Ocampiler

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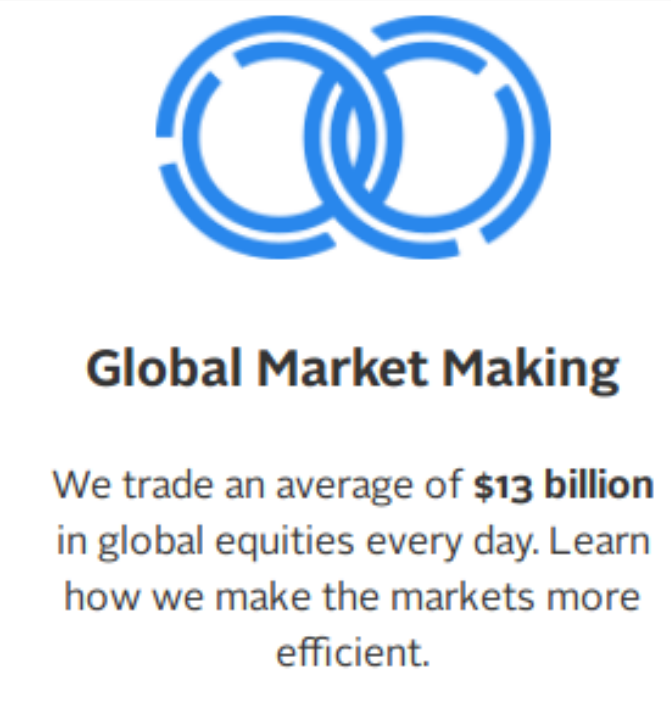
Introdução - O OCAML

- Ocaml é uma linguagem funcional da família ML desenvolvida pelo INRIA (Instituto Nacional de Pesquisa em Informática e Automação da França) em 1996
- Usado pela Jane Street
- Usado pelo COQ (Provador de Teoremas)

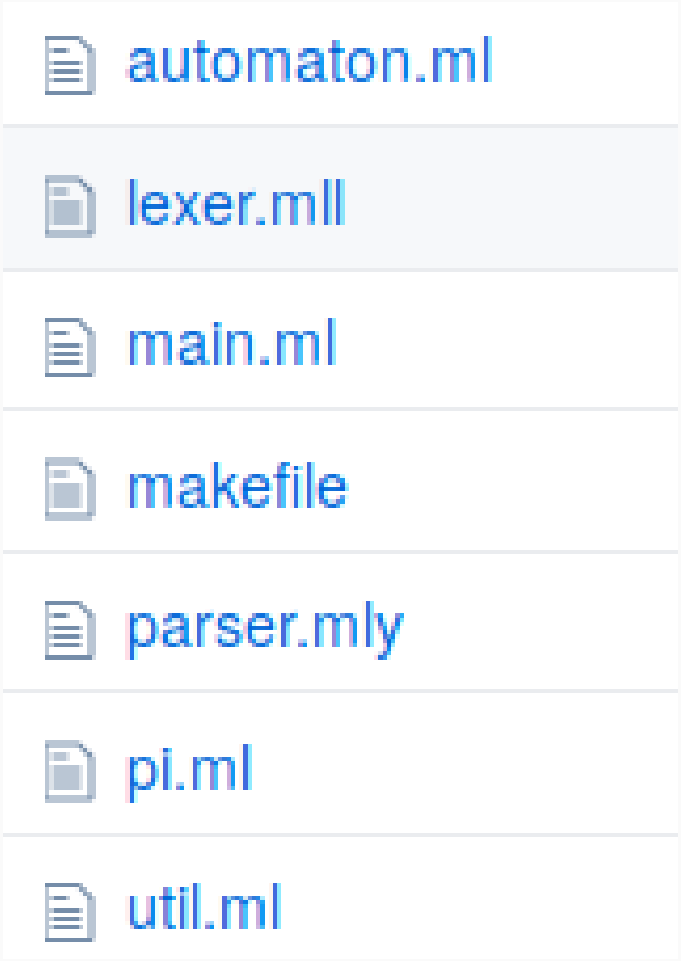


Ambientação ao OCAML X Desafios

- Documentação da linguagem, Real World OCAM, Tutoriais Oficiais e Inria
- Dificuldades para definir a estrutura do projeto (de classes para Variants)
- O desafio da recursão mutua

