

Regulated Rewriting – The Hierarchy

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Hierarchy of Language Families – Description

Notation

ac appearance checking

ε with erasing productions

M matrix grammars

P programmed grammars

RC random context grammars

PER permitting grammars

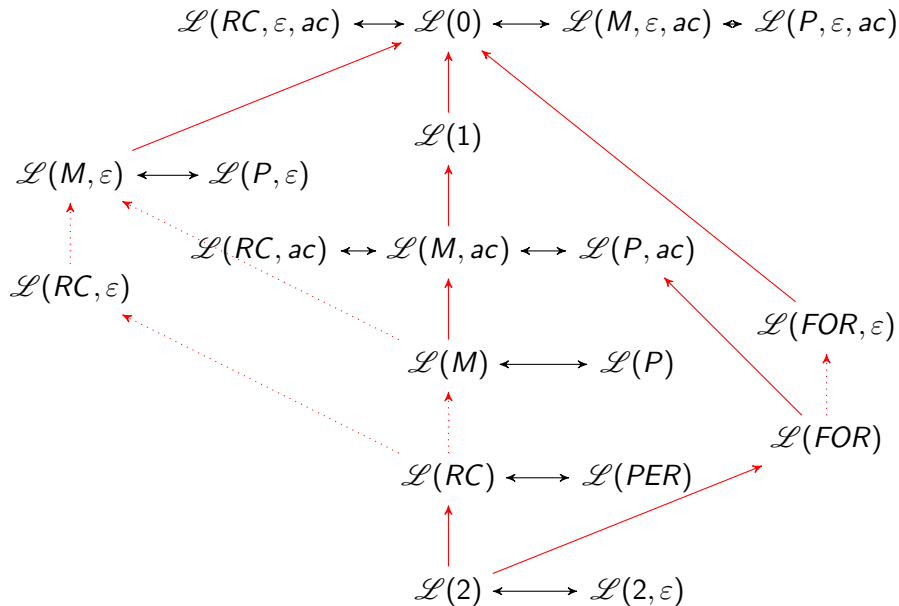
FOR forbidding grammars

0, 1, 2 type-0, type-1, type-2 grammars, respectively

Example

$\mathcal{L}(RC, \varepsilon, ac)$ – the family of languages generated by random context grammars with erasing productions in appearance checking mode

Regulated Rewriting – The Hierarchy



Proof of $\mathcal{L}(M) = \mathcal{L}(P)$

Theorem

$$\mathcal{L}(M) = \mathcal{L}(P).$$

Proof–Basic Idea

- 1 $\mathcal{L}(M) \subseteq \mathcal{L}(P)$: Transform any matrix grammar to an equivalent programmed grammar
- 2 $\mathcal{L}(P) \subseteq \mathcal{L}(M)$: Transform any programmed grammar to an equivalent matrix grammar
- 3 $\mathcal{L}(M) = \mathcal{L}(P)$

Proof of $\mathcal{L}(M) \subseteq \mathcal{L}(P)$ I

Let

$$H = (G, M)$$

be a matrix grammar, where

- $G = (N, T, P, S)$ is a context-free grammar
- M is a finite language over P

Express M as

$$M = \{m_1, \dots, m_r\}$$

for some $r \geq 1$ and

$$m_i = p_{i_1} \dots p_{i_{k_i}}$$

with $k_i = |m_i|$. Set

$$N' = \{A' : A \in N\}$$

Define the homomorphism h from $(T \cup N)^*$ to $(T \cup N')^*$ as

- $h(a) = a$ for every $a \in T$
- $h(A) = A'$ for every $A \in N$

Proof of $\mathcal{L}(M) \subseteq \mathcal{L}(P)$ II

- 1** For every $p_{i_j} : A_{i_j} \rightarrow x_{i_j}$ such that $\text{alph}(x_{i_j}) \cap N \neq \emptyset$ (some nonterminals occur in x_{i_j}) and $j < |m_i|$ (not the last production in m_i), introduce this programmed production:

$$(\langle i, j \rangle : A_{i_j} \rightarrow x_{i_j}, \{\langle i, j+1 \rangle\})$$

- 2** For every $p_{i_j} : A_{i_j} \rightarrow x_{i_j}$ such that $\text{alph}(x_{i_j}) \cap N = \emptyset$ (no nonterminal occurs in x_{i_j}) and $j < |m_i|$ (not the last production in m_i), introduce
- a** $(\langle i, j \rangle : A_{i_j} \rightarrow h(A_{i_j}), \{\langle i, j, 1 \rangle, \dots, \langle i, j, m \rangle\})$
 - b** $(\langle i, j, q \rangle : A_q \rightarrow A_q, \{\langle i, j \rangle'\})$ for $q = 1, \dots, m$ (make sure there is a nonterminal)
 - c** $(\langle i, j \rangle' : h(A_{i_j}) \rightarrow x_{i_j}, \{\langle i, j+1 \rangle\})$
- provided that $N = \{A_1, \dots, A_m\}$
- 3** For every $p_{i_{k_i}} : A_{i_{k_i}} \rightarrow x_{i_{k_i}}$ (simulate the last production of m_i and start simulating a new matrix), introduce

$$(\langle i, k_i \rangle : A_{i_{k_i}} \rightarrow x_{i_{k_i}}, \{\langle 1, 1 \rangle, \dots, \langle r, 1 \rangle\})$$

Proof of $\mathcal{L}(M) \subseteq \mathcal{L}(P)$ III

Let P' consist of all rules constructed above and

$$(\$: S' \rightarrow S, \{\langle 1, 1 \rangle, \dots, \langle r, 1 \rangle\})$$

Define the programmed grammar

$$G' = (N \cup N' \cup \{S'\}, T, P', S')$$

Observe that

$$L(H) = L(G')$$



Proof of $\mathcal{L}(P) \subseteq \mathcal{L}(M)$ I

Let

$$H = (G, R)$$

be a programmed grammar. Consider the simplified description of H which uses productions of the form

$$(p : A \rightarrow x, R(p))$$

- 1** If $(p : A \rightarrow x, Q), (r : B \rightarrow y, R) \in P$ and $r \in Q$, then introduce the matrix

$$(\langle A \rightarrow x \rangle \rightarrow A, A \rightarrow x, B \rightarrow \langle B \rightarrow y \rangle)$$

(simulation will continue)

- 2** If $(p : A \rightarrow x, Q) \in P$, then introduce

$$(\langle A \rightarrow x \rangle \rightarrow A, A \rightarrow x)$$

(simulation ends)

Proof of $\mathcal{L}(P) \subseteq \mathcal{L}(M)$ II

3 If $(p : S \rightarrow x, Q) \in P$, introduce

$$(S' \rightarrow \langle S \rightarrow x \rangle)$$

(simulation starts)

Set

$$\begin{aligned} N' &= N \\ &\cup \{ \langle A \rightarrow x \rangle : A \rightarrow x \in P \} \\ &\cup \{ S' \} \end{aligned}$$

Define the matrix grammar

$$G' = (N', T, P', S')$$

where P' consists of all the above matrices. Observe that

$$L(H) = L(G')$$



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