

UNIT 14B

The Limits of Computing: P and NP

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Decision Problems

- We have seen four examples of decision problems with simple brute-force algorithms that are intractable.
 - The Monkey Puzzle $O(N!)$
 - Traveling Salesperson $O(N!)$
 - Map Coloring $O(3^N)$
 - Satisfiability $O(2^N)$

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Are These Problems Tractable?

- For any one of these problems, is there a single tractable (polynomial) algorithm to solve any instance of the problem?
 - Computer scientists have not been able to prove that general tractable algorithms exist for these problems and we just haven't found them yet.
 - Computer scientists have not been able to prove that general tractable algorithms do not exist for these problems so we should stop looking for these algorithms.

P and NP

- The class **P** consists of all those decision problems that can be solved on a deterministic sequential machine in an amount of time that is polynomial in the size of the input
- The class **NP** consists of all those decision problems whose positive solutions can be verified in polynomial time given the right information, or equivalently, whose solution can be found in polynomial time on a non-deterministic machine.

from Wikipedia

Example

- Finding the Minimum in an Array

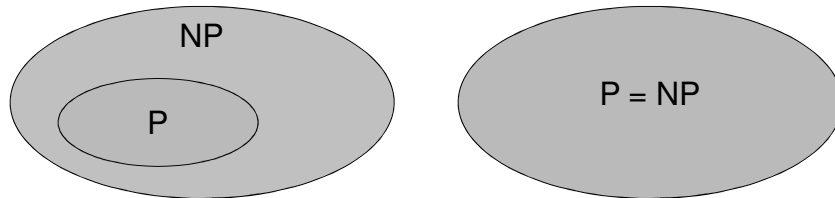
Solvable in polynomial time	yes
Verifiable in polynomial time	yes
- Map Coloring

Verifiable in polynomial time	yes
Solvable in polynomial time	?
- If a problem is in P, it must also be in NP.
- If a problem is in NP, is it also in P?

NP Complete

- The class **NPC** consists of all those problems in NP that are least likely to be in P.
 - Each of these problems is called **NP Complete**.
 - Monkey puzzle, Traveling salesperson, map coloring, and satisfiability are all in NPC.
- Every problem in NPC can be transformed to another problem in NPC.
 - If there were some way to solve one of these problems in polynomial time, we should be able to solve all of these problems in polynomial time.

Complexity Classes



If $P \neq NP$, then some decision problems can't be solved in polynomial time.

If $P = NP$, then all computable problems can be solved in polynomial time.

The Clay Mathematics Institute is offering a \$1M prize for the first person to prove $P = NP$ or $P \neq NP$.
(http://www.claymath.org/millennium/P_vs_NP/)



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Watch out, Homer!



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What's Next?

- Are all computational problems solvable by computer?
 - NO!
There are some that we can't solve no matter how much time we give the computer, no matter how powerful the computer is.