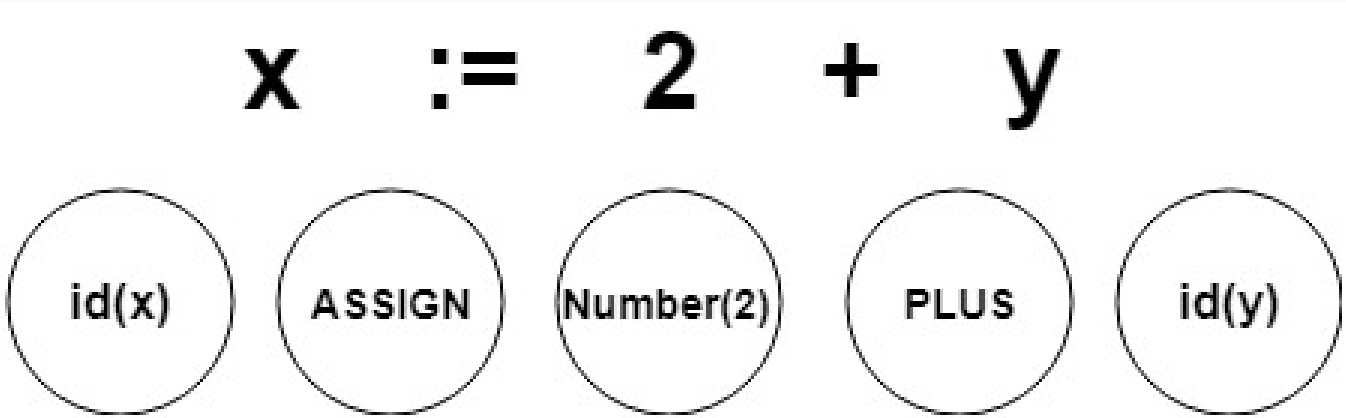
```
type arithmeticExpression =
  | Num of int
  | Sum of expression * expression
  | Sub of expression * expression
  | Mul of expression * expression
  | Div of expression * expression

and booleanExpression =
  | Boo of bool
  | Eq of expression * expression
  | Lt of expression * expression
  | Le of expression * expression
  | Gt of expression * expression
  | Ge of expression * expression
  | And of expression * expression
  | Or of expression * expression
  | Not of expression

and expression =
  | AExp of arithmeticExpression
  | BExp of booleanExpression
  | Id of string
```

Estrutura do Projeto



O Lexer - Ocamllex

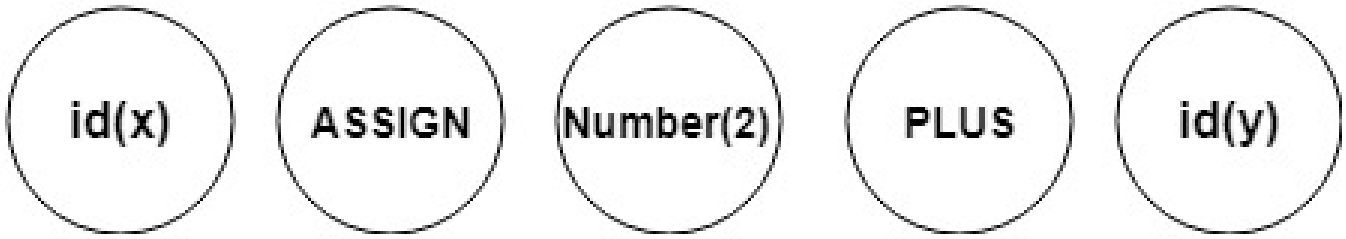
- É um comando que produz um analisador léxico de um conjunto de expressões regulares com ações associadas, gerando tokens.




```
rule token = parse
    [' ' '\t' '\r' '\n'  ]   { token lexbuf }     (* skip blanks *)
  | ['0'-'9']+ as  lxm       { NUMBER( int_of_string lxm) }
  | '+'                      { PLUS }
  | ":="                     { ASSIGN }
  | (['a'-'z' 'A'-'Z' '_'] ['a'-'z' 'A'-'Z' '0'-'9' '_']*) as  lxm      { ID(lxm) }
```

