

Computational Complexity – Homework 11

Discussed on 14.06.2019.

Definition 1. A language L is in \mathbf{P}/poly if there exist a family $\{C_n\}$ of Boolean circuits of size polynomial in n such that for all $x \in \{0, 1\}^n$

$$x \in L \text{ iff } C_n(x) = 1.$$

A family of Boolean circuits $\{C_n \mid n \in \mathbb{N}\}$ is *logspace uniform* if there is a deterministic Turing machine M running in logarithmic space which on input 1^n outputs a description of C_n . Similarly for *polytime uniform* we require M run in polynomial time.

(Note that the definition of \mathbf{NC} requires the logspace uniformity together with polynomial size and polylog depth.)

Exercise 11.1

Show that $\mathbf{BPP} \subseteq \mathbf{P}/\text{poly}$.

Remark: Use one of the results on \mathbf{BPP} which have already been shown in the lecture.

Exercise 11.2

- (a) Show that for every polynomial p the following language is in \mathbf{coNP} :

$$L_p := \left\{ \langle C_1, C_2, \dots, C_n \rangle \mid \begin{array}{l} C_i \text{ is a circuit of size at most } p(i) \text{ which decides SAT for every formula} \\ \text{of length exactly } i \end{array} \right\}.$$

Remark: Assume w.l.o.g. that every formula has length at least one with 0 (false) and 1 (true) the two formulae of length 1. Now, use the circuits C_1, \dots, C_i ($i \geq 0$) to check the correctness of circuit C_{i+1} . (Recall the so-called self-reducibility of SAT.)

- (b) Show that \mathbf{PH} collapses to the second level if $\mathbf{NP} \subseteq \mathbf{P}/\text{poly}$, i.e. if there is a sequence of polynomial sized circuits for SAT.

Remark: It suffices to show that $\Pi_2\text{SAT} \in \Sigma_2^p$.

- (c) What happens if there is a sequence of polynomial sized circuits for SAT that is moreover logspace uniform?
What if it is polytime uniform?

Exercise 11.3

Prove that for $n \geq 100$, most of the boolean functions on n variables require circuits of size at least $2^n/n$.

Exercise 11.4

- (a) Design a circuit family for the parity problem and describe it formally. Prove that there is a logspace uniform one.
- (b) Let $A[0..n]$ be an array of integers. Design a PRAM for summing numbers in an array, i.e. compute $\sum_{i=0}^n A[i]$.
Can you compute the array-suffix-sum, i.e. $\sum_{i=j}^n A[i]$ for all $0 \leq j \leq n$, with the same complexity?