La transpilation de Fortran vers C

Présentation de **Erwan FALAUX-BACHELOT**

travail réalisé avec Yann MIQUEL–ERDMANN

Introduction

Le Fortran : F
Créé par : IMB en 1954
Utilisé surtout dans les supercalculateurs

Problématique

Comment implémenter une conversion rapide de programmes Fortran en programmes C ?

Les expressions régulières

- Expressions régulières
- Automates

définies inductivement sur :

$$\emptyset,\ \varepsilon,\ a \in \Sigma$$

Analyse Lexicale → Analyse Syntaxique → Syntaxe Abstraite → Conversion

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et des additionnelles :

$+,\ ?,\ [a-z],\ \sim$

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$+,\ ?,\ [a - z],\ \sim$

exemple :

[0 - 9]+ (.[0 - 9]+) ?

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exemple :

$\boxed{[0\text{ - }9]+}\,(.[0\text{ - }9]+)\,?$

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$$(\Sigma, Q, I, F, \delta)$$

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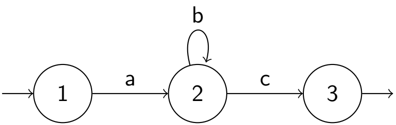
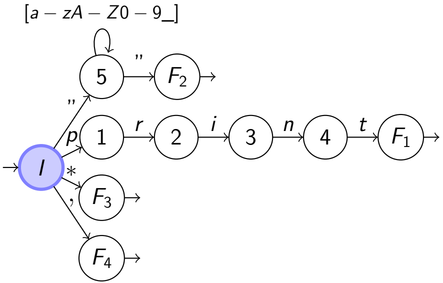


automate pour $a \cdot b * \cdot c$

Les automates : étude d'un exemple

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print*,"Hello World"
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res = [ ]
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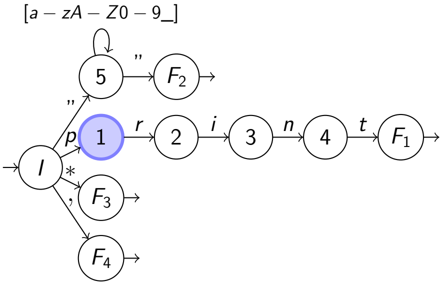


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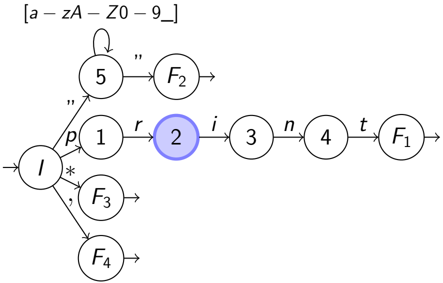

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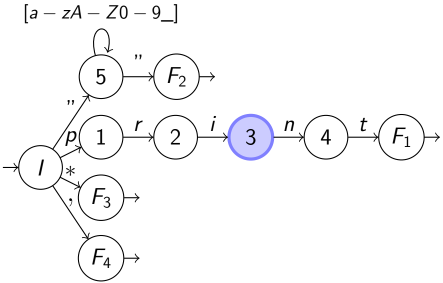

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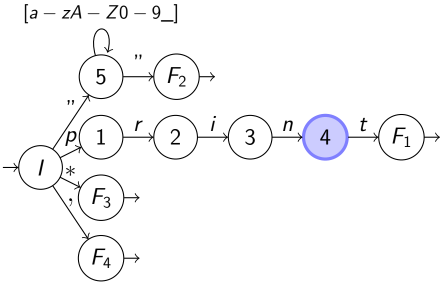


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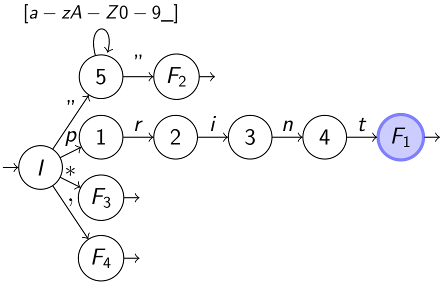


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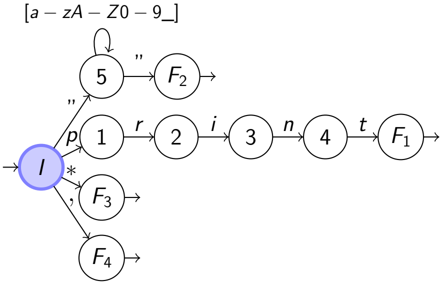

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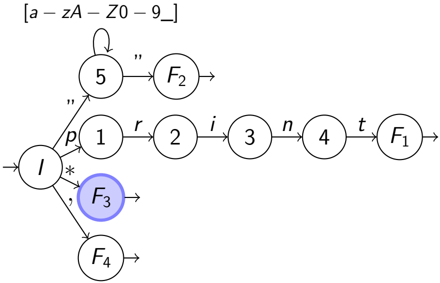


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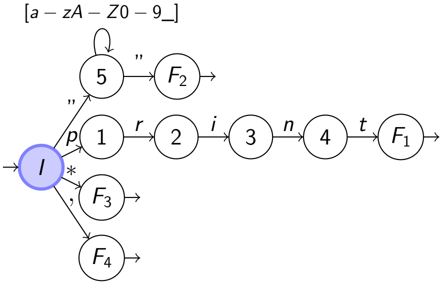


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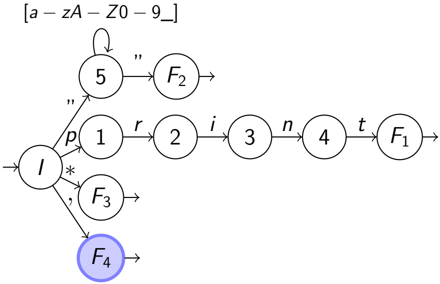

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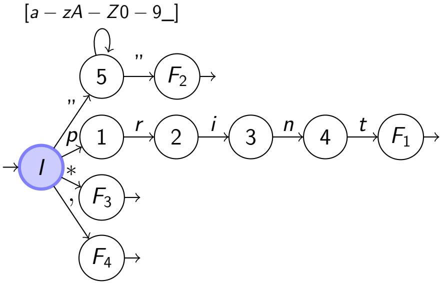

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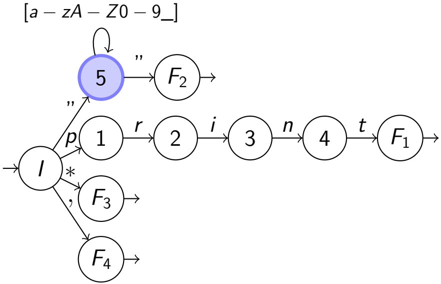


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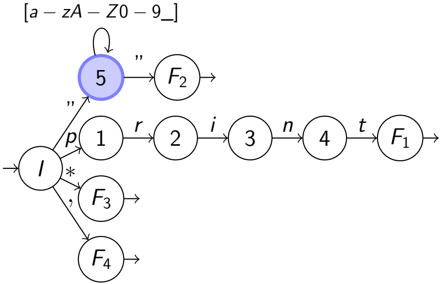


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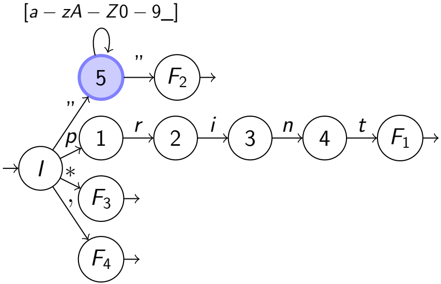


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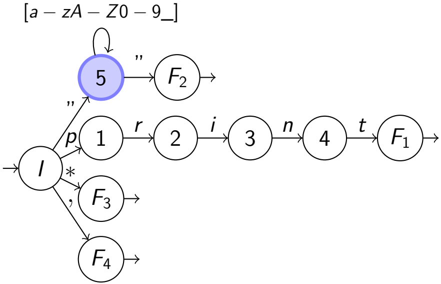

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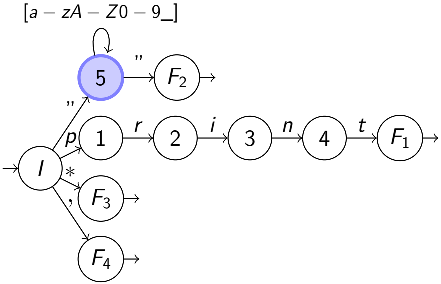


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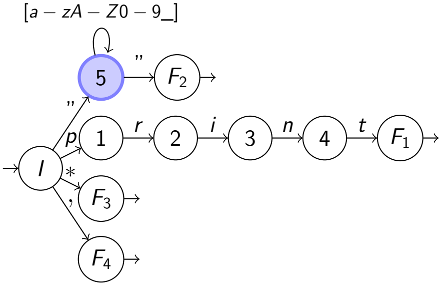

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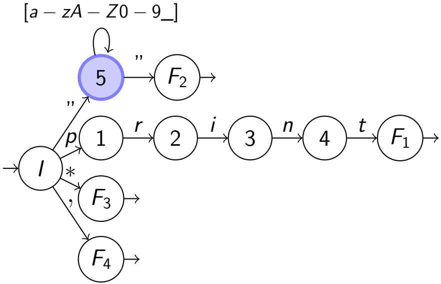

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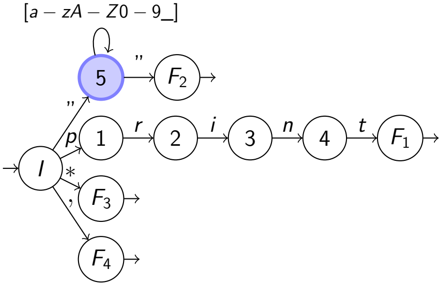


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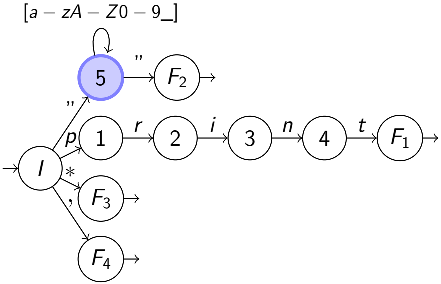

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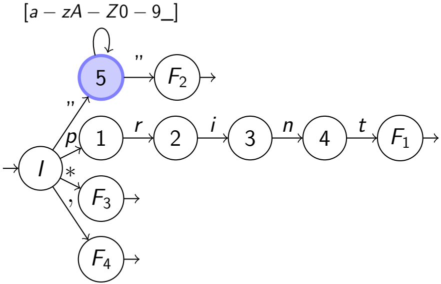


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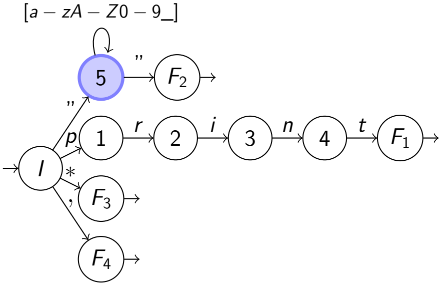

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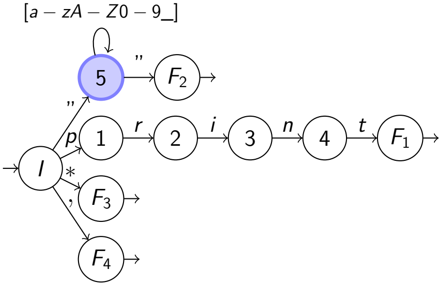

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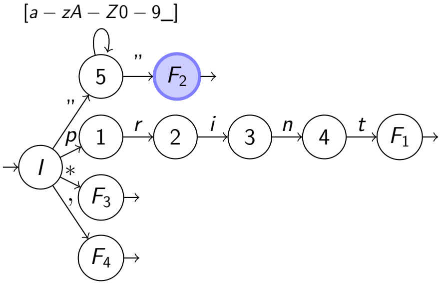

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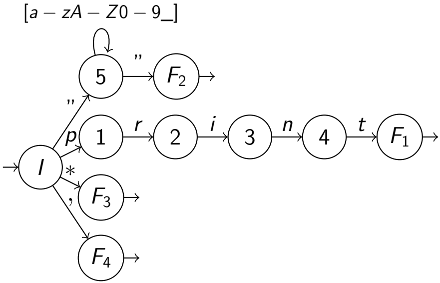
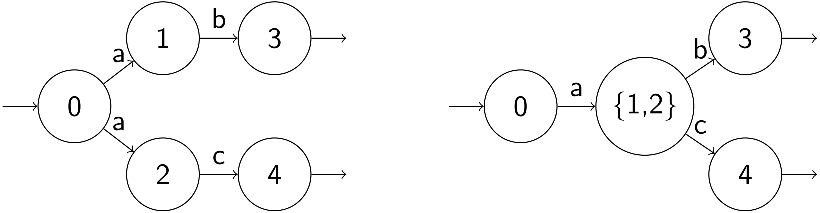
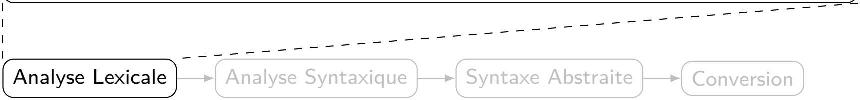


`print*,"Hello World"`

`res = [ 'print' , '*' , ',' , '"Hello World"' ]`

La déterminisation





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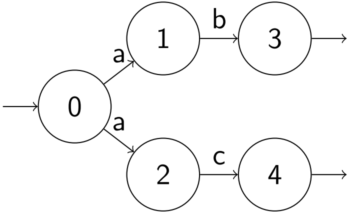
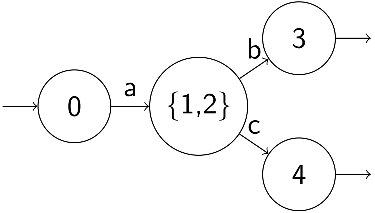



```
type automate = {
  nodes : int list;
  debut_l : int list;
  fin : (int * terminal) list;
  transitions : (char option * int) list array;
}
```

Analyse Lexicale → Analyse Syntaxique → Syntaxe Abstraite → Conversion

La déterminisation

```
type automate_det = {
  nodes : int list;
  debut : int;
  fin : terminal option
    ↪  array;
  transitions : int array
    ↪  array;
}
```



Analyse Syntaxique

- Grammaire
- LL1

Règles de production :

`A -> B`

`A ->` $c, c \in \Sigma^*$

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- Grammaire
- LL1

Règles de production :

A -> B

A -> $c, c \in \Sigma^*$

Exemple :

```
S -> A
A -> aA
A -> B
B -> bB
B -> epsilon
```

Analyse Lexicale → **Analyse Syntaxique** → Syntaxe Abstraite → Conversion

Analyse Syntaxique

- Grammaire
- LL1

```
      S
      |
      A
     / \
    a   A
        |
        B
       / \
      b   B
          |
          ε
```

Arbre de dérivation de ab

Règles de production :

`A -> B`

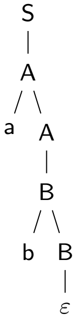
`A ->` $c, c \in \Sigma^*$

Exemple :

```
S -> A
A -> aA
A -> B
B -> bB
B -> epsilon
```

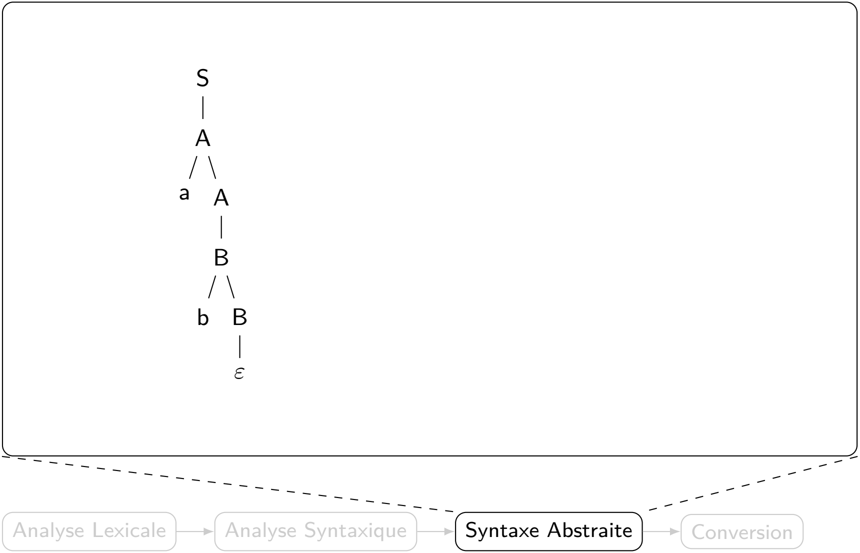
- Grammaire
- LL1

```
                 S -> A
                 A -> aA
[a, b]  +        A -> B          =>
                 B -> bB
                 B -> epsilon
```

