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On the Generative Capacity of Contextual Grammars with Catenation. Necessary Conditions

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Abstract. In this paper our attention is focused on the study of the properties for some families of contextual languages with catenation (see Fortiş, 1999, also Păun, 1982; Păun, 1997). Also, we are defining and analyzing some new properties characteristic to these families of languages. Using these properties we are able to establish some necessary conditions, and some pumping properties for families of contextual languages with catenation.

Key words: Marcus contextual grammar, contextual grammar, contextual grammar with choice, contextual grammar with F-selection.

1. Introduction

In the original definition for contextual grammars with choice, $G = (V, A, C, \varphi)$, the generated language is the smallest language satisfying the following requirements (see Marcus, 1969; Păun, 1982):

1. every word in A is also in $L(G)$;
2. for every word $x \in L(G)$ and for a word $z \in A$, and a context $(u, v) \in \varphi(x)$, the words uxv, xz and zx are also in $L(G)$.

In this form, this definition has offered some support for modeling elaborate constructions in natural languages.

However, the construction of propositions, phrases or texts in a natural language can be done by using, together with the use of contexts, the operation of word catenation. Thus, we are able to obtain generative devices which extend the generative power of classical (Marcus) contextual grammars (see also Fortiş, 1999).

2. Basic Definitions

DEFINITION 1. A *contextual grammar with choice* is a construct

$$G = (V, A, C, \varphi)$$

where V is an alphabet, A is a finite language over V, C is a finite subset of $V^* \times V^*$, and $\varphi : V^* \to 2^C$.

The strings of A are called axioms, the elements $(u, v) \in C$ are called contexts, φ is the selection/choice mapping.

For a contextual grammar defined as above, we can define two relations over V^*: for $x, y \in V^*$, we write

$$\begin{aligned} x \Longrightarrow_{ex} y \quad &\text{iff} \quad y = uxv, \quad \text{for} \quad (u, v) \in \varphi(x), \\ x \Longrightarrow_{in} y \quad &\text{iff} \quad x = x_1x_2x_3, y = x_1ux_2vx_3, \quad \text{for} \\ &\qquad x_1, x_2, x_3 \in V^*, \quad (u, v) \in \varphi(x). \end{aligned}$$

We say that $\Longrightarrow_{ex}$ is an external direct derivation in G, and $\Longrightarrow_{in}$ is an internal derivation step.

The language generated by a contextual grammar with choice, $L_{ex}(G)$, is the smallest language $L \subseteq V^*$ such that:

1. $A \subseteq L$.
2. if $x \in L$ and $(u, v) \in \varphi(x)$, then $uxv \in L$.

The language $L_{in}(G)$ is the smallest language $L \subseteq V^*$ such that:

1. $A \subseteq L$.
2. if $x \in L$ and $x = x_1x_2x_3$, for $x_1, x_2, x_3 \in V^*$, and $(u, v) \in \varphi(x_2)$, then $x_1ux_2vx_3 \in L$.

Denote the family of contextual languages (with choice) externally generated by ECC, and the family of contextual languages (with choice) internally generated by ICC.

DEFINITION 2. A total contextual grammar is a construct

$$G = (V, A, C, \varphi),$$

where V is an alphabet, A is a finite subset of V^*, C is a finite subset of $V^* \times V^*$, and $\varphi : V^* \times V^* \times V^* \to 2^C$.

We define the derivation relation as follows: for $x, y \in V^*$, we write

$$\begin{aligned} x \Longrightarrow_{in} y \quad &\text{iff} \quad x = x_1x_2x_3, y = x_1ux_2vx_3, \quad \text{for} \\ &\qquad x_1, x_2, x_3 \in V^*, (u, v) \in \varphi(x_1, x_2, x_3). \end{aligned}$$

Denote the family of languages generated by total contextual grammars by TC.

Starting from the definition of a (simple) contextual grammar, one can get the following definition

DEFINITION 3. A contextual grammar with catenation is a construct

$$G = (V, A, C),$$

where V is an alphabet, A is a finite language over V and C is a finite set of contexts over V.

The language generated by a contextual grammar with catenation is the smallest language L satisfying the following requirements:

1. $A \subseteq L$;
2. for a word $x \in L$ and a context $(u, v) \in C$, the word uxv is in L;
3. for the words $x, y \in L$, the word xy is in L.

Denote the family of contextual languages with catenation by $CCON$.

