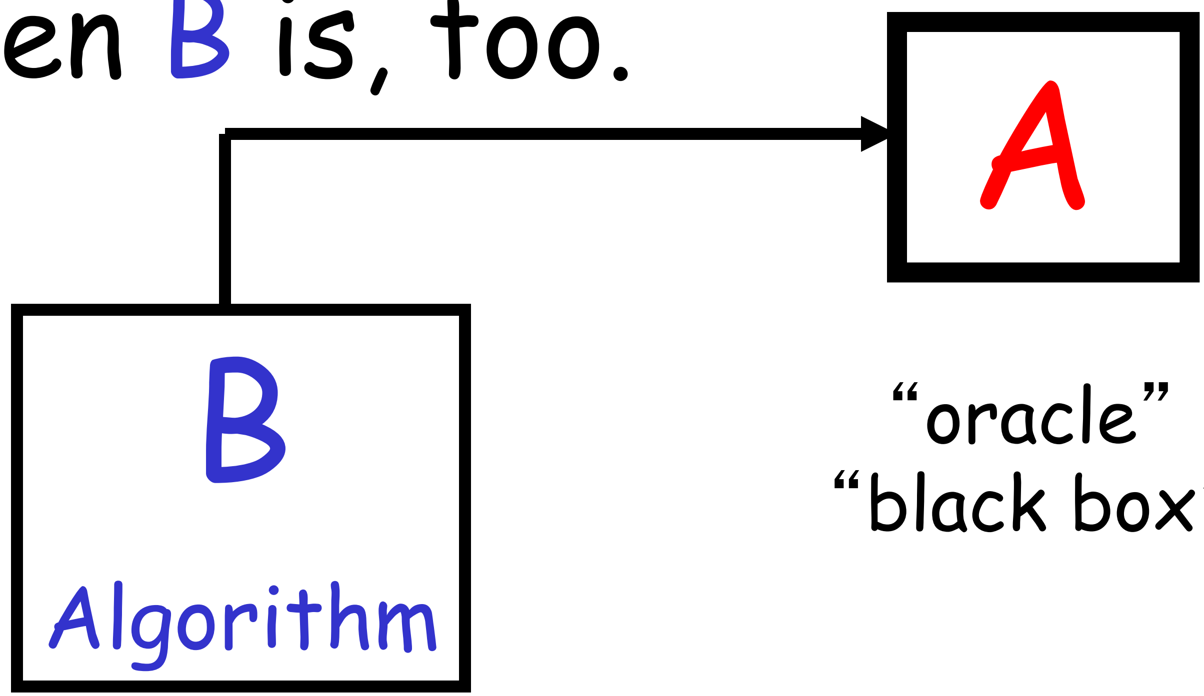
- HC:



Fundamentally Different

Reduction of B to A

- If A is "Easy",
  then B is, too.



"oracle"
"black box"