O Parser - Ocamlyacc

- Ocamlyacc é um Parser Generator de propósito geral que converte uma descrição de uma gramática para uma LALR(1) (Look Ahead Left to Right) em um programa Ocaml para realizar o parser da gramática.
- ASSIGN (ID (x), SUM (NUM (2), ID (y)))



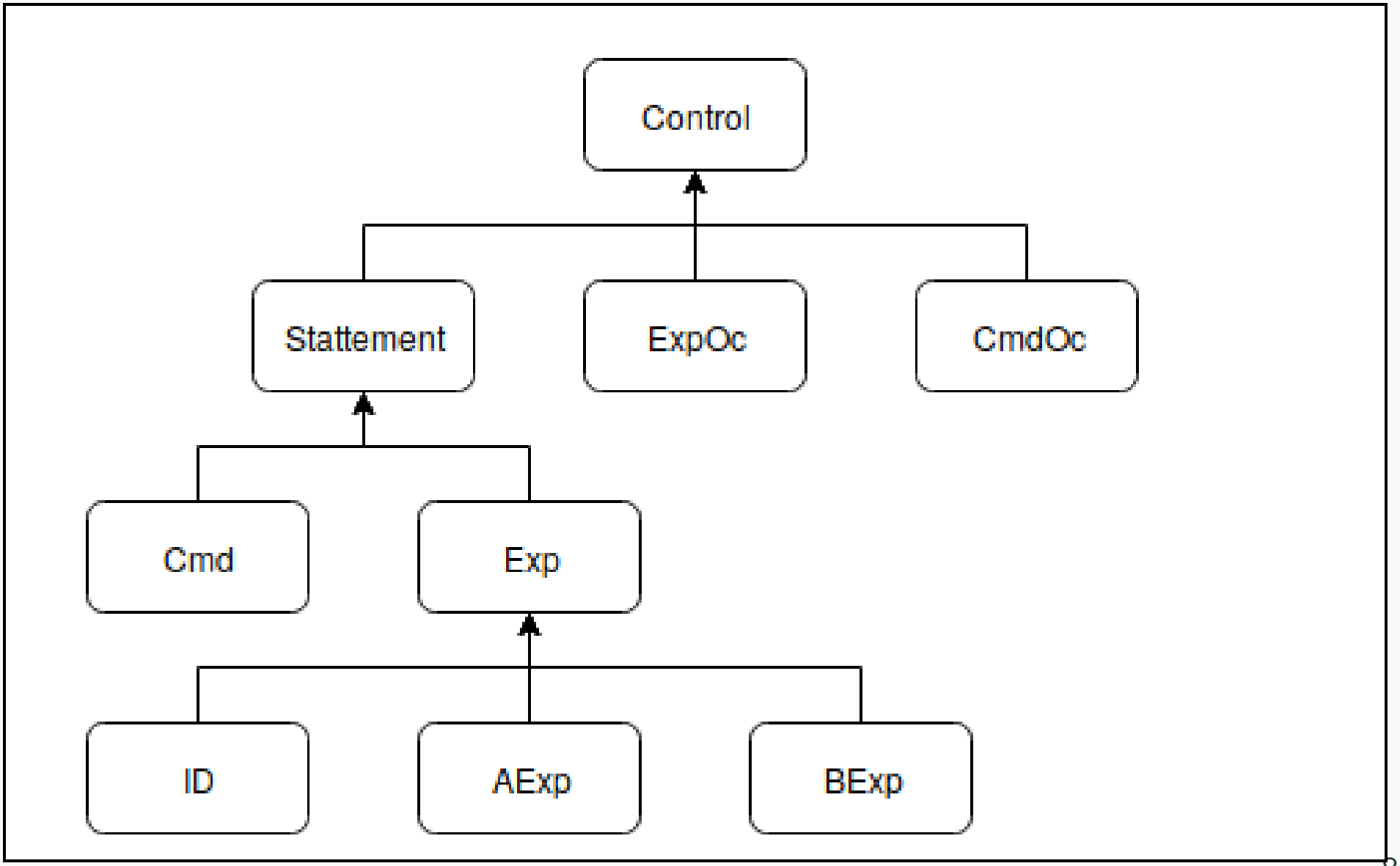
O Parser - Ocamlyacc

```
statement:
   expression { Pi.Exp($1)}
   | command       {Pi.Cmd($1)}
;
```

```
expression:
    arithmeticExpression                    { Pi.AExp( $1) }
    | booleanExpression                     { Pi.BExp( $1) }
    | ID                                    { Pi.Id( $1) }
    | LPAREN expression RPAREN              { $2 }
```

```
arithmeticExpression:
  NUMBER                                                { Pi.Num($1) }
  | arithmeticExpression PLUS arithmeticExpression      { Pi.Sum(Pi.AExp($1), Pi.AExp($3) ) }
  | arithmeticExpression PLUS ID                        { Pi.Sum(Pi.AExp($1), Pi.Id($3) ) }
  | ID PLUS arithmeticExpression                        { Pi.Sum(Pi.Id($1), Pi.AExp($3) ) }
  | ID PLUS ID                                          { Pi.Sum(Pi.Id($1), Pi.Id($3) ) }
```