Related to a contextual grammar with catenation one can define the following relation of derivation: for $x, y \in V^*$, we write

$$x \Longrightarrow y \quad \text{iff} \quad y = uxv, \quad \text{where} \quad (u,v) \in C \quad \text{or}$$
$$y = xz \quad \text{or} \quad y = zx, \quad \text{where} \quad z \in L(G).$$

Using the notation $\Longrightarrow^*$ for the reflexive and transitive closure of the relation $\Longrightarrow$ one can associate with a contextual grammar with catenation, G, the following language

$$L(G) = \{x \in V^* | a \Longrightarrow^* x, \text{ for every } a \in A\}.$$

A natural idea is to restrict the use of contexts and catenation in order to generate a word for a contextual grammar with catenation. This idea is leading us to the following

DEFINITION 4. A contextual grammar with catenation with choice is a construct

$$G = (V, A, C, \varphi),$$

where V is an alphabet, A is a finite language over V, C is a finite set of contexts over V, and $\varphi : V^* \to 2^C$ is the function of selection (the selector).

The language generated by a contextual grammar with catenation, with choice is the smallest language L satisfying the following requirements:

1. $A \subseteq L$;
2. for $x \in L$ and $(u, v) \in \varphi(x)$, $uxv \in L$;
3. for $x, y \in L$ and $(\lambda, \lambda) \in \varphi(xy)$, $xy \in L$.

Denote the family of contextual languages with catenation, with selection by $CSEL$.

We can define now the relation of derivation for contextual grammars with catenation, with choice, as follows: for $x, y \in V^*$, we write

$$x \Longrightarrow y \quad \text{iff} \quad y = uxv \quad \text{with} \quad (u,v) \in \varphi(x) \quad \text{or}$$
$$y = xz, \quad \text{with} \quad (\lambda, \lambda) \in \varphi(xz)$$
$$(y = zx, \quad \text{with} \quad (\lambda, \lambda) \in \varphi(zx), \text{ respectively}).$$

Using the notation $\Longrightarrow^*$ for the reflexive and transitive closure of the relation $\Longrightarrow$ one can associate with a contextual grammar with catenation, with choice, G, the following language

$$L(G) = \{x \in V^* | a \Longrightarrow^* x,\ \text{for every } a \in A\}.$$

DEFINITION 5. A contextual grammar with catenation, in modular presentation, is a system

$$G = (V, A, P),$$

where V is an alphabet, A is a finite language over V and P is a finite set of pairs of the form (S, C), with $S \subseteq V^*$, $S \neq \emptyset$ and C is a finite subset of $V^* \times V^*$.

The pairs (S, C) are called productions, S is the selector of a production and C is its set of contexts.

For a contextual grammar with catenation, in modular presentation, the relation of derivation can be defined as follows: for $x, y \in V^*$ and the production $(S, C) \in P$ we write

$$\begin{aligned} x \Longrightarrow_{ex} y \quad \text{iff} \quad & y = uxv, \text{ with } (x, (u, v)) \in (S, C), \text{ or} \\ & y = xz, \text{ with } (xz, (\lambda, \lambda)) \in (S, C) \\ & (y = zx, \text{ with } (zx, (\lambda, \lambda)) \in (S, C), \text{ respectively}). \end{aligned}$$

We say that a contextual grammar with catenation, in modular presentation,

$$G = (V, A, (S_1, C_1), \ldots, (S_n, C_n)),$$

is of type F (or with F selection), if every selector S_i, for $1 \leqslant i \leqslant n$, is from the family F. Denote by $CCON(F)$ the family of contextual languages with catenation, in modular presentation, of type F.

Also, we can consider the following relation of derivation: for $x, y \in V^*$ and $(S, C) \in P$ we write

$$\begin{aligned} x \Longrightarrow_{in} y \ iff \ & y = x_1 u x_2 v x_3, \quad \text{where} \quad (x_2, (u, v)) \in (S, C), \quad \text{or} \\ & y = x_1 x_2 z x_3, \quad \text{with} \quad (x_2 z, (\lambda, \lambda)) \in (S, C) \\ & (y = x_1 z x_2 x_3, (z x_2, (\lambda, \lambda)) \in (S, C), \quad \text{respectively}), \\ & \text{and} \quad x = x_1 x_2 x_3, z \in L(G). \end{aligned}$$

Denote by $CCON_{in}$ the family of contextual languages with catenation, with internal derivation and by $CCON_{in}(F)$, the family of contextual languages with catenation, in modular presentation, of type F, with internal derivation.