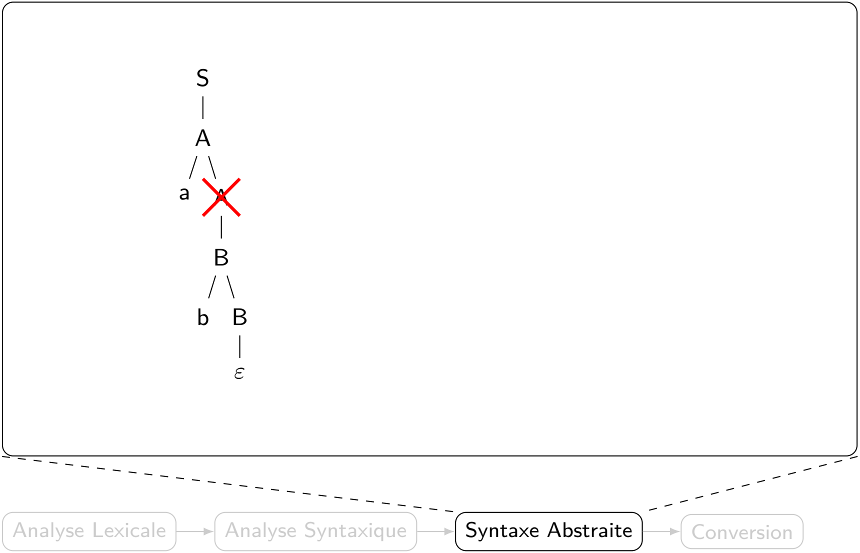


Analyse Lexicale → **Analyse Syntaxique** → Syntaxe Abstraite → Conversion

Syntaxe abstraite



Syntaxe abstraite



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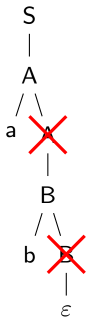

Analyse Lexicale → Analyse Syntaxique → **Syntaxe Abstraite** → Conversion

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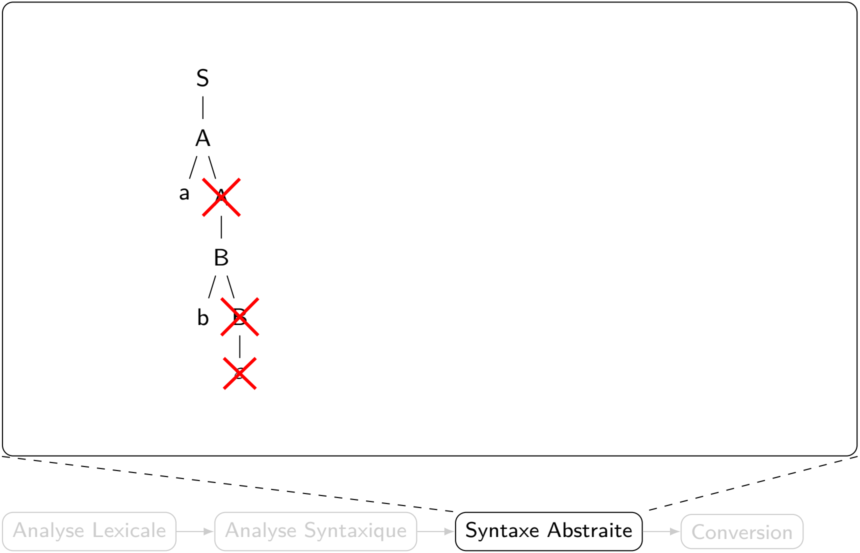

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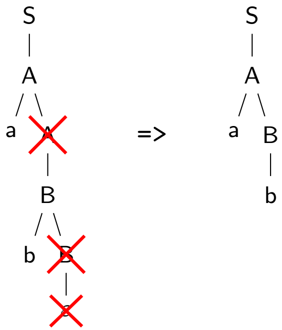

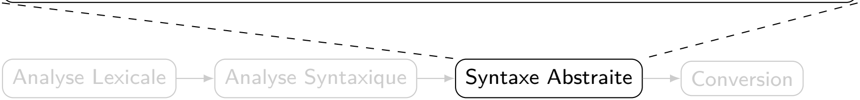

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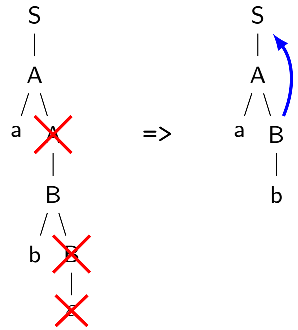

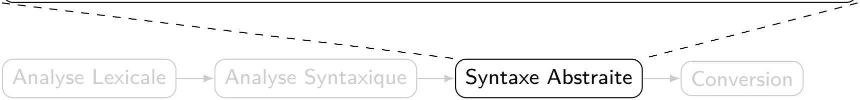

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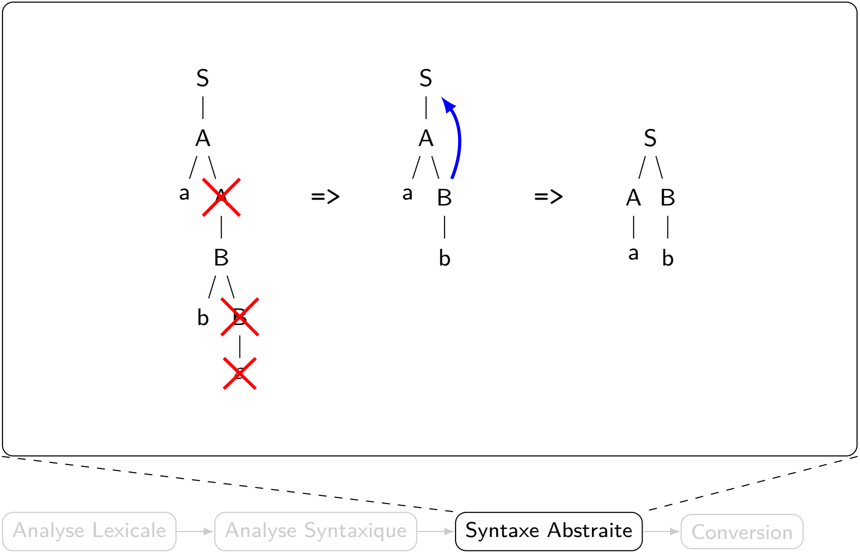

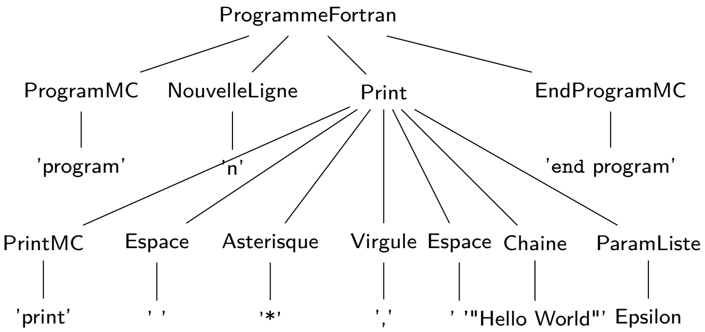
ProgrammeFortran
ProgramMC
NouvelleLigne
Print
EndProgramMC
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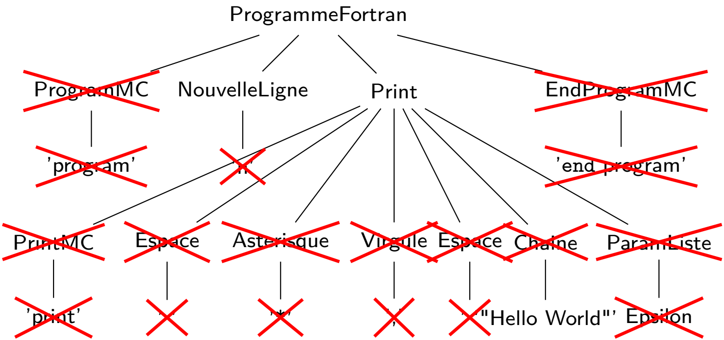
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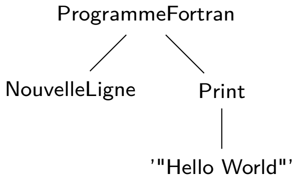
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1. Analyse Lexicale

2. Analyse Syntaxique

3. Convertion vers la syntaxe abstraite

4. Traduction vers le langage de sortie

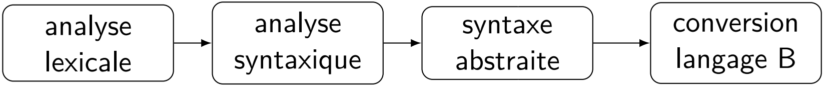
Traduction

parcours en profondeur

convertion en chaîne

Analyse Lexicale → Analyse Syntaxique → Syntaxe Abstraite → **Conversion**

Transpileur



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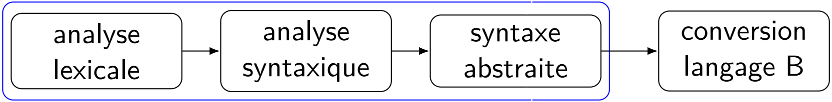
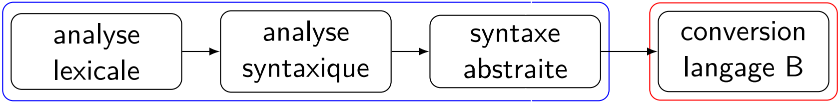


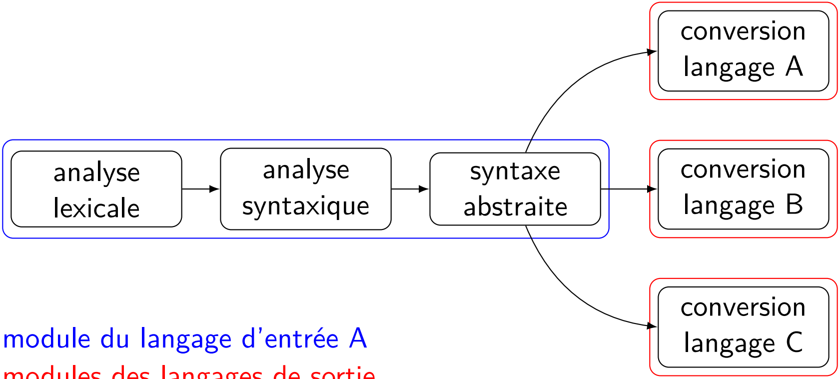
module du langage d'entrée A

Transpileur



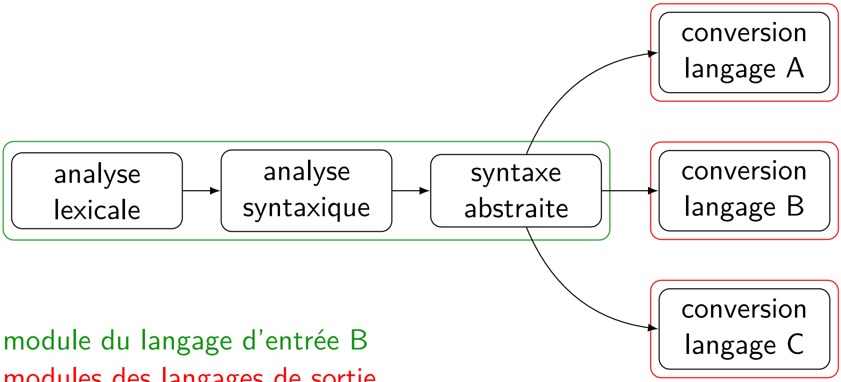
module du langage d'entrée A
modules du langage de sortie

