Prolog Parsing Assistant for Categorial Grammar*

Luiz Arthur Pagani (UFPR)

http://people.ufpr.br/~arthur
arthur@ufpr.br

*This presentation was prepared with LaTeX, in its Linux implementation — TeTeX— and with an IDE program — Kile — both installed in computers running on a Brazilian distribution of Linux — Kurumin — everything according to the free software guidelines.

1 Introduction

- Quasi-arithmetical notation for linguistic description
- AB-model (Ajdukiewicz & Bar-Hillel) is weakly equivalent to context-free grammar
- Classical Categorial Grammars are mild context-sensitive
- Lambek calculus: generalization by natural deduction
- Structural completeness: "for any syntactically coherent string, any substring can be derived as a constituent and any item in that substring as its head" [2, p. 5]

2 Categorial Grammars

- function and argument relation rather than constituent structure
- syntax and semantics homomorphism
- monotonicity (there are no destructive rules such as movement or deletion)
- radical lexicalism

3 Free Categorial Grammar [1]

3.1 Application (R1)

- $X/Y : \phi \quad Y : \alpha \rightarrow X : (\phi\ \alpha)$
- $Y : \alpha \quad Y\backslash X : \phi \rightarrow X : (\phi\ \alpha)$

$$\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \quad \dfrac{\dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex \quad \dfrac{\text{Maria}}{N : m}\,Lex}{N\backslash S : (A\ m)}\,R1}{S : ((A\ m)\ p)}\,R1$$

3.2 Associativity (R3)

- $(X\backslash Y)/Z : \phi \rightarrow X\backslash(Y/Z) : \lambda x_m.\lambda x_n.((\phi\ x_n)\ x_m)$
- $X\backslash(Y/Z) : \phi \rightarrow (X\backslash Y)/Z : \lambda x_m.\lambda x_n.((\phi\ x_n)\ x_m)$

[x_m and x_n fresh]

3.3 β-reduction

- $(\lambda x_n.\alpha\ \beta) \rightarrow \alpha^{x_n \mapsto \beta}$

$$\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \qquad \dfrac{\dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex}{N\backslash(S/N) : \lambda x_0.\lambda x_1.((A\ x_1)\ x_0)}\,R3}{S/N \;:\; (\lambda x_0.\lambda x_1.((A\ x_1)\ x_0)\ p) =_{\beta-red.} \lambda x_1.((A\ x_1)\ p)}\,R1$$

3.4 Composition (R2)

- $X/Y : \phi \quad Y/Z : \gamma \rightarrow X/Z : \lambda x_n.(\phi\ (\gamma\ x_n))$
- $Z\backslash Y : \gamma \quad Y\backslash X : \phi \rightarrow Z\backslash X : \lambda x_n.(\phi\ (\gamma\ x_n))$

[x_n fresh]

3.5 Raising (R4)

- $X : \alpha \rightarrow Y/(X\backslash Y) : \lambda x_n.(x_n\ \alpha)$
- $X : \alpha \rightarrow (Y/X)\backslash Y : \lambda x_n.(x_n\ \alpha)$

[x_n fresh]

$$\dfrac{\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \qquad \dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex}{S/(N\backslash S) : \lambda x_0.(x_0\ p)}\,R4}{\begin{array}{rcl} S/N & : & \lambda x_1.(\lambda x_0.(x_0\ p)\ (A\ x_1)) \\ & & =_{\beta-red.}\ \lambda x_1.((A\ x_1)\ p) \end{array}}\,R2$$

4 Parsing Assistant (sample session)

```
$ swipl
Welcome to SWI-Prolog...
?- [agcl].

     *----------------------------------*
     | Assistente de Análise Gramatical |
     |                para              |
     |    Gramática Categorial Livre    |
     *----------------------------------*
     |        Luiz Arthur Pagani        |
     |          arthur@ufpr.br          |
     *----------------------------------*

Expressão: [pedro,ama,maria].
```

```
1.
n : p, por lx
   pedro

2.
(n\s)/n : A, por lx
   ama

3.
n : m, por lx
   maria


Análise: r4(3, \).
```

$$\frac{\text{Pedro}}{N : p}\ Lex \qquad \frac{\text{ama}}{(N\backslash S)/N : A}\ Lex \qquad \frac{\text{Maria}}{N : m}\ Lex$$

```
1.
n : p, por lx
   pedro

2.
(n\s)/n : A, por lx
   ama

3.
(y_0/n)\y_0 : lambda-x_0.(x_0 m), por r4
   n : m, por lx
      maria


Análise: r3 2.
```

