

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

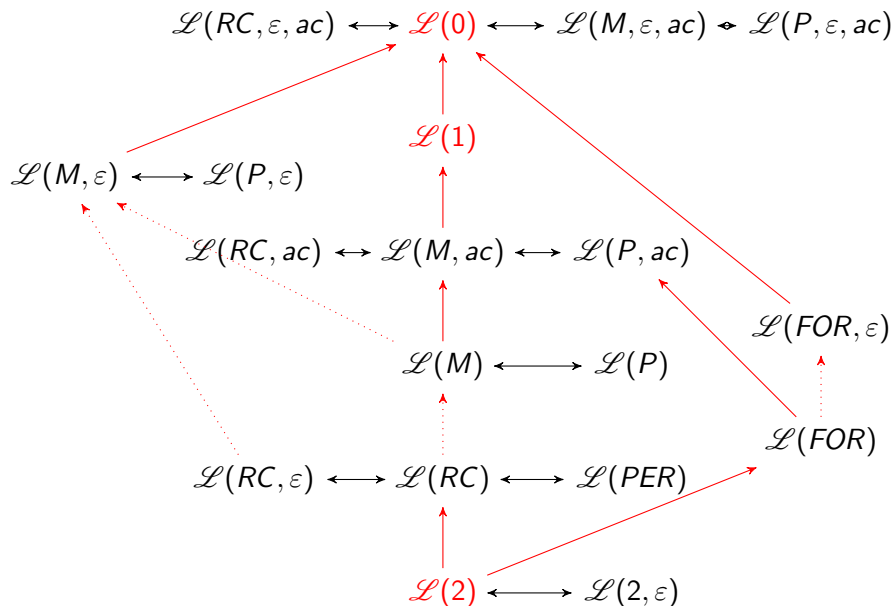
FOR forbidding grammars

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:

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

- 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 $\langle\langle i, j \rangle\rangle : A_{i_j} \rightarrow h(A_{i_j}), \{\langle i, j, 1 \rangle, \dots, \langle i, j, m \rangle\}$
 - b $\langle\langle i, j, q \rangle\rangle : A_q \rightarrow A_q, \{\langle i, j \rangle'\}$ for $q = 1, \dots, m$ (make sure there is a nonterminal)
 - c $\langle\langle i, j \rangle'\rangle : h(A_{i_j}) \rightarrow x_{i_j}, \{\langle i, j + 1 \rangle\}$
- 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

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

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


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





 S. Abraham.
Some questions of phrase-structure grammars.
Computational Linguistics, 4:61–70, 1965.


 J. Dassow and Gh. Păun.
Regulated Rewriting in Formal Language Theory.
Akademie-Verlag, Berlin, 1989.

 H. Fernau and H. Bordihn.
Accepting grammars and systems via context condition grammars.
Journal of Automata, Languages and Combinatorics, 1(2):97–112,
1996.

 D. J. Rosenkrantz.
Programmed grammars and classes of formal languages.
Journal of the ACM, 16:107–131, 1969.

 G. Rozenberg and A. Salomaa.
Handbook of Formal Languages, volume 1–3.
Springer, Berlin, 1997.

 A. P. J. van der Walt.
Random context grammars.
In *Proceedings of Symposium on Formal Languages*, 1970.

 G. Zetsche.
On erasing productions in random context grammars.
In S. Abramsky et al., editor, *Automata, Languages and Programming*,
volume 6199 of *LNCS*, pages 175–186. Springer, Berlin, 2010.