COL 352 Introduction to Automata and Theory of Computation

Nikhil Balaji

Bharti 420
Indian Institute of Technology, Delhi
nbalaji@cse.iitd.ac.in

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Lecture 28: Reductions 3

Universality of CFG

Lemma

$ALL_{CFG} = \{\langle M\rangle \mid M$ *is a PDA and* $L(M) = \Sigma^*\}$ *is undecidable.*

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C be the TM deciding it.

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- C_1 is a start configutation.
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- for each $1 \leq i \leq \ell$, C_i yields C_{i+1}.

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- If M does not accept w, then

  no matter what x is, $N_{M,w}$ will accept x, i.e. $L(N_{M,w}) = \Sigma^*$.

A String Matching Problem

String List Matching Problem

Given two lists $A = \langle s_1, s_2, \ldots, s_n \rangle$ and $B = \langle t_1, t_2, \ldots, t_n \rangle$ of strings of equal length, decide whether there is a sequence of combining elements that produces same string for both lists.

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$$s_{i_1} s_{i_2} \ldots s_{i_n} = t_{i_1} t_{i_2} \ldots t_{i_n}$$

Example: Consider the lists $A = \langle 110, 0011, 0110 \rangle$ and $B = \langle 110110, 00, 110 \rangle$.

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Witness: $s_2 s_3 s_1 = 00110110110$ and $t_2 t_3 t_1 = 00110110110$

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- What about $A = \{0011, 11, 1101\}$ and $B = \{101, 1, 110\}$?

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- What about $A = \{0011, 11, 1101\}$ and $B = \{101, 1, 110\}$?
- What about $A = \{100, 0, 1\}$ and $B = \{1, 100, 0\}$?(Shortest solution lenth = 75)

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Can you design an algorithm to solve this problem? A semi-algorithm?

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Can you design an algorithm to solve this problem? A semi-algorithm?

Theorem

There is no algorithm for the string-list matching problem. In other words, this problem is undecidable.

Post's Correspondence Problem

A Domino game

Given a collection of dominos $\begin{bmatrix} b \\ ca \end{bmatrix}$ $\begin{bmatrix} a \\ ab \end{bmatrix}$ $\begin{bmatrix} ca \\ a \end{bmatrix}$ $\begin{bmatrix} abc \\ c \end{bmatrix}$

- A match is a list of these dominos (with possible repetitions) such that the string formed in top is same as string formed by bottom row.

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- A match is a list of these dominos (with possible repetitions) such that the string formed in top is same as string formed by bottom row.
- Does this collection of dominos have a match?
- Same as the string matching problem
- Called Post's Correspondance Problem or PCP.

Theorem

PCP is undecidable.

- Encode TM computation histories!
- Each transition as a domino!
- Simulate the run using the dominos.

Proof of Undecidability of PCP

Simplifying assumptions

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- Assume that the tape of TM is one-way infinite and never attempts to move left of its left-end.

Proof of Undecidability of PCP

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- Assume that the tape of TM is one-way infinite and never attempts to move left of its left-end.
- If $w = \varepsilon$, then use $\sqcup$ instead of w.

Proof of Undecidability of PCP

Simplifying assumptions

- Assume that the tape of TM is one-way infinite and never attempts to move left of its left-end.
- If $w = \varepsilon$, then use $\sqcup$ instead of w.
- $P = \left\{ \begin{bmatrix} t_1 \\ b_1 \end{bmatrix}, \begin{bmatrix} t_2 \\ b_2 \end{bmatrix}, \ldots, \begin{bmatrix} t_k \\ b_k \end{bmatrix} \right\}$
- Modify PCP so that match must start with a given domino, say the first one.

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We build instance P' of MPCP in several steps.

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  - If $\delta(q, a) = (q', b, L)$, then add domino to P'
    $$\begin{bmatrix} cqa \\ q'cb \end{bmatrix}$$
  - add all dominos (i.e, for all $a \in \Gamma \cup \{\#\}$ to P'.
    $$\begin{bmatrix} a \\ a \end{bmatrix} \quad \begin{bmatrix} \# \\ \sqcup\# \end{bmatrix}$$

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- This completes the reduction, i.e., map from instance of A_{TM} to PCP.
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- MPCP to PCP?