Transpileur



module du langage d'entrée A
modules des langages de sortie

Transpileur



module du langage d'entrée B
modules des langages de sortie

Conclusion

- Conversion rapide
- Partie automatisée rend la création moins pénible
- Processus interchangeable avec les langages souhaités

```
type operateur = Plus | Moins | Fois | Division |
↪   Puissance | Assignation

type comparateur =
    | PlusPetit
    | PlusGrand
    | StrictPlusPetit
    | StrictPlusGrand
    | Egal
    | NonEgal

type operateur_logique = Et | Ou | Non | Equivalent
↪    | NonEquivalent

type syntax =
    | Any
    | Character
```

```
    | Complex
    | Constant
    | Do
    | Double_precision
    | Else
    | Else_if
    | Function
    | If
    | End_if
    | Integer
    | Logical
    | Program
    | Real
    | While
    | Call
    | Print
    | Return
```

```
  | Size
  | For
  | Step
  (* v---only for post-processing---v *)
  | Out
  | Subroutine

type token =
  | Operateur of operateur
  | Comparateur of comparateur
  | OperateurLogique of operateur_logique
  | Syntax of syntax
  | NewLine
  | Name of string
  | Integer of string
  | Floating of string
  | Double of string
```

```
    | Chaine of string
    | Commentaire of string
    | Booleen of bool
    | Parentheseouvrante
    | Parenthesefermante
    | ProgramRoot
    | ToFlatten

(* paramètres et enfants confondus dans la liste
↪  *)
type ast = Noeud of token * ast list

let string_of_token (t : token) : string =
  match t with
    | Operateur Plus -> "Operateur Plus"
    | Operateur Moins -> "Operateur Moins"
    | Operateur Fois -> "Operateur Fois"
```

```
    | Operateur Division -> "Operateur Division"
    | Operateur Puissance -> "Operateur Puissance"
    | Operateur Assignation -> "Operateur Assignation"
    | Comparateur PlusPetit -> "Comparateur PlusPetit"
    | Comparateur PlusGrand -> "Comparateur PlusGrand"
    | Comparateur StrictPlusPetit -> "Comparateur StrictPlusPetit"
    | Comparateur StrictPlusGrand -> "Comparateur StrictPlusGrand"
    | Comparateur Egal -> "Comparateur Egal"
    | Comparateur NonEgal -> "Comparateur NonEgal"
    | OperateurLogique Et -> "OperateurLogique Et"
    | OperateurLogique Ou -> "OperateurLogique Ou"
    | OperateurLogique Non -> "OperateurLogique Non"
```

```
    | OperateurLogique Equivalent -> "OperateurLogique Equivalent"
    | OperateurLogique NonEquivalent -> "OperateurLogique NonEquivalent"
    | Syntax Any -> "Syntax Any"
    | Syntax Character -> "Syntax Character"
    | Syntax Complex -> "Syntax Complex"
    | Syntax Constant -> "Syntax Constant"
    | Syntax Do -> "Syntax Do"
    | Syntax Double_precision -> "Syntax Double_precision"
    | Syntax Else -> "Syntax Else"
    | Syntax Else_if -> "Syntax Else_if"
    | Syntax Function -> "Syntax Function"
    | Syntax If -> "Syntax If"
    | Syntax End_if -> "Syntax End_if"
    | Syntax Out -> "Syntax Out"
```

```
    | Syntax Integer -> "Syntax Integer"
    | Syntax Logical -> "Syntax Logical"
    | Syntax Program -> "Syntax Program"
    | Syntax Real -> "Syntax Real"
    | Syntax Subroutine -> "Syntax Subroutine"
    | Syntax While -> "Syntax While"
    | Syntax Call -> "Syntax Call"
    | Syntax Print -> "Syntax Print"
    | Syntax Return -> "Syntax Return"
    | Syntax Size -> "Syntax Size"
    | Syntax For -> "Syntax For"
    | Syntax Step -> "Syntax Step"
    | NewLine -> "NewLine"
    | Name s -> "Name " ^ s
    | Integer s -> "Integer " ^ s
    | Floating s -> "Floating " ^ s
    | Double s -> "Double " ^ s
```

```
    | Chaine s -> "Chaine " ^ s
    | Commentaire s -> "Commentaire " ^ s
    | Booleen b -> "Booleen " ^ string_of_bool b
    | Parentheseouvrante -> "Parentheseouvrante"
    | Parenthesefermante -> "Parenthesefermante"
    | ProgramRoot -> "ProgramRoot"
    | ToFlatten -> "ToFlatten"

let print_token (t : token) : unit = print_endline
 ↪  (string_of_token t)
```

```ocaml
type libs = string list

let add_lib (l : libs) (name : string) : libs =
  if not (List.mem name l) then name :: l else l
```

```
open Abstract_tokens

type environnement = (string, token) Hashtbl.t
type intent = In | Out | InOut
type var_type_subroutine = (string, intent)
↪  Hashtbl.t

let print_env (env: environnement): unit =
  Hashtbl.iter (fun k v -> print_string k ;
   ↪  print_string " -> " ; print_token v;
   ↪  print_newline ()) env


let rec last_of_list (l: 'a list): 'a =
  match l with
   | [] -> failwith "Liste vide "
   | e::[] -> e
```

```
  | e::q -> last_of_list q


(** crée un environnement à partir de l'ast [t] *)
let create_env_from_ast (t : ast) : environnement =
  let env = Hashtbl.create 0 in
  (** ajoute récursivement sur [t] les variables dans l'environnement *)
  let rec add_env (t : ast) : unit =
    match t with
    | Noeud (Syntax Double_precision, [ Noeud (Name s, []) ])
    | Noeud
        ( Syntax Double_precision,
          [ Noeud (Operateur Assignation, [ Noeud (Name s, []); _ ]) ] ) ->
        Hashtbl.add env s (Syntax Double_precision)
```

```
    | Noeud (Syntax Integer, [ Noeud (Name s, []) ])
    | Noeud
        ( Syntax Integer,
          [ Noeud (Operateur Assignation, [ Noeud (Name s, []); _ ]) ] ) ->
        Hashtbl.add env s (Syntax Integer)
    | Noeud (Syntax Real, [ Noeud (Name s, []) ])
    | Noeud
        ( Syntax Real,
          [ Noeud (Operateur Assignation, [ Noeud (Name s, []); _ ]) ] ) ->
        Hashtbl.add env s (Syntax Real)
    | Noeud (Syntax Logical, [ Noeud (Name s, []) ])
    | Noeud
        ( Syntax Logical,
```

```
          [ Noeud (Operateur Assignation, [ Noeud (Name s, []); _ ]) ] ) ->
        Hashtbl.add env s (Syntax Real)
    | Noeud (Syntax Character, [ Noeud (Syntax Size, _); Noeud (Name s, []) ])
    | Noeud (Syntax Character, [ Noeud (Name s, []) ])
    | Noeud
        ( Syntax Character,
          [
            Noeud
              ( Operateur Assignation,
                [ Noeud (Syntax Size, _); Noeud (Name s, []); _ ] );
          ] )
    | Noeud
        ( Syntax Character,
```

```
            [ Noeud (Operateur Assignation, [ Noeud (Name s, []); _ ]) ] ) ->
          Hashtbl.add env s (Syntax Real)
      | Noeud (Syntax Function, Noeud(Name n,[])::l) ->(
          List.iter add_env l;
          match last_of_list l with
          | Noeud(Syntax Return , Noeud(Name v,[])::_) ->  Hashtbl.add env n (Hashtbl.find env v)
          | _ -> () (* pas de return à la fin de la fct donc c'est une subroutine *)
        )

      | Noeud (_, l) -> List.iter add_env l
  in
  add_env t;
```

```
  env

(** déduis de l'utilisation des variables dans [t] si elles sont in, out out *)
let create_subroutine_intent (t : ast) : var_type_subroutine =
  let sub_intent = Hashtbl.create 0 in
  (** traite récursivement les variables sur [t] *)
  let rec subroutine_intent_aux (t : ast) : unit =
    (* TODO ajouter lorsque la syntaxe abstraite pour le in/out/inout est ok *)
    match t with
    | Noeud (Operateur Assignation, Noeud (Name s, []) :: _)
      when not (Hashtbl.mem sub_intent s) ->
        Hashtbl.add sub_intent s Out
```

```
      | Noeud (Operateur Assignation, Noeud (Name s, []) :: _)
        when Hashtbl.find sub_intent s = In ->
          Hashtbl.replace sub_intent s InOut
      | Noeud (Operateur Assignation, Noeud (Name s, []) :: _)
        when Hashtbl.find sub_intent s = Out ||
          Hashtbl.find sub_intent s = InOut
        ->
          ()
      | Noeud (Name s, []) when not (Hashtbl.mem sub_intent s) ->
          Hashtbl.add sub_intent s In
      | Noeud (Name s, []) when Hashtbl.find sub_intent s = Out ->
          Hashtbl.add sub_intent s InOut
      | Noeud (Name s, [])
```

```
    when Hashtbl.find sub_intent s = Out || Hashtbl.find sub_intent s = InOut
    ->
      ()
  | Noeud (_, l) -> List.iter subroutine_intent_aux l

in
subroutine_intent_aux t;
sub_intent
```

```
type terminal =
    | EOF
    | E
    | PowerOp
    | NotOp
    | AndOp
    | OrOp
    | Dcon
    | Rcon
    | Icon
    | SconSingle
    | SconDouble
    | Ident
    | EOS
    | Return
    | Result
    | Contains
```

```
    | True
    | False
    | Program
    | Function
    | Subroutine
    | EndProgram
    | EndFunction
    | EndSubroutine
    | EndDo
    | EndIf
    | Colon
    | Comma
    | Equal
    | Asterisk
    | LParenthesis
    | RParenthesis
    | Integer
```

```
    | Real
    | Double
    | Complex
    | Character
    | Logical
    | Parameter
    | Intent
    | In
    | Out
    | InOut
    | Call
    | Print
    | Do
    | While
    | If
    | Else
    | Then
```

```
    | Divise
    | Plus
    | Minus
    | IsEqual
    | NotEqual
    | StrictLess
    | LessEqual
    | StrictGreater
    | GreaterEqual
    | Equivalent
    | NotEquivalent
    | Space
    | Recursive

type non_terminal =
    | ExecutableProgram
    | StartCommentBlock
```

```
    | Function_or_Subroutine_star_MainProgram
    | Function_or_Subroutine_star
    | Recursive_opt_Function_or_Subroutine
    | Function_or_Subroutine
    | MainProgram
    | MainRange
    | Contains_Function_opt_EndProgramStmt
    | Contains_Function
    | FunctionSubprogram_star
    | BodyConstruct_star
    | ProgramStmt
    | EndProgramStmt
    | FunctionSubprogram
    | FunctionPrefix
    | FunctionRange
    | FunctionParList
    | FunctionPar_Comma_FunctionPar_star_opt
```

```
    | Comma_FunctionPar_star
    | FunctionPar
    | FunctionResult_opt
    | EndFunctionStmt
    | SubroutineSubprogram
    | SubroutineRange
    | SubroutineParList_opt
    | SubroutinePar_Comma_SubroutinePar_star_opt
    | Comma_SubroutinePar_star
    | SubroutinePar
    | EndSubroutineStmt
    | EndName_opt
    | BodyConstruct
    | SpecificationPartConstruct
    | DeclarationConstruct
    | TypeDeclarationStmt
    | Comma_AttrSpec_star
```

```
    | AttrSpec
    | Intent_in_out
    | In_out
    | TypeDecl_Assignment
    | Comma_ObjectName_star
    | Comma_EntityDecl_star
    | EntityDecl
    | Equal_Expr_opt
    | Asterisk_CharLength_opt
    | CharLength
    | TypeParamValue
    | Expr_Or_Asterisk
    | TypeSpec
    | KindSelector_opt
    | ExecutableConstruct
    | ReturnStmt
    | ActionStmt
```

```
    | AssignmentStmt
    | PrintStmt
    | Comma_OutputItemList_opt
    | FormatIdentifier
    | OutputItemList
    | Comma_OutputItem_star
    | OutputItem
    | DoConstruct
    | BlockDoConstruct
    | LoopControl_opt
    | EndDoStmt
    | Name_opt
    | LoopControl
    | Comma_IntRealDpExpression_opt
    | IntRealDpExpression
    | IfConstruct
    | ElseIfStmt_ExecutionPartConstruct_star_star
```

```
    | ExecutionPartConstruct_star
    | ElseStmt_ExecutionPartConstruct_star_opt
    | IfThenStmt
    | ElseIfStmt
    | ElseStmt
    | EndIfStmt
    | ExecutionPartConstruct
    | ScalarLogicalExpr
    | Expr
    | Level5Expr
    | EquivOp_EquivOperand_star
    | EquivOperand
    | OrOp_OrOperand_star
    | OrOperand
    | AndOp_AndOperand_star
    | AndOperand
    | NotOp_opt
```

```
    | Level4Expr
    | RelOp_Level3Expr_star
    | Level3Expr
    | Level2Expr
    | AddOp_Sign_opt_AddOperand_star
    | Sign_opt_AddOperand
    | Sign_opt
    | AddOperand
    | MultOp_MultOperand_star
    | MultOperand
    | PowerOp_Level1Expr_star
    | Level1Expr
    | Primary
    | FunctionReference_opt
    |
    ↪  FunctionArg_Comma_FunctionArg_star_opt_RParenthes
    | Comma_FunctionArg_star
```

```
    | FunctionArg
    | Name
    | ArrayName
    | ComponentName
    | EndName
    | DummyArgName
    | FunctionName
    | ImpliedDoVariable
    | ProgramName
    | SubroutineName
    | SubroutineNameUse
    | VariableName
    | ObjectName
    | LogicalConstant
    | MultOp
    | AddOp
    | Sign
```

```
    | RelOp
    | EquivOp
    | ScalarIntLiteralConstant
    | Scon
type symbol = | Terminal of terminal | NonTerminal of non_terminal
let safe_token = Ident
let unparsed_tokens = [Space; ]

let repr_of_terminal (t : terminal) : string =
  match t with
    | EOF -> "End of file"
    | E -> "Epsilon"
    | PowerOp -> "\\*\\*"
    | NotOp -> "\\.not\\."
    | AndOp -> "\\.and\\."
    | OrOp -> "\\.or\\."
```

```
    | Dcon ->
    ↪ "(([0-9]+\\.[0-9]*)|(\\.[0-9]+))(d(\\+|-)?[0-9]+)
    | Rcon ->
    ↪ "(([0-9]+\\.[0-9]*)|(\\.[0-9]+))(e(\\+|-)?[0-9]+)
    | Icon -> "[0-9]+(e(\\+|-)?[0-9]+)?"
    | SconSingle -> "['](~[']|'')*[']"
    | SconDouble -> "[\"](~[\"]|\"\")*[\"]"
    | Ident -> "[A-Za-z][A-Za-z0-9_]*"
    | EOS -> "((!~[\\n]*)?\\n[ ]*)+"
    | Return -> "return"
    | Result -> "result"
    | Contains -> "contains"
    | True -> "\\.true\\."
    | False -> "\\.false\\."
    | Program -> "program"
    | Function -> "function"
    | Subroutine -> "subroutine"
```

```
    | EndProgram -> "end program"
    | EndFunction -> "end function"
    | EndSubroutine -> "end subroutine"
    | EndDo -> "end do"
    | EndIf -> "end if"
    | Colon -> ":"
    | Comma -> ","
    | Equal -> "="
    | Asterisk -> "\\*"
    | LParenthesis -> "\\("
    | RParenthesis -> "\\)"
    | Integer -> "integer"
    | Real -> "real"
    | Double -> "double precision"
    | Complex -> "complex"
    | Character -> "character"
    | Logical -> "logical"
```

```
    | Parameter -> "parameter"
    | Intent -> "intent"
    | In -> "in"
    | Out -> "out"
    | InOut -> "inout"
    | Call -> "call"
    | Print -> "print"
    | Do -> "do"
    | While -> "while"
    | If -> "if"
    | Else -> "else"
    | Then -> "then"
    | Divise -> "/"
    | Plus -> "\\+"
    | Minus -> "-"
    | IsEqual -> "(==)|(\\.eq\\.)"
    | NotEqual -> "(/=)|(\\.ne\\.)"
```

```
    | StrictLess -> "(<)|(\\.lt\\.)"
    | LessEqual -> "(<=)|(\\.le\\.)"
    | StrictGreater -> "(>)|(\\.gt\\.)"
    | GreaterEqual -> "(>=)|(\\.ge\\.)"
    | Equivalent -> "\\.eqv\\."
    | NotEquivalent -> "\\.neqv\\."
    | Space -> " "
    | Recursive -> "recursive"

let string_of_terminal (t : terminal) : string =
  match t with
    | EOF -> "EOF"
    | E -> "E"
    | PowerOp -> "PowerOp"
    | NotOp -> "NotOp"
    | AndOp -> "AndOp"
    | OrOp -> "OrOp"
```

```
    | Dcon -> "Dcon"
    | Rcon -> "Rcon"
    | Icon -> "Icon"
    | SconSingle -> "SconSingle"
    | SconDouble -> "SconDouble"
    | Ident -> "Ident"
    | EOS -> "EOS"
    | Return -> "Return"
    | Result -> "Result"
    | Contains -> "Contains"
    | True -> "True"
    | False -> "False"
    | Program -> "Program"
    | Function -> "Function"
    | Subroutine -> "Subroutine"
    | EndProgram -> "EndProgram"
    | EndFunction -> "EndFunction"
```

```
    | EndSubroutine -> "EndSubroutine"
    | EndDo -> "EndDo"
    | EndIf -> "EndIf"
    | Colon -> "Colon"
    | Comma -> "Comma"
    | Equal -> "Equal"
    | Asterisk -> "Asterisk"
    | LParenthesis -> "LParenthesis"
    | RParenthesis -> "RParenthesis"
    | Integer -> "Integer"
    | Real -> "Real"
    | Double -> "Double"
    | Complex -> "Complex"
    | Character -> "Character"
    | Logical -> "Logical"
    | Parameter -> "Parameter"
    | Intent -> "Intent"
```

```
    | In -> "In"
    | Out -> "Out"
    | InOut -> "InOut"
    | Call -> "Call"
    | Print -> "Print"
    | Do -> "Do"
    | While -> "While"
    | If -> "If"
    | Else -> "Else"
    | Then -> "Then"
    | Divise -> "Divise"
    | Plus -> "Plus"
    | Minus -> "Minus"
    | IsEqual -> "IsEqual"
    | NotEqual -> "NotEqual"
    | StrictLess -> "StrictLess"
    | LessEqual -> "LessEqual"
```

```
    | StrictGreater -> "StrictGreater"
    | GreaterEqual -> "GreaterEqual"
    | Equivalent -> "Equivalent"
    | NotEquivalent -> "NotEquivalent"
    | Space -> "Space"
    | Recursive -> "Recursive"

let string_of_non_terminal (nt : non_terminal) : string =
  match nt with
    | ExecutableProgram -> "ExecutableProgram"
    | StartCommentBlock -> "StartCommentBlock"
    | Function_or_Subroutine_star_MainProgram -> "Function_or_Subroutine_star_MainProgram"
    | Function_or_Subroutine_star -> "Function_or_Subroutine_star"
```

```
    | Recursive_opt_Function_or_Subroutine -> "Recursive_opt_Function_or_Subroutine"
    | Function_or_Subroutine -> "Function_or_Subroutine"
    | MainProgram -> "MainProgram"
    | MainRange -> "MainRange"
    | Contains_Function_opt_EndProgramStmt -> "Contains_Function_opt_EndProgramStmt"
    | Contains_Function -> "Contains_Function"
    | FunctionSubprogram_star -> "FunctionSubprogram_star"
    | BodyConstruct_star -> "BodyConstruct_star"
    | ProgramStmt -> "ProgramStmt"
    | EndProgramStmt -> "EndProgramStmt"
    | FunctionSubprogram -> "FunctionSubprogram"
    | FunctionPrefix -> "FunctionPrefix"
    | FunctionRange -> "FunctionRange"
```

```
    | FunctionParList -> "FunctionParList"
    | FunctionPar_Comma_FunctionPar_star_opt ->
    ↪  "FunctionPar_Comma_FunctionPar_star_opt"
    | Comma_FunctionPar_star ->
    ↪  "Comma_FunctionPar_star"
    | FunctionPar -> "FunctionPar"
    | FunctionResult_opt -> "FunctionResult_opt"
    | EndFunctionStmt -> "EndFunctionStmt"
    | SubroutineSubprogram -> "SubroutineSubprogram"
    | SubroutineRange -> "SubroutineRange"
    | SubroutineParList_opt ->
    ↪  "SubroutineParList_opt"
    | SubroutinePar_Comma_SubroutinePar_star_opt ->
    ↪  "SubroutinePar_Comma_SubroutinePar_star_opt"
    | Comma_SubroutinePar_star ->
    ↪  "Comma_SubroutinePar_star"
    | SubroutinePar -> "SubroutinePar"
```

```
    | EndSubroutineStmt -> "EndSubroutineStmt"
    | EndName_opt -> "EndName_opt"
    | BodyConstruct -> "BodyConstruct"
    | SpecificationPartConstruct ->
    ↪  "SpecificationPartConstruct"
    | DeclarationConstruct -> "DeclarationConstruct"
    | TypeDeclarationStmt -> "TypeDeclarationStmt"
    | Comma_AttrSpec_star -> "Comma_AttrSpec_star"
    | AttrSpec -> "AttrSpec"
    | Intent_in_out -> "Intent_in_out"
    | In_out -> "In_out"
    | TypeDecl_Assignment -> "TypeDecl_Assignment"
    | Comma_ObjectName_star ->
    ↪  "Comma_ObjectName_star"
    | Comma_EntityDecl_star ->
    ↪  "Comma_EntityDecl_star"
    | EntityDecl -> "EntityDecl"
```

```
    | Equal_Expr_opt -> "Equal_Expr_opt"
    | Asterisk_CharLength_opt ->
    ↪  "Asterisk_CharLength_opt"
    | CharLength -> "CharLength"
    | TypeParamValue -> "TypeParamValue"
    | Expr_Or_Asterisk -> "Expr_Or_Asterisk"
    | TypeSpec -> "TypeSpec"
    | KindSelector_opt -> "KindSelector_opt"
    | ExecutableConstruct -> "ExecutableConstruct"
    | ReturnStmt -> "ReturnStmt"
    | ActionStmt -> "ActionStmt"
    | AssignmentStmt -> "AssignmentStmt"
    | PrintStmt -> "PrintStmt"
    | Comma_OutputItemList_opt ->
    ↪  "Comma_OutputItemList_opt"
    | FormatIdentifier -> "FormatIdentifier"
    | OutputItemList -> "OutputItemList"
```

```
    | Comma_OutputItem_star ->
    ↪  "Comma_OutputItem_star"
    | OutputItem -> "OutputItem"
    | DoConstruct -> "DoConstruct"
    | BlockDoConstruct -> "BlockDoConstruct"
    | LoopControl_opt -> "LoopControl_opt"
    | EndDoStmt -> "EndDoStmt"
    | Name_opt -> "Name_opt"
    | LoopControl -> "LoopControl"
    | Comma_IntRealDpExpression_opt ->
    ↪  "Comma_IntRealDpExpression_opt"
    | IntRealDpExpression -> "IntRealDpExpression"
    | IfConstruct -> "IfConstruct"
    | ElseIfStmt_ExecutionPartConstruct_star_star ->
    ↪  "ElseIfStmt_ExecutionPartConstruct_star_star"
    | ExecutionPartConstruct_star ->
    ↪  "ExecutionPartConstruct_star"
```

```
    | ElseStmt_ExecutionPartConstruct_star_opt -> "ElseStmt_ExecutionPartConstruct_star_opt"
    | IfThenStmt -> "IfThenStmt"
    | ElseIfStmt -> "ElseIfStmt"
    | ElseStmt -> "ElseStmt"
    | EndIfStmt -> "EndIfStmt"
    | ExecutionPartConstruct -> "ExecutionPartConstruct"
    | ScalarLogicalExpr -> "ScalarLogicalExpr"
    | Expr -> "Expr"
    | Level5Expr -> "Level5Expr"
    | EquivOp_EquivOperand_star -> "EquivOp_EquivOperand_star"
    | EquivOperand -> "EquivOperand"
    | OrOp_OrOperand_star -> "OrOp_OrOperand_star"
    | OrOperand -> "OrOperand"
```

```
    | AndOp_AndOperand_star ->
    ↪  "AndOp_AndOperand_star"
    | AndOperand -> "AndOperand"
    | NotOp_opt -> "NotOp_opt"
    | Level4Expr -> "Level4Expr"
    | RelOp_Level3Expr_star ->
    ↪  "RelOp_Level3Expr_star"
    | Level3Expr -> "Level3Expr"
    | Level2Expr -> "Level2Expr"
    | AddOp_Sign_opt_AddOperand_star ->
    ↪  "AddOp_Sign_opt_AddOperand_star"
    | Sign_opt_AddOperand -> "Sign_opt_AddOperand"
    | Sign_opt -> "Sign_opt"
    | AddOperand -> "AddOperand"
    | MultOp_MultOperand_star ->
    ↪  "MultOp_MultOperand_star"
    | MultOperand -> "MultOperand"
```

```
| PowerOp_Level1Expr_star -> "PowerOp_Level1Expr_star"
| Level1Expr -> "Level1Expr"
| Primary -> "Primary"
| FunctionReference_opt -> "FunctionReference_opt"
| FunctionArg_Comma_FunctionArg_star_opt_RParenthes
  -> "FunctionArg_Comma_FunctionArg_star_opt_RParenthes
| Comma_FunctionArg_star -> "Comma_FunctionArg_star"
| FunctionArg -> "FunctionArg"
| Name -> "Name"
| ArrayName -> "ArrayName"
| ComponentName -> "ComponentName"
| EndName -> "EndName"
```

```
    | DummyArgName -> "DummyArgName"
    | FunctionName -> "FunctionName"
    | ImpliedDoVariable -> "ImpliedDoVariable"
    | ProgramName -> "ProgramName"
    | SubroutineName -> "SubroutineName"
    | SubroutineNameUse -> "SubroutineNameUse"
    | VariableName -> "VariableName"
    | ObjectName -> "ObjectName"
    | LogicalConstant -> "LogicalConstant"
    | MultOp -> "MultOp"
    | AddOp -> "AddOp"
    | Sign -> "Sign"
    | RelOp -> "RelOp"
    | EquivOp -> "EquivOp"
    | ScalarIntLiteralConstant -> "ScalarIntLiteralConstant"
    | Scon -> "Scon"
```

```
type string_or_string_list = S of string | L of string_or_string_list list

(** crée une chaîne de [n] tabulations *)
let tabs_to_string (n : int) : string_or_string_list = S (String.make n '\t')

(** crée une chaîne de [n] retours à la ligne *)
let rec n_new_lines (n : int) : string_or_string_list = S (String.make n '\n')


let string_of_string_or_string_list (sosl : string_or_string_list) : string =
  let rec aux (sosl : string_or_string_list) (acc : string list) : string list =
    match sosl with
```

```
      | S s -> s :: acc
      | L [] -> acc
      | L (e :: q) ->
          let acc2 = aux e acc in
          aux (L q) acc2
  in
  String.concat "" (List.rev (aux sosl []))


let rec last_of_list (l: 'a list): 'a =
  match l with
  | [] -> failwith "Liste vide "
  | e::[] -> e
  | e::q -> last_of_list q

let print_sosl (sosl: string_or_string_list): unit
 ↪  =
```

```
    print_string (string_of_string_or_string_list
     ↪  sosl);
    print_newline ()
```

```
open Symbols

type regex =
  (* cas de base *)
  | Epsilon
  | Caractere of char
  | AllChars
  | Range of char * char
  (* opérations sur les regex*)
  | Concat of regex * regex
  | Ou of regex * regex
  | UnPlus of regex
  | ZeroPlus of regex
  | Vide
  | Facultatif of regex
  | AllBut of bool array