Pi.ml



Automaton.ml

$$\delta(Sum(E_1, E_2) :: C, V, S) = \delta(E_1 :: E_2 :: \#SUM :: C, V, S)$$

$$\delta(\#SUM :: C, Num(N_1) :: Num(N_2) :: V, S) = \delta(C, N_1 + N_2 :: V, S)$$

```
| Sum(AExp(x), AExp(y)) -> (
  (Stack.push (ExpOc(OPSUM)) controlStack);
  (Stack.push (Statement(Exp(AExp(y)))) controlStack);
  (Stack.push (Statement(Exp(AExp(x)))) controlStack);
| Sum(Id(x), AExp(y)) -> (
  (Stack.push (ExpOc(OPSUM)) controlStack);
  (Stack.push (Statement(Exp(AExp(y)))) controlStack);
  (Stack.push (Statement(Exp(Id(x)))) controlStack);
| Sum(AExp(x), Id(y)) ->  (
  (Stack.push (ExpOc(OPSUM)) controlStack);
  (Stack.push (Statement(Exp(Id(y)))) controlStack);
  (Stack.push (Statement(Exp(AExp(x)))) controlStack);
| Sum(Id(x), Id(y)) ->  (
  (Stack.push (ExpOc(OPSUM)) controlStack);
  (Stack.push (Statement(Exp(Id(y)))) controlStack);
  (Stack.push (Statement(Exp(Id(x)))) controlStack);
```

Automaton.ml

$$\delta(Sum(E_1, E_2) :: C, V, S) = \delta(E_1 :: E_2 :: \#SUM :: C, V, S)$$
$$\delta(\#SUM :: C, Num(N_1) :: Num(N_2) :: V, S) = \delta(C, N_1 + N_2 :: V, S)$$

```
| ExpOc(expOc) -> (
  match expOc with
  | OPSUM -> (
    let x = (Stack.pop valueStack) in
      match x with
        | Int(i) -> (
          let y = (Stack.pop valueStack) in
          match y with
            | Int(j) -> (
              (Stack.push (Int(i + j)) valueStack);

            );
            | _ -> raise (AutomatonException "error on #SUM");
        );
        | _ -> raise (AutomatonException "erro on #SUM");
```