- NP-completeness
- P-time reduction
- Cook's theorem

  If $B \in NP$, then

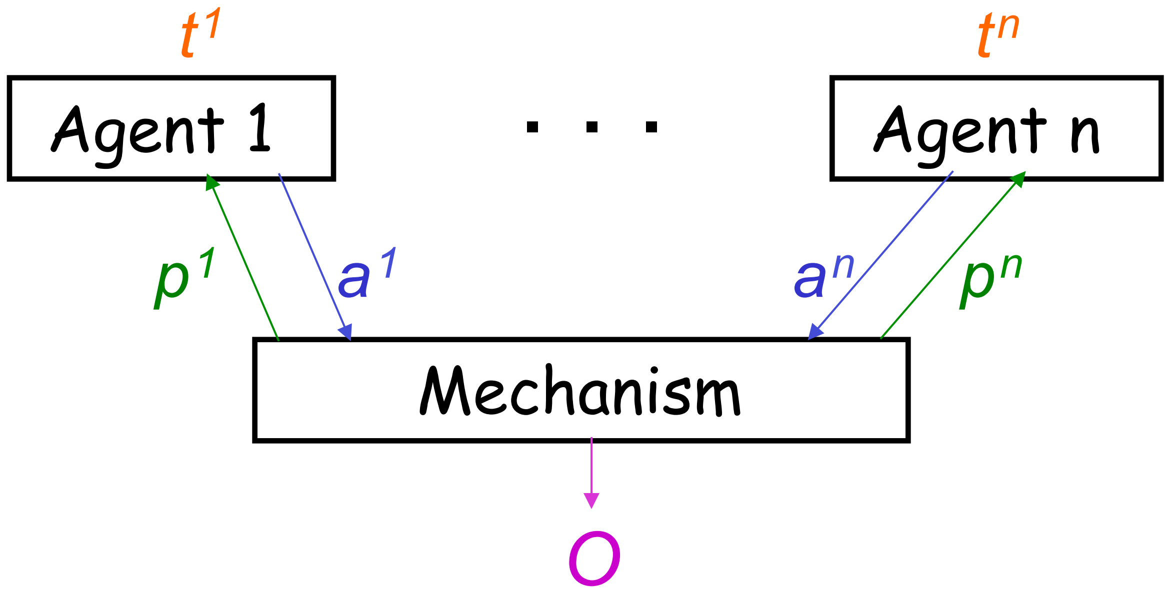
  $B \leq_{P\text{-time}} SAT$
- HC is NP-complete

Equivalence

- NP-complete problems are an equivalence Class under polynomial-time reductions.
- 10k's problems
- Diverse fields

  Math, CS, Engineering, Economics, Physical Sci., Geography, Politics…

Definitions and Notation



(Private) types: $t^1, \ldots, t^n$

Strategies: $a^1, \ldots, a^n$

Payments: $p^i = p^i(a^1, \ldots, a^n)$

Output: $O = O(a^1, \ldots a^n)$

Valuations: $v^i = v^i(t^i, O)$

Utilities: $u^i = v^i + p^i$

Agent i chooses a^i to maximize u^i.

"Strategyproof" Mechanism

For all i, t^i, a^i, and $a^{-i} = (a^1, \ldots, a^{i-1}, a^{i+1}, \ldots a^n)$

$$v^i(t^i, O(a^{-i}, t^i)) + p^i(a^{-i}, t^i)$$
$$\geq v^i(t^i, O(a^{-i}, a^i)) + p^i(a^{-i}, a^i)$$

- "Dominant-Strategy Solution Concept"
  Appropriate for analysis of incentives in Internet-based commerce, according to [NR '01].

- "Truthfulness"

Algorithmic Mechanism Design

N. Nisan and A. Ronen
Games and Economic Behavior **35** (2001), pp. 166--196

- Introduced computational efficiency into mechanism-design framework.
- Polynomial-time computable functions $O(\ )$ and $p^i(\ )$
- Centralized model of computation

Example: Task Allocation

Input: Tasks $z_1, \ldots, z_k$

Agent i's type: $T^i = (t^i_1, \ldots, t^i_k)$
(t^i_j is the minimum time in which i can complete z_j.)

Feasible outputs: $Z = Z^1 \sqcup Z^2 \sqcup \ldots \sqcup Z^n$
(Z^i is the set of tasks assigned to agent i.)

Valuations: $v^i(T^i, Z) = -\sum_{z_j \in Z^i} t^i_j$

Goal: Minimize$_Z$ $\max_i \sum_{z_j \in Z^i} t^i_j$ (NP-hard problem!)

Min-Work Mechanism [NR '01]

$O(\vec{a^1}, \ldots, \vec{a^n})$: Assign z_j to agent with smallest a^i_j

$$p^i(\vec{a^1}, \ldots, \vec{a^n}) = \sum_{z_j \in Z^i} \min_{i \neq i'} a_j^{i'}$$

Theorem: This mechanism is strategyproof and polynomial-time, and the outcome is *n*-approximately optimal.

Notes:

- [NR01] gives a better approximation for $n=2$.
- Open problems: average cases, distrib. comp.