```

```
(** affiche l'expression [c] en argument *)
let print_reg_list (c : regex list) : unit =
  (** affiche en vidant au fur et à mesure la
  ↪  liste *)
  let rec print_list_aux (r : regex list) : unit =
    match r with
    | [] -> ()
    | [ Vide ] -> print_char '_'
    | Vide :: q ->
        print_char '_';
        print_char ' ';
        print_list_aux q
    | [ Epsilon ] -> print_char '#'
    | Epsilon :: q ->
        print_char '#';
        print_char ' ';
        print_list_aux q
```

```
    | [ Caractere c ] -> print_char c
    | Caractere c :: q ->
      print_char c;
      print_char ' ';
      print_list_aux q
    | [ AllChars ] -> print_char '.'
    | AllChars :: q ->
      print_char '.';
      print_char ' ';
      print_list_aux q
    | [ Range (s, e) ] ->
      print_char '[';
      print_char s;
      print_char '-';
      print_char e;
      print_char ']'
    | Range (s, e) :: q ->
```

```
          print_char '[';
          print_char s;
          print_char '-';
          print_char e;
          print_char ']';
          print_char ' ';
          print_list_aux q
    | [ Concat (e1, e2) ] ->
          print_list_aux [ e1 ];
          print_list_aux [ e2 ]
    | Concat (e1, e2) :: q ->
          print_list_aux [ e1 ];
          print_list_aux [ e2 ];
          print_char ' ';
          print_list_aux q
    | [ Ou (e1, e2) ] ->
          print_char '(';
```

```
            print_list_aux [ e1 ];
            print_char '|';
            print_list_aux [ e2 ];
            print_char ')'
        | Ou (e1, e2) :: q ->
            print_char '(';
            print_list_aux [ e1 ];
            print_char '|';
            print_list_aux [ e2 ];
            print_char ')';
            print_char ' ';
            print_list_aux q
        | [ UnPlus e ] ->
            print_char '(';
            print_list_aux [ e ];
            print_string ")+"
        | UnPlus e :: q ->
```

```
        print_char '(';
        print_list_aux [ e ];
        print_string ")+";
        print_char ' ';
        print_list_aux q
    | [ ZeroPlus e ] ->
        print_char '(';
        print_list_aux [ e ];
        print_string ")*"
    | ZeroPlus e :: q ->
        print_char '(';
        print_list_aux [ e ];
        print_string ")*";
        print_char ' ';
        print_list_aux q
    | [ Facultatif e ] ->
        print_char '(';
```

```
          print_list_aux [ e ];
          print_string ")?"
      | Facultatif e :: q ->
          print_char '(';
          print_list_aux [ e ];
          print_string ")?";
          print_char ' ';
          print_list_aux q
      | [ AllBut _ ] ->
          print_string "~(...";
          print_string ")"
      | AllBut _ :: q ->
          print_string "~(...";
          print_string ")";
          print_char ' ';
          print_list_aux q
  in
```

```
  if List.length c = 0 then print_string "[]" else print_list_aux c

(** convertit la chaîne de caractères s à partir de l'index index et l'ajoute à
    la liste c *)
let rec string_to_char_2 (s : string) (c : char list) (index : int) : char list
    =
  if index = String.length s then List.rev c
  else string_to_char_2 s (s.[index] :: c) (index + 1)

exception Invalid_syntax
exception Empty_pile

```

```
(** teste si la liste référencée dans [l] est vide
↪  *)
let is_empty (l : 'a list ref) : bool = List.length
↪  !l == 0

(** dépile un élément de la pile référencée par
↪  [l] *)
let pop (l : 'a list ref) : 'a =
  match !l with
  | [] -> raise Empty_pile
  | x :: q ->
      l := q;
      x

(** convertit l'entier [n] en booléen *)
let bool_of_int (n : int) : bool = if n == 0 then
↪  false else true
```

```ocaml

(** renvoie la disjonction de toutes les
↪  expressions régulières dans la liste
   [l] *)
let or_reg (l : regex list) : regex =
  let rec or_reg_aux (l : regex list) (out : regex)
  ↪  : regex =
    match (l, out) with
    | [], _ -> out
    | x :: q, Epsilon -> or_reg_aux q x
    | x :: q, _ -> or_reg_aux q (Ou (x, out))
  in
  or_reg_aux l Epsilon

(** renvoie la concaténation de toutes les
↪  expressions régulières de [l] *)
let concat_reg (l : regex list) : regex =
```

```
  let rec concat_reg_aux (l : regex list) (out : regex) : regex =
    match (l, out) with
    | [], _ -> out
    | x :: q, Epsilon -> concat_reg_aux q x
    | x :: q, _ -> concat_reg_aux q (Concat (x, out))
  in
  concat_reg_aux l Epsilon

(** transforme, si c'est possible, la chaine de caractères [s] en une expression
    régulière (regex) *)
let rec gen_regex (s : string) : regex =
  let caracters = ref (List.of_seq (String.to_seq s)) in
```

```ocaml
(** fonction auxiliaire qui permet de générer le regex entre parenthèses *)
let parenthesis () : regex =
  let l = ref [] in
  try
    let count = ref 0 in
    let c = ref (pop caracters) in
    let ignore = ref false in
    (* boucle sur le contenu de la parenthèse et ne s'arrete pas si elle est ignorée *)
    while not (!c = ')' && !count = 0 && not !ignore) do
      if not !ignore then (
        if
          (* si on rencontre un \, on ignore le caractère suivant *)
          !c = '\\'
```

```
          then ignore := true
          else if !c = '(' then count := !count + 1
          else if !c = ')' then count := !count - 1)
        else ignore := false;
        l := !c :: !l;
        c := pop caracters
      done;
      let s1 = String.of_seq (List.to_seq (List.rev !l)) in
      gen_regex s1
    with Empty_pile -> raise Invalid_syntax
  in

  (** fonction auxiliaire qui permet de générer le regex entre crochets *)
  let crochet () : regex =
```

```
    let l = ref [] in
    try
      let c = ref (pop caracters) in
      let ignore_left = ref 0 in
      let pile1 = ref [] in
      (* on boucle tant que l'on a pas le crochet final et tant que l'on ignore pas *)
      while not (!c = ']' && not (bool_of_int !ignore_left)) do
        (* si on ignore pas encore, on ignore pour 2 tours si on rencontre un \ *)
        if (not (bool_of_int !ignore_left)) && !c = '\\' then ignore_left := 2;
        (if !ignore_left <> 2 then
           match !pile1 with
           | [ Caractere '-'; Caractere x ] -> pile1 := [ Range (x, !c) ]
```

```
              | Caractere '-' :: Caractere x :: q -> pile1 := Range (x, !c) :: q
              | _ ->
                 if !ignore_left = 1 && !c = 'n' then
                   pile1 := Caractere '\n' :: !pile1
                 else pile1 := Caractere !c :: !pile1;
                 l := !c :: !l);
          c := pop caracters;
          if !ignore_left > 0 then ignore_left := !ignore_left - 1
        done;
        or_reg !pile1
      with Empty_pile -> raise Invalid_syntax
    in