Automaton.ml

$$\delta(Not(E) :: C, V, S) = \delta(E :: \#NOT :: C, V, S)$$
$$\delta(\#NOT :: C, Boo(True) :: V, S) = \delta(C, False :: V, S)$$
$$\delta(\#NOT :: C, Boo(False) :: V, S) = \delta(C, True :: V, S)$$

```
| Not(BExp(x)) -> (
  (Stack.push (ExpOc(OPNOT)) controlStack);
  (Stack.push (Statement(Exp(BExp(x)))) controlStack);

);
| Not(Id(x)) -> (
  (Stack.push (ExpOc(OPNOT)) controlStack);
  (Stack.push (Statement(Exp(Id(x)))) controlStack);
```

Automaton.ml

$$\delta(Not(E) :: C, V, S) = \delta(E :: \#NOT :: C, V, S)$$

$$\delta(\#NOT :: C, Boo(True) :: V, S) = \delta(C, False :: V, S)$$

$$\delta(\#NOT :: C, Boo(False) :: V, S) = \delta(C, True :: V, S)$$

```
| OPNOT -> (
  let x = (Stack.pop valueStack) in
    match x with
      | Bool(i) -> (
        (Stack.push (Bool(not(i))) valueStack);
      );

      | _ -> raise (AutomatonException "erro on #NOT");
    );
```

Automaton.ml

$$\delta(Lt(E_1, E_2) :: C, V, S) = \delta(E_1 :: E_2 :: \#LT :: C, V, S)$$

$$\delta(\#LT :: C, Num(N_1) :: Num(N_2) :: V, S) = \delta(C, N_1 < N_2 :: V, S)$$

```
| Lt(AExp(x), AExp(y)) -> (
  (Stack.push (ExpOc(OPLT)) controlStack);
  (Stack.push (Statement(Exp(AExp(y)))) controlStack);
  (Stack.push (Statement(Exp(AExp(x)))) controlStack);
| Lt(AExp(x), Id(y)) -> (
  (Stack.push (ExpOc(OPLT)) controlStack);
  (Stack.push (Statement(Exp(Id(y)))) controlStack);
  (Stack.push (Statement(Exp(AExp(x)))) controlStack);
| Lt(Id(x), AExp(y)) -> (
  (Stack.push (ExpOc(OPLT)) controlStack);
  (Stack.push (Statement(Exp(AExp(y)))) controlStack);
  (Stack.push (Statement(Exp(Id(x)))) controlStack);
| Lt(Id(x), Id(y)) -> (
  (Stack.push (ExpOc(OPLT)) controlStack);
  (Stack.push (Statement(Exp(Id(y)))) controlStack);
  (Stack.push (Statement(Exp(Id(x)))) controlStack);
```

Automaton.ml

$\delta(Lt(E_1, E_2) :: C, V, S) = \delta(E_1 :: E_2 :: \#LT :: C, V, S)$

$\delta(\#LT :: C, Num(N_1) :: Num(N_2) :: V, S) = \delta(C, N_1 < N_2 :: V, S)$

```
| OPLT -> (
  let x = (Stack.pop valueStack) in
    match x with
      | Bool(i) -> (
        let y = (Stack.pop valueStack) in
        match y with
          | Bool(j) -> (
            (Stack.push (Bool(j < i)) valueStack);

          );
          | _ -> raise (AutomatonException "erro on #OPLT");
      );
      | Int(i) -> (
        let y = (Stack.pop valueStack) in
        match y with
          | Int(j) -> (
            (Stack.push ( Bool ( j < i)) valueStack);

          );
          | _ -> raise (AutomatonException "erro on #OPLT");
```