3. Generative Capacity. Necessary Conditions

In what follows, we shall review some of the properties presented in (Păun, 1997). Also, we define new properties, characteristic to contextual languages with catenation.

DEFINITION 6. We say that a language $L \subseteq V^*$ has the EBS (*external bounded step*) property if there is a constant p such that for each $x \in L$, $|x| > p$, there is $y \in L$ such that $x = uyv$ and $0 < |uv| \leqslant p$ (Păun, 1997).

As proved in (Păun, 1997), a language is ECC if and only if it posses the EBS property. For the families of contextual languages with catenation, the following results hold:

Lemma 1. *The family $CCON$ does not posses the EBS property.*

Proof. It is easy to verify that the language $D_{\{a,b\}}$ (the Dyck language over $\{a, b\}$) is $CCON$ and it is not ECC.

By using this result, we can easily establish the following

Lemma 2. *None of the families $CCON_\omega$, $CSEL_\omega$ with $\omega \in \{in,\ ex\}$ does posses the EBS property.*

Notice that the negative results regarding the EBS property occurs because of the operation of catenation involved in the definition of a contextual grammar with catenation (with internal or external derivation). Thus, we can consider the following properties:

DEFINITION 7. We say that a language $L \subseteq V^*$ has the $EBSC$ (*external bounded step with catenation*) property if there is a constant p such that for each $x \in L$, $|x| > p$, there are $y, z \in L \cup \{\lambda\}$ such that $x = uyzv$ ($uzyv$, respectively), $|uzv| > 0$, $|uv| \leqslant p$ and $|yz| > 0$.

DEFINITION 8. We say that a language $L \subseteq V^*$ has the $LEBSC$ (*external bounded step with limited catenation*) property if there is a constant p such that for each $x \in L$, $|x| > p$, there are $y, z \in L \cup \{\lambda\}$ such that $x = uyzv$ ($uzyv$, respectively), $0 < |uzv| \leqslant p$ and $|yz| > 0$.

Lemma 3. *Every $CSEL$, $CCON(F)$ languages posses the $EBSC$ property.*

Proof. Let L be a $CSEL$ language, x a word in L and the constant p defined as follows

$$p = 2 \cdot \max\{\max_{a \in A}\{|a|\}, \max_{(u,v) \in C}\{|uv|\}\},$$

such that $|x| > p$. Then x is of one of the following forms

1. $x = ux_1v$, with $(u, v) \in C$, $x_1 \in L$.
   In this situation, choose $y = x_1$, $z = \lambda$.
2. $x = x_1x_2$, with $x_1, x_2 \in L$.
   Now, choose $y = x_1, z = x_2$ and $(u, v) = (\lambda, \lambda)$.

In both cases, the conditions of the property $EBSC$ are verified, thus the language L posses the $EBSC$ property.

REMARK 1. Every language L that posses the EBS property also posses the $EBSC$ property. The reverse does not hold.

It is enough to observe that the language $D_{\{a,b\}}$ has the $EBSC$ property (this language is $CSEL$, so we can use the result from Lemma 3).

Also, for the families ICC and $CSEL_{in}$, the following result holds

Lemma 4. *None of the families ICC, $CSEL_{in}$ does posses the $EBSC$ property.*

Proof. Let us consider the following ICC language (observe that this language is also $CSEL_{in}$),

$$L = \{a^n b^n c | n \geqslant 0\}.$$

The language L does not posses the EBS property, so it does not posses the $EBSC$ property either.

Next, we can establish the following result

Lemma 5. *A language is $CSEL$ if and only if it posses the $EBSC$ property.*

Proof. Let $L \subseteq V^*$ a language possessing the $EBSC$ property for a constant p. Construct the following CSEL grammar, $G = (V, A, C, \varphi)$, where

$$\begin{aligned} A &= \{x \in L | \, |x| \leqslant p\} \\ C &= \{(u, v) | u, v \in V^*, 0 < |uv| \leqslant p\}, \\ \varphi(x) &= \{(u, v) \in C | uxv \in L\}, x \in V^*. \end{aligned}$$

Next, for every word of the form xz, with $z \in L$, we add to the set $\varphi(xz)$, constructed as above, the set $\{(\lambda, \lambda)|$ if $xz \in L\}$, and to the set $\varphi(zx)$, the set $\{(\lambda, \lambda)|$ if $zx \in L\}$, with $x \in V^*$.

The equality $L = L(G)$ results immediately, from the definitions of A, C and φ.

