

Complexity Theory
Exercise 3: Time Complexity
3 November 2021

Exercise 3.1. Use the approach presented in lecture 4 to create a quine in your favourite programming language (or just use Python). What is the equivalent of “TM concatenation” here? Also note that the function q is often more complicated than one might think, due to character escaping.

Exercise 3.2. A language $L \in P$ is complete for P under polynomial-time reductions if $L' \leq_p L$ for every $L' \in P$. Show that every language in P except \emptyset and Σ^* is complete for P under polynomial-time reductions.

Exercise 3.3. Let

$$A_{\text{PNTM}} = \{ \langle \mathcal{M}, p, w \rangle \mid \mathcal{M} \text{ is a non-deterministic TM that accepts } w \text{ in time } p(|w|) \\ \text{with } p \text{ a polynomial function} \}$$

Show that A_{PNTM} is NP-complete.

Exercise 3.4. Show that the following problem is NP-complete:

Input: A propositional formula φ in CNF
Question: Does φ have at least 2 different satisfying assignments?

Exercise 3.5. We recall some definitions.

- Given some language L , $L \in \text{coNP}$ if, and only if, $\bar{L} \in \text{NP}$.
- L is coNP-hard if, and only if, $L' \leq_p L$ for every $L' \in \text{coNP}$.
- L is coNP-complete if, and only if, $L \in \text{coNP}$ and L is coNP-hard.

Show that if any coNP-complete problem is in NP, then $\text{NP} = \text{coNP}$.

Exercise 3.6. If G is an undirected graph, a *vertex cover* of G is a subset of the nodes where every edge of G touches one of those nodes. The vertex cover problem asks whether a graph contains a vertex cover of a specified size.

$$\text{VERTEX-COVER} = \{ \langle G, k \rangle \mid G \text{ is an undirected graph that has a } k\text{-node vertex cover.} \}$$

Show that **VERTEX-COVER** is NP-complete.

Hint:

Try to find a reduction from 3-SAT