Automaton.ml

$$\delta(Id(W) :: C, V, E, S) = \delta(C, B :: V, E, S), \text{where } E[W] = l \wedge S[l] = B,$$

```
| Id(id) -> (
  let key = Hashtbl.find environment id  in
    match key with
      | Value(x) -> ();
      | Loc(x) -> (
        let value = Hashtbl.find memory x  in
          match value with
          | Integer(x) ->   (Stack.push (Int(x)) valueStack);
          | Boolean(x) ->  (Stack.push (Bool(x)) valueStack);
      )
  );
```

Automaton.ml

$\delta(Assign(W, X) :: C, V, E, S) = \delta(X :: \#ASSIGN :: C, W :: V, E, S')$,
$\delta(\#ASSIGN :: C, T :: W :: V, E, S) = \delta(C, V, E, S')$, where $E[W] = l \wedge S' = S/[l \mapsto T]$,

```
| Assign(Id(x), y) -> (
    (Stack.push (CmdOc(OPASSIGN)) controlStack );
    (Stack.push (Statement(Exp(y))) controlStack );
    (Stack.push (Str(x)) valueStack);
```

Automaton.ml

$\delta(Assign(W, X) :: C, V, E, S) = \delta(X :: \#ASSIGN :: C, W :: V, E, S')$,
$\delta(\#ASSIGN :: C, T :: W :: V, E, S) = \delta(C, V, E, S')$, where $E[W] = l \wedge S' = S/[l \mapsto T]$,

```
| OPASSIGN -> (
  let value = (Stack.pop valueStack) in
    let id = (Stack.pop valueStack) in
      match id with
      | Str(x) -> (
        let env = (Hashtbl.find environment x ) in
          match env with
          | Loc(l) -> (
            match value with
            | Int(i) -> (
              (Hashtbl.replace memory l (Integer(i)));
            );
            | Bool(b) -> (
              (Hashtbl.replace memory l (Boolean(b)));
            );
            | _ -> raise (AutomatonException "erro on #assign")

          );
          | Value(v) -> (

          );

      );
      | _ -> raise (AutomatonException "error on #assign")
```

Automaton.ml

$$\delta(Loop(X, M) :: C, V, E, S) = \delta(X :: \#LOOP :: C, Loop(X, M) :: V, E, S),$$
$$\delta(\#LOOP :: C, Boo(true) :: Loop(X, M) :: V, E, S) = \delta(M :: Loop(X, M) :: C, V, E, S),$$
$$\delta(\#LOOP :: C, Boo(false) :: Loop(X, M) :: V, E, S) = \delta(C, V, E, S),$$

```
| Loop( BExp(x), y) -> (
  (Stack.push (CmdOc(OPLOOP)) controlStack);
  (Stack.push (Statement(Exp(BExp(x)))) controlStack );
  (Stack.push (Cmd_to_vstack(Statement(Cmd(Loop(BExp(x), y))))) valueStack );

);
| Loop(Id(x), y) -> (
  (Stack.push (CmdOc(OPLOOP)) controlStack);
  (Stack.push (Statement(Exp(Id(x)))) controlStack );
  (Stack.push (Cmd_to_vstack(Statement(Cmd(Loop(Id(x), y))))) valueStack );
```

Automaton.ml

$\delta(Loop(X, M) :: C, V, E, S) = \delta(X :: \#LOOP :: C, Loop(X, M) :: V, E, S)$,
$\delta(\#LOOP :: C, Boo(true) :: Loop(X, M) :: V, E, S) = \delta(M :: Loop(X, M) :: C, V, E, S)$,
$\delta(\#LOOP :: C, Boo(false) :: Loop(X, M) :: V, E, S) = \delta(C, V, E, S)$,

```
| OPLOOP -> (
  let condloop = (Stack.pop valueStack) in
    let loopV = (Stack.pop valueStack) in
    match condloop with
      | Bool(true) -> (
        match loopV with
          | Cmd_to_vstack(Statement(Cmd(Loop(x,m)))) -> (

            (Stack.push (Statement(Cmd(Loop(x,m)))) controlStack);
            (Stack.push (Statement(Cmd(m))) controlStack);

          )
          | _ -> raise (AutomatonException "erro on #LOOP");
      );
      | Bool(false) -> ();  (* Não faz nada já que o pop foi feito antes *)
      | _ -> raise (AutomatonException "error on #loop")
```