```

```
(** fonction auxiliaire générale qui génère le regex à partir de la chaine,
    qui stocke au fur et à mesure dans la pile et qui ignore les caractères à
    effets lorsque ignore est à vrai *)
let rec gen_regex_2 (pile : regex list) (ignore : bool) : regex =
  (* s'il n'y a plus rien a convertir, on concatène les expressions régulières*)
  if is_empty caracters then concat_reg pile
  else
    let c = pop caracters in
    if ignore then
      if c = 'n' then gen_regex_2 (Caractere '\n' :: pile) false
      else gen_regex_2 (Caractere c :: pile) false
```

```
        else
          match c with
           | '\\' -> gen_regex_2 pile true
           | '(' -> gen_regex_2 (parenthesis () :: pile) false
           | '[' -> gen_regex_2 (crochet () :: pile) false
           | ')' | ']' -> raise Invalid_syntax
           | '|' -> (
               let left = gen_regex_2 [] false in
               match (pile, left) with
               | [], _ -> raise Invalid_syntax
               | [ Caractere c ], AllChars | [ AllChars ], Caractere c ->
                   if c = '\n' then
                     gen_regex_2 [ Ou (Caractere c, AllChars) ] false
```

```
      else gen_regex_2 [ AllChars ] false
  | Caractere c :: q, AllChars | AllChars :: q, Caractere c ->
      if c = '\n' then
        gen_regex_2 (Ou (Caractere c, AllChars) :: q) false
      else gen_regex_2 (AllChars :: q) false
  | [ Range (d, f) ], AllChars | [ AllChars ], Range (d, f) ->
      if int_of_char d < 32 || int_of_char f < 32 then
        gen_regex_2 [ Ou (Range (d, f), AllChars) ] false
      else gen_regex_2 [ AllChars ] false
  | Range (d, f) :: q, AllChars | AllChars :: q, Range (d, f) ->
```

```
                if int_of_char d < 32 || int_of_char f < 32 then
                  gen_regex_2 (Ou (Range (d, f), AllChars) :: q) false
                else gen_regex_2 (AllChars :: q) false
            | [ x ], _ -> gen_regex_2 [ Ou (x, left) ] false
            | x :: q, _ -> gen_regex_2 (Ou (x, left) :: q) false)
        | '#' -> (
            match pile with
            | [] -> gen_regex_2 [ Epsilon ] false
            | Concat (_, _) :: _
            | Caractere _ :: _
            | Ou (_, _) :: _
            | Range (_, _) :: _ ->
```

```
                gen_regex_2 pile false
            | _ -> gen_regex_2 (Epsilon :: pile) false)
        | '+' -> (
            match pile with
            | [] -> raise Invalid_syntax
            | Epsilon :: q -> gen_regex_2 pile false
            | [ x ] -> gen_regex_2 [ UnPlus x ] false
            | x :: q -> gen_regex_2 (UnPlus x :: q) false)
        | '*' -> (
            match pile with
            | [] -> raise Invalid_syntax
            | Epsilon :: q -> gen_regex_2 pile false
```

```
                    | [ x ] -> gen_regex_2 [ ZeroPlus x ] false
                    | x :: q -> gen_regex_2 (ZeroPlus x :: q) false)
                | '.' -> gen_regex_2 (AllChars :: pile) false
                | '?' -> (
                    match pile with
                    | [] -> raise Invalid_syntax
                    | Epsilon :: q -> gen_regex_2 pile false
                    | [ x ] -> gen_regex_2 [ Facultatif x ] false
                    | x :: q -> gen_regex_2 (Facultatif x :: q) false)
                | '~' -> (
                    let c = ref (pop caracters) in
```

```
                match !c with
                | '[' ->
                    let reg = crochet () in
                    let rec recon_crochet e =
                      match e with
                      | Caractere c ->
                          gen_regex_2
                            (AllBut (Array.init 128 (( <> ) (int_of_char c)))
                            :: pile)
                            false
                      | Range (b1, b2) ->
                          gen_regex_2
                            (AllBut
                               (Array.init 128 (fun i ->
```

```
                                    i < int_of_char b1 || i > int_of_char b2))
                              :: pile)
                              false
                    | Ou (e1, e2) -> (
                        match (recon_crochet e1, recon_crochet e2) with
                        | AllBut l1, AllBut l2 ->
                            gen_regex_2
                              (AllBut (Array.map2 ( && ) l1 l2) :: pile)
                              false
                        | _ -> failwith "impossible")
                    | _ -> raise Invalid_syntax
```

```
                    in
                    recon_crochet reg
                | '(' ->
                    let reg = parenthesis () in
                    let rec recon_parntethis e =
                      match e with
                      | Caractere c ->
                          gen_regex_2
                            (AllBut (Array.init 128 ((
                            ↪  <> ) (int_of_char c)))
                            :: pile)
                            false
                      | Range (b1, b2) ->
                          gen_regex_2
                            (AllBut
                               (Array.init 128 (fun i
                               ↪  ->
```

```
                                    i < int_of_char b1 || i > int_of_char b2))
                              :: pile)
                              false
                       | AllChars ->
                            gen_regex_2
                              (AllBut (Array.init 128 (( < ) 32)) :: pile)
                              false
                       | Ou (e1, e2) -> (
                            match (recon_parntethis e1, recon_parntethis e2) with
                            | AllBut l1, AllBut l2 ->
                                gen_regex_2
```

```
                                (AllBut (Array.map2 ( && ) l1 l2) :: pile)
                                false
                          | _ -> failwith "impossible")
                      | _ -> raise Invalid_syntax
                  in
                  recon_parntethis reg
              | '\\' ->
                  gen_regex_2
                    (AllBut
                       (Array.init 128 (( <> ) (int_of_char (pop caracters))))
                    :: pile)
                    false
              | ')' | ']' -> raise Invalid_syntax
```

```
                | c1 ->
                    gen_regex_2
                      (AllBut (Array.init 128 (( <> ) (int_of_char c1))) :: pile)
                      false)
            | _ -> gen_regex_2 (Caractere c :: pile) false
  in
  let reg = gen_regex_2 [] false in
  if not (is_empty caracters) then raise Invalid_syntax else reg
```

```ocaml
open Symbols

type pattern = symbol list
type rule = symbol * pattern list
type rule_hashtable = (symbol, pattern list)
↪ Hashtbl.t
type grammar = { rules_htbl : rule_hashtable;
↪ start_symbol : Symbols.symbol }

(** pour un symbole [s], renvoie sa représentation
↪ sous forme de chaîne *)
let string_of_symbol (s : symbol) : string =
  match s with
  | Terminal t -> string_of_terminal t
  | NonTerminal nt -> string_of_non_terminal nt

(** affiche le symbole [s] *)
```

```ocaml
let print_symbol (s : symbol) : unit = print_string (string_of_symbol s)

(** affiche chaque pattern de [patterns] *)
let print_patterns (patterns : pattern list) : unit =
  List.iter
    (fun pattern ->
      List.iter (fun s -> print_string (string_of_symbol s ^ " ")) pattern;
      print_newline ())
    patterns

(** affiche chaque règle de [r] *)
let print_rule_list (r : rule_hashtable) : unit =
  Hashtbl.iter
    (fun s patterns ->
```

```
        print_string (string_of_symbol s ^ " -> \n");
        print_patterns patterns;
        print_newline ())
    r

(** affiche la grammaire [g] *)
let print_grammar (g : grammar) =
  print_string "{\nrules: ";
  print_rule_list g.rules_htbl;
  print_string "\nstart_symbol: ";
  print_symbol g.start_symbol;
  print_string "\n}\n"

(** teste si le symbole [s] est terminal *)
let is_terminal_symbol (s : symbol) : bool =
  match s with Terminal _ -> true | NonTerminal _
   ↪  -> false
```

```ocaml

(** teste si le symbole [s] est non terminal *)
let is_non_terminal_symbol (s : symbol) : bool = not (is_terminal_symbol s)

(** teste si la règle associe un symbole [s] est terminal *)
let is_terminal ((s, _) : rule) : bool = is_terminal_symbol s

(** teste si la règle [r] est non terminale*)
let is_non_terminal (r : rule) : bool = not (is_terminal r)

(** renvoie la liste des terminaux de [r] *)
let terminals (r : rule list) : rule list = List.filter is_terminal r
```

```ocaml

(** renvoie la liste des non terminaux de [r] *)
let non_terminals (r : rule list) : rule list = List.filter is_non_terminal r

(** renvoie la règle associée au symbole [s] dans la grammaire [g] *)
let rule_of_symbol (g : grammar) (s : symbol) : rule =
  if Hashtbl.mem g.rules_htbl s then (s, Hashtbl.find g.rules_htbl s)
  else
    failwith
      ("the hashed grammar does not contain " ^ string_of_symbol s
      ^ " as a key\n")
```

```
open Grammar_functions
open Symbols
let grammar = { start_symbol = NonTerminal
 ↪  ExecutableProgram;
rules_htbl = Hashtbl.of_seq (List.to_seq
 ↪  [(NonTerminal ExecutableProgram,[[NonTerminal
 ↪  StartCommentBlock;NonTerminal
 ↪  Function_or_Subroutine_star_MainProgram;];[NonTermi
 ↪  Function_or_Subroutine_star_MainProgram;];]);
(NonTerminal StartCommentBlock,[[Terminal EOS;];]);
(NonTerminal
 ↪  Function_or_Subroutine_star_MainProgram,[[NonTermina
 ↪  Recursive_opt_Function_or_Subroutine;NonTerminal
 ↪  Function_or_Subroutine_star_MainProgram;];[NonTermi
 ↪  MainProgram;NonTerminal
 ↪  Function_or_Subroutine_star;];]);
```

```
(NonTerminal Function_or_Subroutine_star,[[NonTerminal Recursive_opt_Function_or_Subroutine;NonTerminal Function_or_Subroutine_star;];[Terminal E;];]);
(NonTerminal Recursive_opt_Function_or_Subroutine,[[Terminal Recursive;NonTerminal Function_or_Subroutine;];[NonTerminal Function_or_Subroutine;];]);
(NonTerminal Function_or_Subroutine,[[NonTerminal FunctionSubprogram;];[NonTerminal SubroutineSubprogram;];]);
(NonTerminal MainProgram,[[NonTerminal ProgramStmt;NonTerminal MainRange;];]);
```

```
(NonTerminal MainRange,[[NonTerminal BodyConstruct;NonTerminal BodyConstruct_star;NonTerminal Contains_Function_opt_EndProgramStmt;];[NonTerminal Contains_Function_opt_EndProgramStmt;];]);
(NonTerminal Contains_Function_opt_EndProgramStmt,[[NonTerminal Contains_Function;NonTerminal EndProgramStmt;];[NonTerminal EndProgramStmt;];]);
(NonTerminal Contains_Function,[[Terminal Contains;Terminal EOS;NonTerminal FunctionSubprogram_star;];]);
```

```
(NonTerminal FunctionSubprogram_star,[[Terminal Recursive;NonTerminal FunctionSubprogram;NonTerminal FunctionSubprogram_star;];[NonTerminal FunctionSubprogram;NonTerminal FunctionSubprogram_star;];[Terminal E;];]);
(NonTerminal BodyConstruct_star,[[NonTerminal BodyConstruct;NonTerminal BodyConstruct_star;];[Terminal E;];]);
(NonTerminal ProgramStmt,[[Terminal Program;NonTerminal ProgramName;Terminal EOS;];]);
(NonTerminal EndProgramStmt,[[Terminal EndProgram;NonTerminal EndName_opt;Terminal EOS;];]);
```

```
(NonTerminal FunctionSubprogram,[[NonTerminal FunctionPrefix;NonTerminal FunctionName;NonTerminal FunctionRange;];]);
(NonTerminal FunctionPrefix,[[NonTerminal TypeSpec;Terminal Function;];[Terminal Function;];]);
(NonTerminal FunctionRange,[[NonTerminal FunctionParList;NonTerminal FunctionResult_opt;Terminal EOS;NonTerminal BodyConstruct_star;NonTerminal EndFunctionStmt;];]);
(NonTerminal FunctionParList,[[Terminal LParenthesis;NonTerminal FunctionPar_Comma_FunctionPar_star_opt;Terminal RParenthesis;];]);
```

```
(NonTerminal FunctionPar_Comma_FunctionPar_star_opt,[[NonTerminal FunctionPar;NonTerminal Comma_FunctionPar_star;];[Terminal E;];]);
(NonTerminal Comma_FunctionPar_star,[[Terminal Comma;NonTerminal FunctionPar;NonTerminal Comma_FunctionPar_star;];[Terminal E;];]);
(NonTerminal FunctionPar,[[NonTerminal DummyArgName;];]);
(NonTerminal FunctionResult_opt,[[Terminal Result;Terminal LParenthesis;NonTerminal VariableName;Terminal RParenthesis;];[Terminal E;];]);
(NonTerminal EndFunctionStmt,[[Terminal EndFunction;NonTerminal EndName_opt;Terminal EOS;];]);
```

```
(NonTerminal SubroutineSubprogram,[[Terminal Subroutine;NonTerminal SubroutineName;NonTerminal SubroutineRange;];]);
(NonTerminal SubroutineRange,[[NonTerminal SubroutineParList_opt;Terminal EOS;NonTerminal BodyConstruct_star;NonTerminal EndSubroutineStmt;];]);
(NonTerminal SubroutineParList_opt,[[Terminal LParenthesis;NonTerminal SubroutinePar_Comma_SubroutinePar_star_opt;Terminal RParenthesis;];[Terminal E;];]);
(NonTerminal SubroutinePar_Comma_SubroutinePar_star_opt,[[NonTerm
SubroutinePar;NonTerminal Comma_SubroutinePar_star;];[Terminal E;];]);
```

```
(NonTerminal Comma_SubroutinePar_star,[[Terminal Comma;NonTerminal SubroutinePar;NonTerminal Comma_SubroutinePar_star;];[Terminal E;];]);
(NonTerminal SubroutinePar,[[NonTerminal DummyArgName;];]);
(NonTerminal EndSubroutineStmt,[[Terminal EndSubroutine;NonTerminal EndName_opt;Terminal EOS;];]);
(NonTerminal EndName_opt,[[NonTerminal EndName;];[Terminal E;];]);
(NonTerminal BodyConstruct,[[NonTerminal SpecificationPartConstruct;];[NonTerminal ExecutableConstruct;];]);
(NonTerminal SpecificationPartConstruct,[[NonTerminal DeclarationConstruct;];]);
```

```
(NonTerminal DeclarationConstruct,[[NonTerminal TypeDeclarationStmt;];]);
(NonTerminal TypeDeclarationStmt,[[NonTerminal TypeSpec;NonTerminal Comma_AttrSpec_star;NonTerminal TypeDecl_Assignment;Terminal EOS;];]);
(NonTerminal Comma_AttrSpec_star,[[Terminal Comma;NonTerminal AttrSpec;NonTerminal Comma_AttrSpec_star;];[Terminal E;];]);
(NonTerminal AttrSpec,[[Terminal Parameter;];[NonTerminal Intent_in_out;];]);
(NonTerminal Intent_in_out,[[Terminal Intent;Terminal LParenthesis;NonTerminal In_out;Terminal RParenthesis;];]);
(NonTerminal In_out,[[Terminal In;];[Terminal Out;];[Terminal InOut;];]);
```

```
(NonTerminal TypeDecl_Assignment,[[Terminal Colon;Terminal Colon;NonTerminal EntityDecl;NonTerminal Comma_EntityDecl_star;];[NonTerminal ObjectName;NonTerminal Comma_ObjectName_star;];]);
(NonTerminal Comma_ObjectName_star,[[Terminal Comma;NonTerminal ObjectName;NonTerminal Comma_ObjectName_star;];[Terminal E;];]);
(NonTerminal Comma_EntityDecl_star,[[Terminal Comma;NonTerminal EntityDecl;NonTerminal Comma_EntityDecl_star;];[Terminal E;];]);
(NonTerminal EntityDecl,[[NonTerminal ObjectName;NonTerminal Asterisk_CharLength_opt;NonTerminal Equal_Expr_opt;];]);
```

```
(NonTerminal Equal_Expr_opt,[[Terminal Equal;NonTerminal Expr;];[Terminal E;];]);
(NonTerminal Asterisk_CharLength_opt,[[Terminal Asterisk;NonTerminal CharLength;];[Terminal E;];]);
(NonTerminal CharLength,[[Terminal LParenthesis;NonTerminal TypeParamValue;Terminal RParenthesis;];[NonTerminal ScalarIntLiteralConstant;];]);
(NonTerminal TypeParamValue,[[NonTerminal Expr_Or_Asterisk;];]);
(NonTerminal Expr_Or_Asterisk,[[NonTerminal Expr;];[Terminal Asterisk;];]);
```

```
(NonTerminal TypeSpec,[[Terminal Integer;NonTerminal KindSelector_opt;];[Terminal Double;];[Terminal Complex;NonTerminal KindSelector_opt;];[Terminal Logical;NonTerminal KindSelector_opt;];[Terminal Real;NonTerminal KindSelector_opt;];[Terminal Character;];]);
(NonTerminal KindSelector_opt,[[Terminal LParenthesis;NonTerminal Expr;Terminal RParenthesis;];[Terminal E;];]);
(NonTerminal ExecutableConstruct,[[NonTerminal ActionStmt;];[NonTerminal DoConstruct;];[NonTerminal IfConstruct;];[NonTerminal ReturnStmt;];]);
(NonTerminal ReturnStmt,[[Terminal Return;Terminal EOS;];]);
```

```
(NonTerminal ActionStmt,[[NonTerminal AssignmentStmt;];[NonTerminal PrintStmt;];]);
(NonTerminal AssignmentStmt,[[NonTerminal Name;Terminal Equal;NonTerminal Expr;Terminal EOS;];]);
(NonTerminal PrintStmt,[[Terminal Print;NonTerminal FormatIdentifier;NonTerminal Comma_OutputItemList_opt;Terminal EOS;];]);
(NonTerminal Comma_OutputItemList_opt,[[Terminal Comma;NonTerminal OutputItemList;];[Terminal E;];]);
(NonTerminal FormatIdentifier,[[Terminal Asterisk;];]);
(NonTerminal OutputItemList,[[NonTerminal OutputItem;NonTerminal Comma_OutputItem_star;];]);
```

```
(NonTerminal Comma_OutputItem_star,[[Terminal Comma;NonTerminal OutputItem;NonTerminal Comma_OutputItem_star;];[Terminal E;];]);
(NonTerminal OutputItem,[[NonTerminal Expr;];]);
(NonTerminal DoConstruct,[[NonTerminal BlockDoConstruct;];]);
(NonTerminal BlockDoConstruct,[[Terminal Do;NonTerminal LoopControl_opt;NonTerminal ExecutionPartConstruct_star;NonTerminal EndDoStmt;];]);
(NonTerminal LoopControl_opt,[[NonTerminal LoopControl;Terminal EOS;];[Terminal EOS;];]);
(NonTerminal EndDoStmt,[[Terminal EndDo;NonTerminal Name_opt;Terminal EOS;];]);
(NonTerminal Name_opt,[[NonTerminal Name;];[Terminal E;];]);
```

```
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↪   LParenthesis;NonTerminal Expr;Terminal
↪   RParenthesis;];[NonTerminal
↪   VariableName;Terminal Equal;NonTerminal
↪   IntRealDpExpression;Terminal Comma;NonTerminal
↪   IntRealDpExpression;NonTerminal
↪   Comma_IntRealDpExpression_opt;];]);
(NonTerminal
↪   Comma_IntRealDpExpression_opt,[[Terminal
↪   Comma;NonTerminal
↪   IntRealDpExpression;];[Terminal E;];]);
(NonTerminal IntRealDpExpression,[[NonTerminal
↪   Expr;];]);
```

```
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↪   IfThenStmt;NonTerminal
↪   ExecutionPartConstruct_star;NonTerminal
↪   ElseIfStmt_ExecutionPartConstruct_star_star;NonTerm
↪   ElseStmt_ExecutionPartConstruct_star_opt;NonTermina
↪   EndIfStmt;];]);
(NonTerminal
↪   ElseIfStmt_ExecutionPartConstruct_star_star,[[NonTe
↪   ElseIfStmt;NonTerminal
↪   ExecutionPartConstruct_star;NonTerminal
↪   ElseIfStmt_ExecutionPartConstruct_star_star;];[Term
↪   E;];]);
(NonTerminal
↪   ExecutionPartConstruct_star,[[NonTerminal
↪   ExecutionPartConstruct;NonTerminal
↪   ExecutionPartConstruct_star;];[Terminal E;];]);
```

```
(NonTerminal
↪   ElseStmt_ExecutionPartConstruct_star_opt,[[NonTermi
↪   ElseStmt;NonTerminal
↪   ExecutionPartConstruct_star;];[Terminal E;];]);
(NonTerminal IfThenStmt,[[Terminal If;Terminal
↪   LParenthesis;NonTerminal
↪   ScalarLogicalExpr;Terminal
↪   RParenthesis;Terminal Then;Terminal EOS;];]);
(NonTerminal ElseIfStmt,[[Terminal Else;Terminal
↪   If;Terminal LParenthesis;NonTerminal
↪   ScalarLogicalExpr;Terminal
↪   RParenthesis;Terminal Then;Terminal EOS;];]);
(NonTerminal ElseStmt,[[Terminal Else;Terminal
↪   EOS;];]);
(NonTerminal EndIfStmt,[[Terminal EndIf;Terminal
↪   EOS;];]);
```

```
(NonTerminal ExecutionPartConstruct,[[NonTerminal ExecutableConstruct;];]);
(NonTerminal ScalarLogicalExpr,[[NonTerminal Expr;];]);
(NonTerminal Expr,[[NonTerminal Level5Expr;];]);
(NonTerminal Level5Expr,[[NonTerminal EquivOperand;NonTerminal EquivOp_EquivOperand_star;];]);
(NonTerminal EquivOp_EquivOperand_star,[[NonTerminal EquivOp;NonTerminal EquivOperand;NonTerminal EquivOp_EquivOperand_star;];[Terminal E;];]);
(NonTerminal EquivOperand,[[NonTerminal OrOperand;NonTerminal OrOp_OrOperand_star;];]);
(NonTerminal OrOp_OrOperand_star,[[Terminal OrOp;NonTerminal OrOperand;NonTerminal OrOp_OrOperand_star;];[Terminal E;];]);
```

```
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(NonTerminal AndOperand,[[NonTerminal NotOp_opt;NonTerminal Level4Expr;];]);
(NonTerminal NotOp_opt,[[Terminal NotOp;];[Terminal E;];]);
(NonTerminal Level4Expr,[[NonTerminal Level3Expr;NonTerminal RelOp_Level3Expr_star;];]);
(NonTerminal RelOp_Level3Expr_star,[[NonTerminal RelOp;NonTerminal Level3Expr;NonTerminal RelOp_Level3Expr_star;];[Terminal E;];]);
```

```
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(NonTerminal AddOp_Sign_opt_AddOperand_star,[[NonTerminal AddOp;NonTerminal Sign_opt_AddOperand;NonTerminal AddOp_Sign_opt_AddOperand_star;];[Terminal E;];]);
(NonTerminal Sign_opt_AddOperand,[[NonTerminal Sign_opt;NonTerminal AddOperand;];]);
(NonTerminal Sign_opt,[[NonTerminal Sign;];[Terminal E;];]);
```

```
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(NonTerminal Level1Expr,[[NonTerminal Primary;];]);
```

```
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    Rcon;];[Terminal Dcon;];[NonTerminal
    Name;NonTerminal
    FunctionReference_opt;];[NonTerminal
    Scon;];[NonTerminal LogicalConstant;];[Terminal
    LParenthesis;NonTerminal Expr;Terminal
    RParenthesis;];]);
(NonTerminal FunctionReference_opt,[[Terminal
    LParenthesis;NonTerminal
    FunctionArg_Comma_FunctionArg_star_opt_RParenthesis
    E;];]);
(NonTerminal
    FunctionArg_Comma_FunctionArg_star_opt_RParenthesis
    FunctionArg;NonTerminal
    Comma_FunctionArg_star;Terminal
    RParenthesis;];[Terminal RParenthesis;];]);
```

```
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(NonTerminal FunctionArg,[[NonTerminal Expr;];]);
(NonTerminal Name,[[Terminal Ident;];]);
(NonTerminal ArrayName,[[Terminal Ident;];]);
(NonTerminal ComponentName,[[Terminal Ident;];]);
(NonTerminal EndName,[[Terminal Ident;];]);
(NonTerminal DummyArgName,[[Terminal Ident;];]);
(NonTerminal FunctionName,[[Terminal Ident;];]);
(NonTerminal ImpliedDoVariable,[[Terminal Ident;];]);
(NonTerminal ProgramName,[[Terminal Ident;];]);
(NonTerminal SubroutineName,[[Terminal Ident;];]);
(NonTerminal SubroutineNameUse,[[Terminal Ident;];]);
(NonTerminal VariableName,[[Terminal Ident;];]);
```

```
(NonTerminal ObjectName,[[Terminal Ident;];]);
(NonTerminal LogicalConstant,[[Terminal True;];[Terminal False;];]);
(NonTerminal MultOp,[[Terminal Asterisk;];[Terminal Divise;];]);
(NonTerminal AddOp,[[NonTerminal Sign;];]);
(NonTerminal Sign,[[Terminal Plus;];[Terminal Minus;];]);
(NonTerminal RelOp,[[Terminal IsEqual;];[Terminal NotEqual;];[Terminal StrictLess;];[Terminal LessEqual;];[Terminal StrictGreater;];[Terminal GreaterEqual;];]);
(NonTerminal EquivOp,[[Terminal Equivalent;];[Terminal NotEquivalent;];]);
(NonTerminal ScalarIntLiteralConstant,[[Terminal Icon;];]);
```

```
(NonTerminal Scon,[[Terminal SconSingle;];[Terminal
↪  SconDouble;];]);
]))}
```

```
open Regex
open Symbols
open Vector
module IntSet = Set.Make (Int)

(* différentes représentations d'automates utiles lors de sa transformation en automate déterministe *)
type automate = {
  nodes : int list;
  debut_l : int list;
  fin : (int * terminal) list;
  transitions : (char option * int) list array;
}

type automate_sans_eps = {
  nodes : int list;
```

```
  debut_l : int list;
  fin : (int * terminal) list;
  transitions_sans_eps : (char * int) list array;
}

type pre_automate_det = {
  mutable nodes : int list;
  debut : int;
  mutable fin : terminal option array;
  mutable pre_transitions : int array Vector.t;
}

(* automate de sortie utile pour la transpilation
 ↪  *)
type automate_det = {
  nodes : int list;
  debut : int;
```

```
  fin : terminal option array;
  transitions : int array array;
      (* transitions.(i).(j), i le sommet de départ, j l'entier du caractère *)
}

(** Renvoie la liste de toutes les lignes dans le fichier [file_name]. *)
let read_file (file_name : string) : string list =
  let rec lire file liste =
    let line = input_line file in
    ();
    try lire file (line :: liste)
    with End_of_file ->
      close_in file;
      line :: liste
  in
```

```
  List.rev (lire (open_in file_name) [])

(** Renvoie la liste [[0...n-1]] *)
let range_list (n : int) : int list =
  let l = ref [] in
  for i = 0 to n - 1 do
    l := i :: !l
  done;
  !l

(** crée l'automate de stage 1 à partir d'une expression régulière [reg] et d'un
    terminal [t] *)
let automate_gen (reg : regex) (t : terminal) : automate =
  let dico = Hashtbl.create 0 in
  let a =
```

```
    ref { nodes = []; debut_l = [ 0 ]; fin = [ (1, t) ]; transitions = [||] }
  in

  (** ajoute la transition [n1 -> n2] étiquetée par [c] à l'automate *)
  let add_transition ((n1, c, n2) : int * char option * int) =
    if Hashtbl.mem dico n1 then
      Hashtbl.replace dico n1 ((c, n2) :: Hashtbl.find dico n1)
    else Hashtbl.add dico n1 [ (c, n2) ]
  in

  let next_node = ref 2 in