$$\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \qquad \dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex \qquad \dfrac{\dfrac{\text{Maria}}{N : m}\,Lex}{(y_0\backslash N)/y_0 : \lambda x_0.(x_0\ m)}\,R4}{}$$

```
1.
n : p, por lx
   pedro

2.
n\(s/n) : lambda-x_1.lambda-x_2.((A x_2) x_1), por r3
   (n\s)/n : A, por lx
      ama

3.
(y_0/n)\y_0 : lambda-x_0.(x_0 m), por r4
   n : m, por lx
      maria


Análise: r2 3.
```

$$\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \qquad \dfrac{\dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex \qquad \dfrac{\text{Maria}}{N : m}\,Lex}{N\backslash(S/N) : \lambda x_1.\lambda x_2.((A\ x_2)\ x_1)}\,R3}{(y_0\backslash N)/y_0 : \lambda x_0.(x_0\ m)}\,R4$$

```
1.
n : p, por lx
   pedro

2.
n\s : lambda-x_3.(lambda-x_0.(x_0 m) (lambda-x_1.lambda-x_2.((A x_2) x_1) x_3)), por r2
   n\(s/n) : lambda-x_1.lambda-x_2.((A x_2) x_1), por r3
      (n\s)/n : A, por lx
         ama
   (s/n)\s : lambda-x_0.(x_0 m), por r4
      n : m, por lx
         maria


Análise: red 2.
```

$$\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \qquad \dfrac{\dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex \qquad \dfrac{\text{Maria}}{N : m}\,Lex}{N\backslash(S/N) : \lambda x_1.\lambda x_2.((A\ x_2)\ x_1)}\,R3 \qquad \dfrac{}{(S\backslash N)/S : \lambda x_0.(x_0\ m)}\,R4}{N\backslash S : \lambda x_3.(\lambda x_0.(x_0\ m)\ (\lambda x_1.\lambda x_2.((A\ x_2)\ x_1)\ x_3))}\,R2$$

($\beta-$reduction $\times 3$)

```
1.
n : p, por lx
   pedro

2.
n\s : lambda-x_3.((A m) x_3), por redução-beta
   n\s : lambda-x_3.(lambda-x_2.((A x_2) x_3) m), por redução-beta
      n\s : lambda-x_3.((lambda-x_1.lambda-x_2.((A x_2) x_1) x_3) m), por redução-beta
         n\s : lambda-x_3.(lambda-x_0.(x_0 m) (lambda-x_1.lambda-x_2.((A x_2) x_1) x_3)), por r2
            n\(s/n) : lambda-x_1.lambda-x_2.((A x_2) x_1), por r3
               (n\s)/n : A, por lx
                  ama
            (s/n)\s : lambda-x_0.(x_0 m), por r4
               n : m, por lx
                  maria
```

Análise: r1 2.

$$\dfrac{\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \qquad \dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex}{N\backslash(S/N) : \lambda x_1.\lambda x_2.((A\ x_2)\ x_1)}\,R3 \qquad \dfrac{\text{Maria}}{N : m}\,Lex}{(S\backslash N)/S : \lambda x_0.(x_0\ m)}\,R4}{N\backslash S :\ \lambda x_3.(\lambda x_0.(x_0\ m)\ (\lambda x_1.\lambda x_2.((A\ x_2)\ x_1)\ x_3))}\,R2$$

$$=_{\beta-red.}\ \lambda x_3.((\lambda x_1.\lambda x_2.((A\ x_2)\ x_1)\ x_3)\ m)$$
$$=_{\beta-red.}\ \lambda x_3.(\lambda x_2.((A\ x_2)\ x_3)\ m)$$
$$=_{\beta-red.}\ \lambda x_3.((A\ m)\ x_3)$$

```
1.
s : (lambda-x_3.((A m) x_3) p), por r1
   n : p, por lx
      pedro
   n\s : lambda-x_3.((A m) x_3), por redução-beta
      n\s : lambda-x_3.(lambda-x_2.((A x_2) x_3) m), por redução-beta
         n\s : lambda-x_3.((lambda-x_1.lambda-x_2.((A x_2) x_1) x_3) m), por redução-beta
            n\s : lambda-x_3.(lambda-x_0.(x_0 m) (lambda-x_1.lambda-x_2.((A x_2) x_1) x_3)), por r2
               n\(s/n) : lambda-x_1.lambda-x_2.((A x_2) x_1), por r3
                  (n\s)/n : A, por lx
                     ama
               (s/n)\s : lambda-x_0.(x_0 m), por r4
                  n : m, por lx
                     maria


Análise: red 1.
```