Automaton.ml

$$\delta(Cond(X, M_1, M_2) :: C, V, E, S) = \delta(X :: \#COND :: C, Cond(X, M_1, M_2) :: V, E, S),$$
$$\delta(\#COND :: C, Boo(true) :: Cond(X, M_1, M_2) :: V, E, S) = \delta(M_1 :: C, V, E, S),$$
$$\delta(\#COND :: C, Boo(false) :: Cond(X, M_1, M_2) :: V, E, S) = \delta(M_2 :: C, V, E, S),$$

```
| Cond(BExp(x), y, z) -> (
  (Stack.push (CmdOc(OPCOND)) controlStack);
  (Stack.push (Statement(Exp(BExp(x)))) controlStack );
  (Stack.push (Cmd_to_vstack(Statement(Cmd(Cond(BExp(x), y, z))))) valueStack );

);
| Cond(Id(x), y, z) -> (
  (Stack.push (CmdOc(OPCOND)) controlStack);
  (Stack.push (Statement(Exp(Id(x)))) controlStack );
  (Stack.push (Cmd_to_vstack(Statement(Cmd(Cond(Id(x), y, z))))) valueStack );
```

Automaton.ml

$\delta(Cond(X, M_1, M_2) :: C, V, E, S) = \delta(X :: \#COND :: C, Cond(X, M_1, M_2) :: V, E, S)$,
$\delta(\#COND :: C, Boo(true) :: Cond(X, M_1, M_2) :: V, E, S) = \delta(M_1 :: C, V, E, S)$,
$\delta(\#COND :: C, Boo(false) :: Cond(X, M_1, M_2) :: V, E, S) = \delta(M_2 :: C, V, E, S)$,

```
| OPCOND -> (
  let ifcond = (Stack.pop valueStack) in
    let condV = (Stack.pop valueStack) in
    match ifcond with
      | Bool(true) -> (
        match condV with
          | Cmd_to_vstack(cond) ->(
            match cond with
            | (Statement(Cmd(Cond(x,m1,m2)))) -> (
              (Stack.push (Statement(Cmd(m1))) controlStack);
            )
            | _ -> raise (AutomatonException "erro on #COND 1");
          )
          | _ -> raise (AutomatonException "erro on #COND 2");
      );
```

Automaton.ml

$\delta(Cond(X, M_1, M_2) :: C, V, E, S) = \delta(X :: \#COND :: C, Cond(X, M_1, M_2) :: V, E, S)$,
$\delta(\#COND :: C, Boo(true) :: Cond(X, M_1, M_2) :: V, E, S) = \delta(M_1 :: C, V, E, S)$,
$\delta(\#COND :: C, Boo(false) :: Cond(X, M_1, M_2) :: V, E, S) = \delta(M_2 :: C, V, E, S)$,

```
| Bool(false) -> (
  match condV with
    | Cmd_to_vstack(cond) ->(
      match cond with
      | (Statement(Cmd(Cond(x,m1,m2)))) -> (
        (Stack.push (Statement(Cmd(m2))) controlStack);
      );
      | _ -> raise (AutomatonException "erro on #COND 3");
    )
    | _ -> raise (AutomatonException "erro on #COND 4");
);
| _ -> raise (AutomatonException "erro on #COND 5" );
```

Exemplos

- Vejamos agora alguns exemplos...

- Fatorial

- Fibonacci