DEFINITION 9. A language $L \subseteq V^*$ has the IBS (*internal bounded step*) property if there is a constant p such that for each $x \in L$ with $|x| > p$, there is $y \in L$ such that $x = x_1ux_2vx_3$, $y = x_1x_2x_3$ and $0 < |uv| \leqslant p$ (Păun, 1997).

A language $L \subseteq V^*$ has the BLI (*bounded length increase*) if there is a constant p such that for each $x \in L$ with $|x| > p$ there is $y \in L$ with $0 < |x| - |y| \leqslant p$ (Păun, 1997).

Lemma 6. *The family $CCON$ has the IBS property.*

Proof. For a language $L \in CCON$ it is enough to choose a value

$$p = 3 \cdot \max\{\max_{a \in A}\{|a|\}, \max_{(u,v) \in C}\{|uv|\}\}.$$

Then a word $x \in L$ with $|x| > p$ is of one of the following forms

1. $x = u_1u_2 \dots u_n a v_n \dots v_2 v_1$. Choose $u = u_i$, $v = v_i$ with $1 \leqslant i \leqslant n$. Then the word $y = u_1u_2 \dots u_{i-1}u_{i+1} \dots u_n a v_n \dots v_{i+1}v_{i-1} \dots v_2v_1$ is also in L and $0 < |uv| \leqslant p$
2. $x = u_1x_1x_2v_1$, with $u_1x_1v_1, x_2 \in L$. Next we analyze the word $x_2 \in L$. If the form of this word is the form from 1, it is easy to find the words $u, y, v \in V^*$ satisfying the conditions of the property IBS; otherwise we shall continue our analysis with a subword of x_2, let this word be $x_2^{(1)} \in L$. After a finite number of steps we can, eventually, identify the words $x_2^{(k)}, x_2^{(k+1)} \in L$, with $x_2^{(k+1)} \in Sub(x_2^{(k)})$ and $0 < |x_2^{(k+1)}| \leqslant p$. In this situation choose $u = x_2^{(k+1)}$ and $v = \lambda$. The word y obtained by eliminating the substring $x_2^{(k+1)}$ from the word x is also in L, and $0 < |uv| \leqslant y$.

For the $CSEL$ family, the result is negative:

Lemma 7. *The family $CSEL$ does not posses the IBS property.*

Proof. In order to prove this result, we shall consider the language

$$L = \left\{a^{2^n} | n \geqslant 0\right\}.$$

This language is generated by the following CSEL grammar

$$G = (\{a\}, \{a\}, \varphi),$$

where $\{(\lambda, \lambda)\} \subseteq \varphi\left(a^{2^m}\right)$ for $m \geqslant 1$. This language is not with bounded length increase, because the difference between two consecutive words in this language is $2^k - 2^{k-1}$, for $k > 0$. Consequently, $CSEL$ does not posses the IBS property.

REMARK 2. From the result in Lemma 7 it follows that there are $CSEL$ languages that are not TC. In fact, the families TC and $CSEL$ are incomparable.

Also, from the proof for Lemma 7, one can establish the following Lemma:

Lemma 8. *The family $CSEL$ does not posses the BLI property.*

Proof. It is enough to observe that the proof for Lemma 7 is based on the fact that the property IBS does imply the property BLI.

Now it is not hard to establish a similar result for $CCON_{in}$,

Lemma 9. *The family $CCON_{in}$ does posses the IBS property.*

As for the case of the EBS property, we can introduce the following properties

DEFINITION 10. A language $L \subseteq V^*$ has the $IBSC$ (*internal bounded step with catenation*) property if there is a constant p such that for each $x \in L$, with $|x| > p$, there are $y, z \in L \cup \{\lambda\}$, where $x = x_1 u x_2 z v x_3$ (or $x = x_1 u z x_2 v x_3$), $y = x_1 x_2 x_3$, $|uzv| > 0$ and $|uv| \leqslant p$.

DEFINITION 11. A language $L \subseteq V^*$ has the $LIBSC$ (*limited internal bounded step with catenation*) property if there is a constant p such that for each $x \in L$, with $|x| > p$, there are $y, z \in L \cup \{\lambda\}$, where $x = x_1 u x_2 z v x_3$ (or $x = x_1 u z x_2 v x_3$), $y = x_1 x_2 x_3$, and $0 < |uzv| \leqslant p$.