```

```
let rec automate_gen_aux (reg : regex) ((node_before, node_after) : int * int)
    : unit =
  match reg with
  | Vide -> ()
  | Epsilon -> add_transition (node_before, None, node_after)
  | AllChars ->
      for i = 32 to 127 do
        add_transition (node_before, Some (char_of_int i), node_after)
      done
  | Caractere x -> add_transition (node_before, Some x, node_after)
  | Concat (g, d) ->
      let node = !next_node in
      next_node := !next_node + 1;
```

```
            automate_gen_aux g (node_before, node);
            automate_gen_aux d (node, node_after)
        | Ou (g, d) ->
            automate_gen_aux g (node_before, node_after);
            automate_gen_aux d (node_before, node_after)
        | Range (a1, a2) ->
            for i = int_of_char a1 to int_of_char a2 do
              automate_gen_aux (Caractere (char_of_int i)) (node_before, node_after)
            done
        | ZeroPlus e ->
            automate_gen_aux e (node_before, node_before);
            automate_gen_aux Epsilon (node_before, node_after)
```

```
      | UnPlus e ->
        automate_gen_aux e (node_before,
         ↪  node_before);
        automate_gen_aux e (node_before,
         ↪  node_after)
      | Facultatif e ->
        automate_gen_aux e (node_before,
         ↪  node_after);
        automate_gen_aux Epsilon (node_before,
         ↪  node_after)
      | AllBut e ->
        for i = 0 to 127 do
          if e.(i) then
            add_transition (node_before, Some
             ↪  (char_of_int i), node_after)
        done
   in
```

```
automate_gen_aux reg (0, 1);

let l1 = List.of_seq (Hashtbl.to_seq_keys dico) in
let rec build_trans (l : int list) (arr : (char option * int) list array) :
    unit =
  match l with
  | [] -> ()
  | x :: q ->
      arr.(x) <- Hashtbl.find dico x;
      build_trans q arr
in
let arr = Array.make !next_node [] in
build_trans l1 arr;
{
  nodes = range_list !next_node;
```

```
    debut_l = !a.debut_l;
    fin = !a.fin;
    transitions = arr;
  }

(** construit la disjonction des automates de [l_a], qui reconnait donc l'union
    des language des automates de [l_a] *)
let ou_automates (l_a : automate list) : automate =
  (** construit la disjonction de la liste [l] avec un automate [out] *)
  let rec ou_automate_aux (l : automate list) (out : automate) =
    match l with
    | [] -> out
    | x :: q ->
        let inc = List.length out.nodes in
```

```
          let x2 =
            {
              nodes = List.map (( + ) inc) x.nodes;
              debut_l = List.map (( + ) inc)
               ↪  x.debut_l;
              fin = List.map (fun (x, y) -> (x + inc,
               ↪  y)) x.fin;
              transitions = [||];
            }
          in
          ou_automate_aux q
            {
              nodes = out.nodes @ x2.nodes;
              debut_l = out.debut_l @ x2.debut_l;
              fin = out.fin @ x2.fin;
              transitions =
                Array.init
```

```
                    (inc + Array.length x.transitions)
                    (fun i ->
                      if i < inc then out.transitions.(i)
                      else
                        List.map
                          (fun (c, x) -> (c, x + inc))
                          x.transitions.(i - inc));
              }
  in
  let a =
    ou_automate_aux l_a
      { nodes = []; debut_l = []; fin = []; transitions = [||] }
  in
  let nouv_d = List.length a.nodes in

```

```
(** Ajoute le début unique à l'automate par une transition [k -> x] étiquetée
    par epsilon (où k est l'état de départ, x est un ancien départ d'un
    élément de [l]) à out *)
let rec ajouter_debut (l : int list) (out : (char option * int) list array) :
    (char option * int) list array =
  Array.append out [| List.map (fun x -> (None, x)) l |]
in
{
  nodes = nouv_d :: a.nodes;
  debut_l = [ nouv_d ];
  fin = a.fin;
  transitions = ajouter_debut a.debut_l a.transitions;
```

```
  }

(** enlève les doublons dans la liste [l] *)
let remove_duplicates (l : 'a list) : 'a list =
  let tbl = Hashtbl.create 0 in
  let rec aux (l : 'a list) (out : 'a list) : 'a
   ↪  list =
    match l with
    | [] -> out
    | x :: q ->
        if Hashtbl.mem tbl x then aux q out
        else (
          Hashtbl.add tbl x 0;
          aux q (x :: out))
  in
  aux l []

```

```
(*
  Étapes pour enlever les epsilon-transitions:
  - On prend un sommet
  - On regarde toutes les epsilon-transitions
   ↪ sortantes (pas les boucles)
  - On regarde tous les transitions entrantes
  - On ajoute des nouvelles transitons des
   ↪ entrantes vers les sortantes
  - On supprime l'epsilon-transition

  Requis:
  - transitions entrantes de chaque sommet =>
   ↪ précalculé
*)

(** enlève les epsilon-transitions dans l'automate
↪ [a] en effectuant les étapes
```

```
    ci-dessus *)
let enleve_epsilon_trans (a : automate) : automate_sans_eps =
  let len = List.length a.nodes in
  (* on stocke les degrés entrants et sortants de chaque sommet *)
  (* les éléments stockés ne sont pas linéarisés *)
  let entrants = Array.make len [] in

  (* degré entrant de chaque sommet *)
  let degres = Array.make len 0 in

  let trans_temp = ref a.transitions in
  let fin_temp = ref a.fin in
  let deg_traite = ref 0 in

```

```
  (** trouve le premier sommet de degré zéro *)
  let rec find_premier_deg_zero () : int =
    let deg = !deg_traite in
    if degres.(!deg_traite) <= 0 then incr deg_traite;
    while !deg_traite < len && degres.(!deg_traite) > 0 do
      incr deg_traite
    done;
    if deg == !deg_traite then (
      incr deg_traite;
      find_premier_deg_zero ())
    else if !deg_traite >= len then -1
    else !deg_traite
  in

  (* construit les listes d'entrants de chaque sommet *)
```

```
Array.iteri
  (fun e l ->
    List.iter
      (fun (c, s) ->
        entrants.(s) <- (e, c) :: entrants.(s);
        degres.(s) <- degres.(s) + 1)
      l)
  a.transitions;
(* ajouter un de degré entrant pour chaque entrée *)
List.iter (fun x -> degres.(x) <- degres.(x) + 1) a.debut_l;

(* applique l'algorithme de suppression des epsilon transitions sur chacun des sommets *)
List.iter
  (fun node_i ->
```

```
    (* récupération les transitions entrantes
     ↪  avec epsilon transitions qui ne sont pas
     ↪  des boucles + enlever du degré entrant
     ↪  pour chaque epsilon transition *)
    let res =
      remove_duplicates
        (List.fold_left
           (fun acc x ->
             match x with
             | _, Some x -> acc
             | node, None ->
                 degres.(node_i) <-
                  ↪  degres.(node_i) - 1;
                 if node == node_i then acc else
                  ↪  node :: acc)
           [] entrants.(node_i))
    in
```

```
    (* on enlève les epsilon entrants de chaque epsilon transition *)
    entrants.(node_i) <-
      List.filter (fun (_, c) -> c != None) entrants.(node_i);
    (* on enlève les sortants de chaque epsilon transition *)
    !trans_temp.(node_i) <-
      List.filter
        (fun (c, x) -> not (c == None && x == node_i))
        !trans_temp.(node_i);
    List.iter
      (fun x ->
        !trans_temp.(x) <-
          List.filter
```

```
                (fun (c, x1) -> not (c == None && x1
                ↪  == node_i))
                !trans_temp.(x))
          res;
        (* ajoute les transitions des entrants avec
        ↪  epsilon transitions vers les sortants et
        ↪  actualise les entrants/sortants/degré de
        ↪  deux sommets *)
        List.iter
          (fun x ->
            List.iter
              (fun (c, node) ->
                !trans_temp.(x) <- (c, node) ::
                ↪  !trans_temp.(x);
                entrants.(node) <- (x, c) ::
                ↪  entrants.(node);
                degres.(node) <- degres.(node) + 1)
```

```
                (List.filter
                   (fun (c, n) -> not (n == node_i && c
                   ↪  = None))
                   !trans_temp.(node_i)))
            res;

        (* récupération des états de fin du sommet de
        ↪  départ *)
        let fins =
          List.fold_left
            (fun acc (x, t) -> if x == node_i then t
            ↪  :: acc else acc)
            [] a.fin
        in
```

```
    (* applique l'ensemble des états de fin aux sommets qui avaient une epsilon transition *)
    List.iter
      (fun x -> List.iter (fun t -> fin_temp := (x, t) :: !fin_temp) fins)
      res)
  a.nodes;

(* enlever les nodes qui ne sont plus atteintes *)
let todo = ref (find_premier_deg_zero ()) in
while !todo <> -1 do
  List.iter (fun (_, x) -> degres.(x) <- degres.(x) - 1) !trans_temp.(!todo);
  todo := find_premier_deg_zero ()
done;
```

```

    (* enlever les option car toutes les transition (devraient être) sans epsilon transition *)
    {
      nodes = List.filter (fun x -> degres.(x) > 0) a.nodes;
      debut_l = a.debut_l;
      fin = List.filter (fun (x, _) -> degres.(x) > 0) !fin_temp;
      transitions_sans_eps =
        Array.map
          (fun x ->
            List.map
              (fun (c, n) ->
                match c with None -> failwith "pas correct" | Some c1 -> (c1, n))
```

```
             (List.filter (fun (_, n) -> degres.(n) > 0) x))
         !trans_temp;
  }

(** Donne à chaque ensemble d'éléments [elem] un entier à partir de la table de
    linéarisation [lin_tbl] et cette de délinéarisation [delin_tbl] *)
let lin (elem : IntSet.t) (lin_tbl : (IntSet.t, int) Hashtbl.t)
    (delin_tbl : IntSet.t Vector.t) : int =
  if not (Hashtbl.mem lin_tbl IntSet.empty) then
    Hashtbl.add lin_tbl IntSet.empty 0;

  if Hashtbl.find lin_tbl IntSet.empty <> Vector.length delin_tbl then
```

```
    failwith "La taille des deux tables n'est pas la même";

  if not (Hashtbl.mem lin_tbl elem) then (
    Hashtbl.add lin_tbl elem (Hashtbl.find lin_tbl IntSet.empty);
    Hashtbl.replace lin_tbl IntSet.empty (Hashtbl.find lin_tbl IntSet.empty + 1);
    Vector.push delin_tbl elem);
  Hashtbl.find lin_tbl elem

(** Pour chaque entier [elem], renvoie l'ensemble de sommets corrspondant, à
    l'aide de la table de délinéarisation [delin_tbl] *)
let delin (elem : int) (delin_tbl : IntSet.t Vector.t) : IntSet.t =
```

```
    if elem = -1 then IntSet.empty
    else if elem >= Vector.length delin_tbl then
      failwith "L'élément demandé n'est pas dans la table"
    else Vector.get delin_tbl elem

(** déterminise l'automate [a] *)
let determinise (a : automate_sans_eps) : automate_det =
  (* crée les deux table utiles pour la linéarisation / délinéarisation *)
  let lin_tbl = Hashtbl.create (List.length a.nodes) in
  let delin_tbl = Vector.create ~dummy:IntSet.empty in