$$\dfrac{\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \qquad \dfrac{\dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex}{N\backslash(S/N) : \lambda x_1.\lambda x_2.((A\ x_2)\ x_1)}\,R3 \qquad \dfrac{\dfrac{\text{Maria}}{N : m}\,Lex}{(S\backslash N)/S : \lambda x_0.(x_0\ m)}\,R4}{\begin{array}{rl} N\backslash S : & \lambda x_3.(\lambda x_0.(x_0\ m)\ (\lambda x_1.\lambda x_2.((A\ x_2)\ x_1)\ x_3)) \\ & =_{\beta-red.}\ \lambda x_3.((\lambda x_1.\lambda x_2.((A\ x_2)\ x_1)\ x_3)\ m) \\ & =_{\beta-red.}\ \lambda x_3.(\lambda x_2.((A\ x_2)\ x_3)\ m) \\ & =_{\beta-red.}\ \lambda x_3.((A\ m)\ x_3) \end{array}}\,R2}{S : (\lambda x_3.((A\ m)\ x_3)\ p)}\,R1$$

```
1.
s : ((A m) p), por redução-beta
   s : (lambda-x_3.((A m) x_3) p), por r1
      n : p, por lx
         pedro
      n\s : lambda-x_3.((A m) x_3), por redução-beta
         n\s : lambda-x_3.(lambda-x_2.((A x_2) x_3) m), por redução-beta
            n\s : lambda-x_3.((lambda-x_1.lambda-x_2.((A x_2) x_1) x_3) m), por redução-beta
               n\s : lambda-x_3.(lambda-x_0.(x_0 m) (lambda-x_1.lambda-x_2.((A x_2) x_1) x_3)), por r2
                  n\(s/n) : lambda-x_1.lambda-x_2.((A x_2) x_1), por r3
                     (n\s)/n : A, por lx
                        ama
                  (s/n)\s : lambda-x_0.(x_0 m), por r4
                     n : m, por lx
                        maria
Análise: ajuda.
```

$$\dfrac{\dfrac{\dfrac{\dfrac{\text{Pedro}}{N : p}\,Lex \qquad \dfrac{\text{ama}}{(N\backslash S)/N : A}\,Lex}{N\backslash(S/N) : \lambda x_1.\lambda x_2.((A\ x_2)\ x_1)}\,R3 \qquad \dfrac{\text{Maria}}{N : m}\,Lex}{(S\backslash N)/S : \lambda x_0.(x_0\ m)}\,R4}{\begin{array}{rl} N\backslash S : & \lambda x_3.(\lambda x_0.(x_0\ m)\ (\lambda x_1.\lambda x_2.((A\ x_2)\ x_1)\ x_3)) \\ & =_{\beta-red.}\ \lambda x_3.((\lambda x_1.\lambda x_2.((A\ x_2)\ x_1)\ x_3)\ m) \\ & =_{\beta-red.}\ \lambda x_3.(\lambda x_2.((A\ x_2)\ x_3)\ m) \\ & =_{\beta-red.}\ \lambda x_3.((A\ m)\ x_3) \end{array}}\,R2$$

$$\dfrac{}{\begin{array}{rl} S : & (\lambda x_3.((A\ m)\ x_3)\ p) \\ & =_{\beta-red.}\ ((A\ m)\ p) \end{array}}\,R1$$

```
r1(N) ou r1 N          : R1 a partir de N
r2(N) ou r2 N          : R2 a partir de N
r3(N) ou r3 N          : R3 em N
r4(N) ou r4 N          : R4 em N (o assistente vai solicitar o conectivo principal)
r4(N, C)               : R4 em N usando C (/ ou \\) como conectivo principal
red(N) ou red N        : redução-beta da representação semântica em N
desfaz(N) ou desfaz N : desfaz a última operação em N
análise                : mostra novamente a análise já feita
nova                   : solicita uma nova expressão para ser analisada
encerra                : encerra o assistente de análise gramatical

Análise: encerra.

Análise encerrada.
$
```

5 Conclusions

- Mainly a didactic tool
- But a step by step processing model – psycholinguistics interrest
- Easily adaptable to Classical Categorial Grammar and Lambek calculus
- To do list
  - complete lambda calculus?
  - linguistic data
  - syntactic variable presentation
  - graphical interface

References

[1] Joel M. Cohen. The equivalence of two concepts of categorial grammar. *Information and Control*, 10:475–484, 1967.

[2] Mary McGee Wood. *Categorial Grammars*. Routledge, London, 1993.

Prolog Parsing Assistant for Categorial Grammar