Now we can prove that

Lemma 10. *The families $CCON_{in}$, $CSEL_{in}$ does posses the $IBSC$ property.*

Proof. Indeed, if $x \in L$ with $|x| > p$, where p is an integer convenable chosen for a language $L \in CSEL_{in}$, it follows that

$$\begin{aligned} x = x_1 u x_2 v x_3, &\quad \text{with} \quad x_1 x_2 x_3 \in L, (u,v) \in C \text{ or} \\ x = x_1 x_2 z x_3, &\quad \text{with} \quad x_1 x_2 x_3 \in L, z \in L \text{ or} \\ x = x_1 z x_2 x_3, &\quad \text{with} \quad x_1 x_2 x_3 \in L, z \in L. \end{aligned}$$

so the language $L \in CSEL_{in}$ posses the $IBSC$ property. One can choose the value p as follows:

$$p = \max\{\max_{(u,v)\in C}\{|uv|\}, \max_{a\in A}\{|a|\}\}.$$

Lemma 11. *Each of the $LIBSC$ and $IBSC$ properties imply the IBS property.*

REMARK 3. Every $CSEL_{in}$ language satisfying the $LIBSC$ property is ICC.

Proof. Let L be a $CSEL_{in}$ language satisfying the $LIBSC$ property and $G = (V, A, C, \varphi)$ be a CSEL$_{in}$ grammar generating the language L, $L = L(G)$. Then in every derivation of a word $x \in L$ we can use only catenation with words from the language $\{z \in V^* || z| \leqslant p\}$.

This language being finite, we can add contexts of the form (λ, z) and (z, λ), where $z \in V^*$, with $|z| \leqslant p$, to the set of contexts, C.

Also, we can modify the selector φ (and construct a selector φ') such that if $\varphi(xz) = \{(\lambda, \lambda)\}$ in the original $CSEL_{in}$ language, we have that $\{(\lambda, z)\} \in \varphi'(x)$.

DEFINITION 12. A language $L \subseteq V^*$ has the IAP property if the length set of L contains infinite arithmetic progression (Păun, 1997).

Lemma 12. *The family $CSEL$ does not posses the IAP property.*

Proof. We shall consider the following sets

$$L_k = \left\{a^i | 2^{2k+1} \leqslant i \leqslant 2^{2(k+1)}\right\}.$$

The language $L = \bigcup_{k \geqslant 0} L_k$ is $CSEL$, but does not have the IAP property.

Indeed, the following CSEL$_{in}$ grammar,

$$G = (\{a\}, \{a, a^2\}, \{(\lambda, \lambda), (\lambda, a)\}, \varphi),$$

where

$$\varphi(a^i a^j) = \begin{cases} \{(\lambda, \lambda)\}, & \text{if} \quad 2^{2(k+1)} \geqslant i + j \geqslant 2^{2k+1},\ k \geqslant 0 \\ \{(\lambda, a)\}, & \text{if} \quad 2^{2(k+1)} > i + j \geqslant 2^{2k+1},\ k \geqslant 0 \end{cases}$$

generates the language $L(G) = \{a^k | 2^{2(k+1)} \geqslant k \geqslant 2^{2k+1}, k \geqslant 0\}$.

Lemma 13. *For languages in $CSEL$ there are no pumping properties.*

Proof. Consider a language $L \subseteq V^*$ and $c \notin V$. Then the language $L_1 = V^* \cup L\{c\}$ is $CSEL$. On the other hand, consider the language L from the proof of Lemma 12. Then no substring of a word $a^i c$, with $a^i \in L$, $i \geqslant 0$ can be pumped.

As expected, the following Lemma holds

Lemma 14. *The families $CCON$, $CCON_{in}$ have the IAP property. The family $CSEL_{in}$ has the IAP property.*

Proof. It is enough to consider a word $x \in L$, where L is a language from $CCON$, $CCON_{in}$. Then each of the words $\underbrace{x \ldots x}_{m}$, with $m \geqslant 1$, is in L.

For the family $CSEL_{in}$ we can construct the following result

Lemma 15. *If $L \subseteq V^*$, $L \in CCON_{in}$, there are two constants p, q such that every $z \in L$, $|z| > p$, can be written in the form $z = uvwxy$ with $u, v, w, x, y \in V^*$, $0 < |vx| \leqslant q$, and $uv^iwx^iy \in L$ for all $i \geqslant 0$.*

Proof. Let us consider the following values for p and q

$$q = 2 \cdot \max\{\max\{|uv|, (u, v) \in C\}, \max\{|z|, z \in A\}\},$$
$$p = 3 \cdot \max\{\max\{|uv|, (u, v) \in C\}, \max\{|z|, z \in A\}\}.$$