```

```
  let start_node = lin (IntSet.of_list a.debut_l)
   ↪  lin_tbl delin_tbl in
  let todo = ref [ start_node ] in

  let a_det =
    {
      nodes = [ start_node ];
      debut = start_node;
      fin = [||];
      pre_transitions = Vector.create
       ↪  ~dummy:(Array.make 1 0);
    }
  in

  Vector.push a_det.pre_transitions (Array.make 128
   ↪  (-1));
  (* pour le début *)
```

```
  let fin = IntSet.of_list (List.map (fun (a, b) -> a) a.fin) in

  (** trouve les successeurs de tous les sommets de [l] et on les stocke dans
      [arr] *)
  let rec trouver_suivants (l : IntSet.t) (arr : int array) : unit =
    let len = Array.length arr in

    (* on rassemble les éléments accessibles depuis tous les sommets de l *)
    let storage = Array.make len IntSet.empty in
    IntSet.iter
      (fun x ->
        List.iter
          (fun (c, e) ->
```

```
              storage.(int_of_char c) <- IntSet.add e storage.(int_of_char c))
            a.transitions_sans_eps.(x))
        l;

      (* on linéarise les sommets obtenus et on les stocke dans arr *)
      for i = 0 to len - 1 do
        if not (IntSet.is_empty storage.(i)) then
          arr.(i) <- lin storage.(i) lin_tbl delin_tbl
      done
    in

    (** teste si le sommet [elem] linéarisé contient des éléments finaux et
        l'ajoute aux finaux si c'est le cas *)
```

```
  let ajouter_fin (elem : int) : unit =
    let res =
      remove_duplicates
        (List.map
           (fun e -> List.assoc e a.fin)
           (IntSet.to_list (IntSet.inter fin (delin elem delin_tbl))))
    in
    match res with
    | [] -> ()
    | [ e ] -> a_det.fin.(elem) <- Some e
    | [ e1; e2 ] ->
        (* L'un des deux est un safe_token, elle peut être vue autrement donc elle est ignorée *)
        if e1 = safe_token then a_det.fin.(elem) <- Some e2
```

```
        else if e2 = safe_token then a_det.fin.(elem) <- Some e1
        else (
          print_char '"';
          print_string (repr_of_terminal e1);
          print_string "\" \"";
          print_string (repr_of_terminal e2);
          print_char '"';
          print_string "on un état final commun";
          print_newline ();
          failwith "" (* il a plus d'un élément final *))
    | _ -> failwith "A syntax can't have more than one output"
  in

  let finished = ref false in
```

```
    let seen = ref IntSet.empty in
    (* on construit l'automate déterministe *)
    while not !finished do
      match !todo with
      | [] -> finished := true
      | x :: q ->
            let init_len = Hashtbl.find lin_tbl IntSet.empty in
            todo := q;
            let suivants = Array.make 128 (-1) in
            trouver_suivants (delin x delin_tbl) suivants;

            let arr = Vector.get a_det.pre_transitions x in
            for i = 0 to 127 do
              if suivants.(i) >= init_len then
```

```
          (* si c'est un nouveau noeud, on l'ajoute a la liste de traitement, on l'ajoute dans l'automate et on vérifie s'il est final *)
          if not (IntSet.mem suivants.(i) !seen) then (
            seen := IntSet.add suivants.(i) !seen;
            todo := suivants.(i) :: !todo;
            Vector.push a_det.pre_transitions (Array.make 128 (-1));
            a_det.nodes <- suivants.(i) :: a_det.nodes);
        (* noeud déjà existant/complétion nouveau noeud, comme on ne traite qu'une fois chaque sommets,
```

```
            on sait que les sommets trouvé sont les bons, on les remplace *)
            if suivants.(i) <> -1 then arr.(i) <- suivants.(i)
          done;
          Vector.set a_det.pre_transitions x arr
  done;

  (* gérer le cas des mots vides, qui sont donc à la fois initiaux et finaux *)
  a_det.fin <- Array.make (List.length a_det.nodes) None;
  List.iter ajouter_fin a_det.nodes;
  {
    nodes = a_det.nodes;
    debut = a_det.debut;
    fin = a_det.fin;
```

```
    transitions = Vector.to_array a_det.pre_transitions;
  }

(** effectue le delta 1 sur l'automate [a] à partir de [node] avec l'étiquette
    [c] *)
let exec_char (a : automate_det) (node : int) (c : char) : int =
  a.transitions.(node).(int_of_char c)

(** effectue le delta étoile sur l'automate [a] avec le texte [texte] *)
let execution_mot (a : automate_det) (texte : char list) :
    int * char list * char list =
  let node = ref a.debut in
```

```
  let last_found = ref (-1) in
  let text_as_last = ref texte in
  let texte = ref texte in
  let text_read = ref [] in
  let last_read = ref [] in

  (* tant que l'on est pas dans le puit *)
  while !node != -1 do
    match !texte with
    | [] -> node := -1 (* forcer la fin de la boucle *)
    | c :: q ->
        (* on effectue le delta 1 *)
        text_read := c :: !text_read;
        node := exec_char a !node c;
        texte := q;
        (* on note si on passe par un état final *)
```

```
            if !node = -1 then (if !last_found = -1 then last_read := !text_read)
            else (
              (match a.fin.(!node) with
              | None -> ()
              | Some t ->
                  last_found := !node;
                  text_as_last := !texte);
              last_read := !text_read)
  done;
  (* on renvoie le dernier état final trouvé*)
  (!last_found, !text_as_last, !last_read)

(** exécute l'automate [a] en boucle sur le texte [txt] pour créer une liste de
    lexèmes *)
let exec (a : automate_det) (txt : string) : (symbol * string) list =
```

```
(** exécute l'automate [a] en boucle sur le texte [texte] et concatène le
    résultat dans [out] *)
let rec exec_aux (a : automate_det) (texte : char list)
    (out : (terminal * string) list) : (terminal * string) list =
  match texte with
  | [] -> List.rev out
  | _ -> (
      match execution_mot a texte with
      | -1, _, s ->
          print_string "Le lexème '";
          print_string (String.of_seq (List.to_seq (List.rev s)));
          print_string "' n'est pas un lexème reconnu\n";
```

```
                failwith ""
            | x, q, s -> (
                let s = String.of_seq (List.to_seq
                 ↪  (List.rev s)) in
                match a.fin.(x) with
                | None ->
                    print_string "Le lexème '";
                    print_string s;
                    print_string "' n'est pas un lexème
                     ↪  reconnu\n";
                    failwith ""
                | Some t -> exec_aux a q ((t, s) ::
                 ↪  out)))
    in
    let res = exec_aux a (List.of_seq (String.to_seq
     ↪  txt)) [] in
```

```
  let tbl = Hashtbl.create (List.length unparsed_tokens) in
  List.iter (fun x -> Hashtbl.add tbl x ()) unparsed_tokens;
  List.map
    (fun (t, s) -> (Terminal t, s))
    (List.filter (fun (x, _) -> not (Hashtbl.mem tbl x)) res)

(** exécute l'automate [a] sur le fichier [f_name] *)
let exec_of_file (a : automate_det) (f_name : string) : (symbol * string) list =
  exec a
    (List.fold_left (fun acc line -> acc ^ line ^ "\n") "" (read_file f_name))
```

```ocaml
open Grammar_functions
open Symbols

module SymbolSet = Set.Make (struct
  type t = symbol

  let compare = compare
end)

(* arbre de syntaxe (non abstraite) *)
type at = Noeud of (symbol * string) * at list
type symbol_SS_Htbl = (symbol, SymbolSet.t)
↪  Hashtbl.t

let print_SymbolSet (ss : SymbolSet.t) : unit =
  print_endline "SymbolSet(";
  SymbolSet.iter
```

```
    (fun s ->
      print_symbol s;
      print_newline ())
    ss;
  print_endline ")\n"

let print_SymbolSet_Hastable (h : symbol_SS_Htbl) :
↪  unit =
  Hashtbl.iter
    (fun s ss ->
      print_string (string_of_symbol s ^ " -> ");
      print_SymbolSet ss;
      print_newline ())
    h

(* returns a hashtable containing the first set of
↪  every non terminal *)
```

```
let first (g : grammar) : symbol_SS_Htbl =
  (* prog dyn, filling first_h *)
  let first_h = Hashtbl.create (Hashtbl.length g.rules_htbl) in

  let rec first_of_rule ((s, patterns) : rule) : unit =
    if is_terminal (s, patterns) then
      Hashtbl.add first_h s (SymbolSet.singleton s)
    else if
      (* checking if already computed *)
      not (Hashtbl.mem first_h s)
    then
      Hashtbl.add first_h s
        (List.fold_left
          (fun acc d ->
            let f = first_of_pattern s d in
```

```
                    if SymbolSet.disjoint f acc then SymbolSet.union f acc
                    else (
                      print_symbol s;
                      print_newline ();
                      print_SymbolSet f;
                      prerr_newline ();
                      print_SymbolSet acc;
                      print_newline ();
                      failwith "the first set is not disjoined"))
                SymbolSet.empty patterns)
    else ()
  and first_of_pattern (s : symbol) (d : pattern) : SymbolSet.t =
    match d with
    | [] -> failwith "empty pattern"
```

```
    | Terminal t :: q -> SymbolSet.singleton
    ↪  (Terminal t)
    | fst_symbol :: q ->
      first_of_rule (fst_symbol, Hashtbl.find
      ↪  g.rules_htbl fst_symbol);
      if
        SymbolSet.mem (Terminal E) (Hashtbl.find
        ↪  first_h fst_symbol)
        && q <> []
      then
        SymbolSet.union (first_of_pattern s q)
          (SymbolSet.remove (Terminal E)
          ↪  (Hashtbl.find first_h fst_symbol))
      else Hashtbl.find first_h fst_symbol
  in
  Hashtbl.iter (fun name pattern -> first_of_rule
  ↪  (name, pattern)) g.rules_htbl;
```

```
  first_h

let rec first_of_pattern (fst_ss_htbl : symbol_SS_Htbl) (p : pattern) : SymbolSet.t =
  (* print_endline ("first_of_pattern "); print_patterns [p];print_newline (); *)
  match p with
  | [] -> failwith "empty pattern in first_of_pattern"
  | Terminal t :: _ -> SymbolSet.singleton (Terminal t)
  | NonTerminal nt :: q ->
     if
       SymbolSet.mem (Terminal E) (Hashtbl.find fst_ss_htbl (NonTerminal nt))
       && q <> []
```

```
        then
          SymbolSet.union
            (first_of_pattern fst_ss_htbl q)
            (SymbolSet.remove (Terminal E)
               (Hashtbl.find fst_ss_htbl (NonTerminal
               ↪  nt)))
        else Hashtbl.find fst_ss_htbl (NonTerminal
        ↪  nt)

(* returns a hashtable containing the follow set of
↪  every non terminal (all the terminals that can
↪  occur after a rule) *)
let follow (g : grammar) : symbol_SS_Htbl =
  (* contains the terminals following the key in
  ↪  the hashtable *)
  let follow_non_terminal =
    Hashtbl.of_seq
```

```
        (Seq.map
           (fun (name, pattern) -> (name, SymbolSet.empty))
           (Hashtbl.to_seq g.rules_htbl))
    in

    (* contains the rule names in which the key appears in at the end *)
    let parent_on_end =
      Hashtbl.of_seq
        (Seq.map
           (fun (name, pattern) -> (name, SymbolSet.empty))
           (Hashtbl.to_seq g.rules_htbl))
    in