Let $z \in L$, with $|z| > p$. Then the word $z \in L$ can be written in one of the following forms:

1. $z = z_1t_1z_2t_2z_3$, with $(t_1, t_2) \in C$, $z_1z_2z_3 \in L$. Choose $u = z_1$, $v = t_1$, $w = z_2$, $x = t_2$ and $y = z_3$. Then $0 < |vx| \leqslant q$. Also, observe that there exist the derivation

$$a \Longrightarrow^* z_1z_2z_3 \Longrightarrow z_1t_1z_2t_2z_3$$
$$\Longrightarrow^* z_1t_1^iz_2t_2^iz_3, \text{ with } a \in A,\ i > 0.$$

   so $uv^iwx^iy \in L$ for all $i \geqslant 0$.

2. $z = z^{(0)} = z_1z_2z^{(1)}z_3$, with $|z^{(1)}| < |z_1z_2z_3|$ ($z = z_1xz_2z_3$, with $|z^{(1)}| < |z_1z_2z_3|$, respectively). In this situation, we focus our attention on the subword $z^{(1)}$ and repeat the analysis for this subword of z. If this subword is of the form 1, then it is easy to finish our proof for this case also. Presume that $z^{(1)}$ is of the same form as $z^{(0)}$. Then, using mathematical induction, we can identify either an axiom $a \in A$ such that $z = z_1'z_2'az_3'$ ($z = z_1'az_2'z_3'$, respectively), and $z_1'z_2'z_3' \in L$; or a context $(t_1, t_2) \in C$, such that $z = z_1't_1'z_2't_2'z_3'$. Then, for the first situation, choose $u = z_1'$, $v = \lambda$, $w = z_2'$, $x = a$, $y = z_3'$. Then $0 < |vx| \leqslant q$. Also, observe that there exist the derivation

$$a_1 \Longrightarrow^* z_1'z_2'z_3' \Longrightarrow z_1'z_2'az_3'$$
$$\Longrightarrow^* z_1'z_2'a^iz_3', \text{ with } a \in A,\ i > 0.$$

For the family $CCON$, since the inclusion $CCON \subseteq CF$ holds, it follows that we can apply the Bar-Hillel Lemma.

Using a similar reasoning, we can produce a similar result for $CSEL_{in}$ languages. Thus, we obtain that exist some pumping properties for the family $CSEL_{in}$ also.

REMARK 4. For $CSEL$ languages, there is no pumping properties, as established in Lemma 13. However, we can define a structure for the words generated by this family of languages by imposing more control in derivation. In this way we can obtain new families of languages, offering more properties (see Fortiş, 1998; Fortiş, 2000 and Vide-Păun, 1998).

References

Fortiş, F. (1998). On fully bracketed languages with finite selection, In *11th Romanyan Symposium on Computer Science (ROSYCS'98)*, Iaşi, 28–30 May, 1998.

Fortiş, F., (2000). Contextual grammars with catenation. closure properties, *Ann. of the Univ. of the West*, Informatics Series, **39**(2), 80–95.

Fortiş, F. (2000). FBICC(FIN) in the Chomsky Hierarchy, In *2nd International Workshop on Symbolic and Numeric Algorithms for Scientific Computing*, SYNASC 2000, Timişoara, Romania, 4–6 Oct. 2000 (also *Ann. of the Univ. of the West*, Informatics Series, vol. 40, **1** (2001)).

Marcus, S. (1969). Deux types nouveaux de grammaires génératives. *Cah. Ling. Th. Appl.*, **6**, 69–74.

Marcus, S. (1969). Contextual grammars. *Rev. Roum. Math. Pures et Appl.*, **14**(10), 1525–1534.

Martín-Vide, C., Gh. Păun (1998). Structured contextual grammars. *Grammars*, **1**(1).

Păun, Gh. (1982). *Contextual Grammars*, Ed. Academiei, Bucureşti, 149 pp. (in Romanian).

Păun, Gh. (1997). *Marcus Contextual Grammars*. Kluwer Academic Publishers, 375 pp.

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Apie grandininių konteksto gramatikų generatyvinę galią. Būtinos sąlygos

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Straipsnyje nagrinėjamos tam tikro grandininių konteksto gramatikų poklasio savybės. Išskiriamos ir analizuojamos kai kurios naujos šio poklasio gramatikomis nusakomų kalbų savybės. Naudojantis šiomis savybėmis yra apibrėžiamos būtinos generavimo sąlygos ir eilučių įsiurbos sąlygos.