```

```
(* fills the follow_non_terminal and parent_on_end *)
let rec pattern_follow (s : symbol) (d : pattern) : unit =
  match d with
  | NonTerminal s1 :: s2 :: q ->
      Hashtbl.replace follow_non_terminal (NonTerminal s1)
        (SymbolSet.add s2 (Hashtbl.find follow_non_terminal (NonTerminal s1)));
      pattern_follow s (s2 :: q)
  | Terminal s1 :: q -> pattern_follow s q
  | NonTerminal s1 :: [] ->
      if NonTerminal s1 <> s && NonTerminal s1 <> Terminal E then
```

```
            Hashtbl.replace parent_on_end
             ↪  (NonTerminal s1)
              (SymbolSet.add s (Hashtbl.find
               ↪  parent_on_end (NonTerminal s1)))
          else ()
      | [] -> ()
  in

  let patterns_follow (s : symbol) (patterns :
   ↪  pattern list) : unit =
    List.iter (pattern_follow s) patterns
  in
  Hashtbl.iter patterns_follow g.rules_htbl;

  let first_h = first g in
  (* contains the terminals that can appear after a
   ↪  key in the grammar*)
```

```
  let follow_h = Hashtbl.create (Hashtbl.length first_h) in

  let rec union_and_next_on_epsilon (next_hashtable : symbol_SS_Htbl)
      (s : symbol) (acc : SymbolSet.t) : SymbolSet.t =
    if is_non_terminal_symbol s then
      if SymbolSet.mem (Terminal E) (Hashtbl.find next_hashtable s) then (
        follow_of_symbol s;
        SymbolSet.remove (Terminal E)
          (SymbolSet.union acc
             (SymbolSet.union (Hashtbl.find follow_h s)
                (Hashtbl.find next_hashtable s))))
```

```
        else SymbolSet.union acc (Hashtbl.find
         ↪  next_hashtable s)
      else SymbolSet.singleton s
    and follow_of_symbol (s : symbol) : unit =
      (* checking if already computed *)
      if not (Hashtbl.mem follow_h s) then
        let follow_non_terminal_set =
          SymbolSet.fold
            (union_and_next_on_epsilon first_h)
            (Hashtbl.find follow_non_terminal s)
            (SymbolSet.singleton (Terminal EOF))
        in
        let follow_parent_on_end_set =
          SymbolSet.fold
            (fun s ->
              follow_of_symbol s;
              union_and_next_on_epsilon follow_h s)
```

```
          (Hashtbl.find parent_on_end s)
          (SymbolSet.singleton (Terminal EOF))
      in

      Hashtbl.replace follow_h s
        (SymbolSet.union follow_non_terminal_set follow_parent_on_end_set)
    else ()
  in
  Hashtbl.iter (fun s _ -> follow_of_symbol s) g.rules_htbl;
  follow_h

let analyse_LL1_of_symbol (g : grammar) (text : (symbol * string) list)
    (s : symbol) : at * (symbol * string) list =
  let follow_sshtbl = follow g in
```

```
  let first_sshtbl = first g in

  let rec analyse_LL1_of_pattern (text : (symbol *
   ↪  string) list) (s : symbol)
      (p : pattern) : at * (symbol * string) list =
    (* print_endline "analyse_LL1_of_pattern"; *)
    if p = [ Terminal E ] then
      (Noeud ((s, ""), [ Noeud ((Terminal E, ""),
       ↪  []) ]), text)
    else
      let txt = ref text in
      let t =
        Noeud
          ( (s, ""),
            List.map
              (fun (s_p : symbol) ->
```

```
                let tree, txt' = analyse_LL1_of_symbol_aux !txt s_p in
                txt := txt';
                tree)
              p )
    in
    (t, !txt)
and analyse_LL1_of_symbol_aux (text : (symbol * string) list) (s : symbol) :
    at * (symbol * string) list =
   (* print_endline ("analyse_LL1_of_symbol_aux " ^ string_of_symbol s); *)
   (*print_patterns [ List.map fst text ];
   print_newline ();*)
   if is_terminal (s, []) then
     (* print_endline "is terminal"; *)
```

```
      match text with
      | [] -> failwith "no text to match in analyse_LL1, text is empty"
      | t1 :: q ->
          if fst t1 = s then (Noeud (t1, []), q)
          else failwith "the expected terminal does not match the text"
    else
      (* print_endline "is non_terminal"; *)
      match text with
      | [] ->
          if
            (* print_endline "Terminal E"; *)
            SymbolSet.mem (Terminal E) (Hashtbl.find first_sshtbl s)
            && SymbolSet.mem (Terminal EOF) (Hashtbl.find follow_sshtbl s)
```

```
        then (
          let l =
            List.filter
              (fun p ->
                SymbolSet.mem (Terminal E) (first_of_pattern first_sshtbl p))
              (Hashtbl.find g.rules_htbl s)
          in
          if l = [] then (
            print_string
              ("on " ^ string_of_symbol s ^ ", expected "
              ^ string_of_symbol (Terminal E)
              ^ " in first of patterns but first of patters is\n");
```

```
              print_SymbolSet (Hashtbl.find first_sshtbl s);
              failwith "error 1")
            else ();
            analyse_LL1_of_pattern text s (List.nth l 0))
          else failwith "text is epsilon but more symbols are expected"
      | _ ->
          if
            (*print_SymbolSet (Hashtbl.find first_sshtbl s);
            print_SymbolSet (Hashtbl.find follow_sshtbl s);*)
            SymbolSet.mem (Terminal E) (Hashtbl.find first_sshtbl s)
            && SymbolSet.mem
```

```
                    (fst (List.nth text 0))
                    (Hashtbl.find follow_sshtbl s)
             then (
               let l =
                 List.filter
                   (fun p ->
                     SymbolSet.mem (Terminal E) (first_of_pattern first_sshtbl p))
                   (Hashtbl.find g.rules_htbl s)
               in
               if l = [] then (
                 print_string
                   ("on " ^ string_of_symbol s ^ ", expected "
                   ^ string_of_symbol (Terminal E)
```

```
              ^ " in first of patterns but first of patters is\n");
            print_SymbolSet (Hashtbl.find first_sshtbl s);
            failwith "error 2")
          else ();
          analyse_LL1_of_pattern text s (List.nth l 0))
        else (
          (* print_endline "cas 2";
          print_symbol (fst (List.nth text 0));
          print_newline (); *)
          let l =
            List.filter
              (fun p ->
                SymbolSet.mem
                  (fst (List.nth text 0))
```

```
                (first_of_pattern first_sshtbl
                 ↪  p))
              (Hashtbl.find g.rules_htbl s)
          in
          if l = [] then (
            print_string
              ("on " ^ string_of_symbol s ^ ",
               ↪  expected "
              ^ string_of_symbol (fst (List.nth
               ↪  text 0))
              ^ " in first of patterns but first
               ↪  of patters is\n");
            print_SymbolSet (Hashtbl.find
             ↪  first_sshtbl s);
            failwith "error 3")
          else ();
```

```
            analyse_LL1_of_pattern text s (List.nth l 0))
  in
  analyse_LL1_of_symbol_aux text s

let analyse_LL1 (g : grammar) (text : (symbol * string) list) : at =
  fst (analyse_LL1_of_symbol g (text @ [ (Terminal EOF, "") ]) g.start_symbol)
```

```ocaml
open Abstract_tokens
open LL1
open Symbols

(** écrase les noeuds à écraser à partir de [t] et l'ajoute à ceux de la liste
    [l] (pour remonter des arguments par exemple) *)
let flatten (t : ast) (l : ast list) : ast list =
  let rec aux (t : ast) (out : ast list) : ast list =
    match t with
    | Noeud (ToFlatten, []) -> out
    | Noeud (ToFlatten, x :: q) ->
        (* vide l'entièreté des éléments de x dans out puis ceux de q *)
        let out = aux x out in
```

```
        aux (Noeud (ToFlatten, q)) out
      | _ -> t :: out
  in
  List.rev_append (aux t []) l

(** convertis l'arbre de syntaxe abstrait [t] pour
↪  que les fonctions, dont le
    nom est stocké au fur et à mesure dans
      ↪  [curr_func], aient leur valeur de
    retour *)
let rec link_return_function (t : ast) (return_val
↪  : string option) : ast =
  match t with
  | Noeud (Syntax Function, l) ->
      let name, l =
        List.fold_left
          (fun (_name, _l) (x : ast) ->
```

```
          match x with
          | Noeud (Name s, []) when _name = "" -> (s, x :: _l)
          | Noeud (Syntax Out, [ Noeud (Name s, []) ]) -> (s, _l)
          | _ -> (_name, x :: _l))
        ("", []) l
    in
    let l =
      match l with
      | Noeud (Syntax Return, []) :: q -> List.rev l
      | _ ->
          let (l : ast list) =
            Noeud (Syntax Return, [ Noeud (Name name, []) ]) :: l
          in
```

```
         List.rev l
     in
     Noeud
       ( Syntax Function,
        List.map (fun x -> link_return_function x (Some name)) l )
  | Noeud (Syntax Subroutine, l) ->
     Noeud
       ( Syntax Function,
        match List.rev l with
        | Noeud (Syntax Return, []) :: q -> List.rev q
        | _ -> l )
  | Noeud (Syntax Return, []) -> (
     match return_val with
     | None -> failwith "Return doit être dans une fonction"
```

```
        | Some s -> Noeud (Syntax Return, [ Noeud
        ↪  (Name s, []) ]))
    | Noeud (x, l) ->
        Noeud (x, List.map (fun x ->
        ↪  link_return_function x return_val) l)

(** Si [t] est un commentaire, le convertit pour
↪  séparer les différentes lignes,
    sinon renvoie une erreur *)
let convert_comments (t : ast) : ast list =
  let nb = ref 0 in
  match t with
    | Noeud (Commentaire s, []) ->
        let l = List.map String.trim
        ↪  (String.split_on_char '\n' s) in
        let l2 =
          List.map
```

```
          (fun (s : string) : ast ->
            if s = "" then Noeud (NewLine, [])
            else (
              incr nb;
              Noeud (Commentaire (String.sub s 1 (String.length s - 1)), []))
          l
      in
      if !nb = 0 then match l2 with [] -> l2 | _ :: q -> q else l2
  | _ -> failwith "l'argument donné n'est pas un commentaire"

(** Enlève le niveau d'abstraction de l'arbre de syntaxe [t] créé avec LL1 *)
let convert_to_abstract (t : at) : ast =
  let rec convert_to_abstract_aux (t : at) : ast =
```

```
    match t with
    | Noeud ((NonTerminal ExecutableProgram, _), l) -> (
        match l with
        | [
          Noeud ((NonTerminal StartCommentBlock, s1), l1);
          Noeud ((NonTerminal Function_or_Subroutine_star_MainProgram, s), l);
        ] ->
            Noeud
              ( ProgramRoot,
                convert_to_abstract_aux (Noeud ((Terminal EOS, s1), []))
                :: flatten
                     (convert_to_abstract_aux
```

```
                                    (Noeud
                                        ( ( NonTerminal
                                              
                                                ↪  Function_or_Subrout
                                                s ),
                                            l )))
                                []  )
                    | [
                    Noeud ((NonTerminal
                     ↪  Function_or_Subroutine_star_MainProgram,
                     ↪  s), l);
                    ] ->
                        Noeud
                           ( ProgramRoot,
                             flatten
                                (convert_to_abstract_aux
                                    (Noeud
```

```
                              ( ( NonTerminal Function_or_Subroutine_star_
                                  s ),
                                l )))
                        [] )
            | _ -> failwith "ExecutableProgram")
        | Noeud ((NonTerminal Function_or_Subroutine_star_MainProgram, _), l) -> (
            match l with
            | [
             Noeud ((NonTerminal Recursive_opt_Function_or_Subroutine, s), l);
             Noeud ((NonTerminal Function_or_Subroutine_star_MainProgram, s1), l1);
```

```
    ] ->
        Noeud
          ( ToFlatten,
            [
              convert_to_abstract_aux
                (Noeud
                   ((NonTerminal
                   ↪   Recursive_opt_Function_or_Sul
                   ↪   s), l));
              convert_to_abstract_aux
                (Noeud
                   ( ( NonTerminal
                   ↪   Function_or_Subroutine_star_I
                       s1 ),
                     l1 ));
            ] )
    | [
```

```
        Noeud ((NonTerminal MainProgram, s), l);
        Noeud
          ( (NonTerminal Function_or_Subroutine_star, _),
            [ Noeud ((Terminal E, _), []) ] );
      ] ->
          convert_to_abstract_aux (Noeud ((NonTerminal MainProgram, s), l))
      | [
        Noeud ((NonTerminal MainProgram, s), l);
        Noeud ((NonTerminal Function_or_Subroutine_star, s1), l1);
      ] ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux
```

```
                    (Noeud ((NonTerminal MainProgram, s), l));
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal Function_or_Subroutine_star, s1), l1));
              ] )
          | _ -> failwith "Function_or_Subroutine_star_MainProgram")
      | Noeud ((NonTerminal Function_or_Subroutine_star, _), l) -> (
        match l with
          | [
            Noeud ((NonTerminal Recursive_opt_Function_or_Subroutine, s), l);
            Noeud
```

```
            ( (NonTerminal Function_or_Subroutine_star, _),
              [ Noeud ((Terminal E, _), []) ] );
        ] ->
            convert_to_abstract_aux
              (Noeud ((NonTerminal Recursive_opt_Function_or_Subroutine, s), l))
        | [
          Noeud ((NonTerminal Recursive_opt_Function_or_Subroutine, s), l);
          Noeud ((NonTerminal Function_or_Subroutine_star, s1), l1);
        ] ->
            Noeud
              ( ToFlatten,
```

```
                        [
                          convert_to_abstract_aux
                            (Noeud
                               ((NonTerminal
                               ↪  Recursive_opt_Function_or_Su
                               ↪  s), l));
                          convert_to_abstract_aux
                            (Noeud ((NonTerminal
                            ↪  Function_or_Subroutine_star,
                            ↪  s1), l1));
                        ] )
                | _ -> failwith
                ↪  "Function_or_Subroutine_star")
            | Noeud
                ( (NonTerminal
                ↪  Recursive_opt_Function_or_Subroutine,
                ↪  _),
```

```
            [
              Noeud ((Terminal Recursive, _), []);
              Noeud ((NonTerminal Function_or_Subroutine, s), l);
            ] )
      | Noeud
          ( (NonTerminal Recursive_opt_Function_or_Subroutine, _),
            [ Noeud ((NonTerminal Function_or_Subroutine, s), l) ] ) ->
          convert_to_abstract_aux
            (Noeud ((NonTerminal Function_or_Subroutine, s), l))
      | Noeud
          ( (NonTerminal Function_or_Subroutine, _),
```

```
              [ Noeud ((NonTerminal FunctionSubprogram,
              ↪  s), l) ] ) ->
            convert_to_abstract_aux (Noeud
            ↪  ((NonTerminal FunctionSubprogram, s),
            ↪  l))
        | Noeud
            ( (NonTerminal Function_or_Subroutine, _),
              [ Noeud ((NonTerminal
              ↪  SubroutineSubprogram, s), l) ] ) ->
            convert_to_abstract_aux
              (Noeud ((NonTerminal
              ↪  SubroutineSubprogram, s), l))
        | Noeud
            ( (NonTerminal FunctionSubprogram, _),
              [
                Noeud ((NonTerminal FunctionPrefix, s),
                ↪  l);
```

```
                Noeud ((NonTerminal FunctionName, s1),
                 ↪  l1);
                Noeud ((NonTerminal FunctionRange, s2),
                 ↪  l2);
              ] ) -> (
          match l with
          | [ Noeud ((Terminal Function, _), []) ] ->
              Noeud
                ( Syntax Function,
                  flatten
                    (Noeud
                       ( ToFlatten,
                         [
                           convert_to_abstract_aux
                             (Noeud ((NonTerminal
                              ↪  FunctionName, s1),
                              ↪  l1));
```

```
                                        convert_to_abstract_aux
                                          (Noeud ((NonTerminal FunctionRange, s2), l2));
                                      ] ))
                                 [] )
                    | _ ->
                        Noeud
                          ( Syntax Function,
                            flatten
                              (Noeud
                                 ( ToFlatten,
                                   [
                                     convert_to_abstract_aux
                                       (Noeud ((NonTerminal FunctionPrefix, s), l));
```

```
                                   convert_to_abstract_aux
                                     (Noeud ((NonTerminal
                                     ↪   FunctionName, s1),
                                     ↪   l1));
                                   convert_to_abstract_aux
                                     (Noeud ((NonTerminal
                                     ↪   FunctionRange, s2),
                                     ↪   l2));
                                 ] ))
                             [] ))
      | Noeud
          ( (NonTerminal FunctionPrefix, _),
            [
              Noeud ((NonTerminal TypeSpec, s), l);
              Noeud ((Terminal Function, _), []);
            ] ) ->
```

```
        convert_to_abstract_aux (Noeud ((NonTerminal TypeSpec, s), l))
    | Noeud
        ( (NonTerminal FunctionRange, _),
          [
            Noeud ((NonTerminal FunctionParList, s), l);
            Noeud ((NonTerminal FunctionResult_opt, s4), l4);
            Noeud ((Terminal EOS, s1), l1);
            Noeud ((NonTerminal BodyConstruct_star, s3), l3);
            Noeud ((NonTerminal EndFunctionStmt, s2), l2);
          ] ) ->
        let n = ref [] in
        let n3 = ref [] in
```

```
            let n4 = ref [] in
            (match l3 with
            | [ Noeud ((Terminal E, _), []) ] -> ()
            | _ ->
                n3 :=
                  [
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal
                        ↪  BodyConstruct_star, s3),
                        ↪  l3));
                  ]);
            (match l with
            | [
             Noeud ((Terminal LParenthesis, _), []);
             Noeud
```

```
              ( (NonTerminal
               ↪  FunctionPar_Comma_FunctionPar_star_opt,
               ↪  _),
                [ Noeud ((Terminal E, _), []) ] );
            Noeud ((Terminal RParenthesis, _), []);
          ] ->
              ()
          | _ ->
              n :=
                [
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal
                     ↪  FunctionParList, s), l));
                ]);
          (match l4 with
          | [ Noeud ((Terminal E, _), []) ] -> ()
          | _ ->
```

```
            n4 :=
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal FunctionResult_opt, s4), l4));
              ]);
        Noeud
          ( ToFlatten,
            flatten
              (Noeud (ToFlatten, !n))
              (flatten
                 (Noeud (ToFlatten, !n4))
                 (convert_to_abstract_aux (Noeud ((Terminal EOS, s1), l1))
                 :: flatten
                      (Noeud (ToFlatten, !n3))
```

```
                      [
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal EndFunctionStmt, s2), l2));
                      ])) )
    | Noeud
        ( (NonTerminal FunctionResult_opt, _),
          [
            Noeud ((Terminal Result, _), []);
            Noeud ((Terminal LParenthesis, _), []);
            Noeud ((NonTerminal VariableName, s), l);
            Noeud ((Terminal RParenthesis, _), []);
          ] ) ->
        Noeud
          ( Syntax Out,
```

```
            [
              convert_to_abstract_aux (Noeud
              ↪  ((NonTerminal VariableName, s),
              ↪  l));
            ] )
    | Noeud
        ( (NonTerminal FunctionParList, _),
          [
            Noeud ((Terminal LParenthesis, _), []);
            Noeud ((NonTerminal
            ↪  FunctionPar_Comma_FunctionPar_star_opt,
            ↪  s), l);
            Noeud ((Terminal RParenthesis, _), []);
          ] ) ->
        convert_to_abstract_aux
```

```
          (Noeud ((NonTerminal FunctionPar_Comma_FunctionPar_star_opt, s), l))
    | Noeud
        ( (NonTerminal FunctionPar_Comma_FunctionPar_star_opt, _),
          [
            Noeud ((NonTerminal FunctionPar, s), l);
            Noeud
              ( (NonTerminal Comma_FunctionPar_star, _),
                [ Noeud ((Terminal E, _), []) ] );
          ] ) ->
        convert_to_abstract_aux (Noeud ((NonTerminal FunctionPar, s), l))
```

```
      | Noeud
          ( (NonTerminal
           ↪  FunctionPar_Comma_FunctionPar_star_opt,
           ↪  _),
            [
              Noeud ((NonTerminal FunctionPar, s),
               ↪  l);
              Noeud ((NonTerminal
               ↪  Comma_FunctionPar_star, s1), l1);
            ] ) ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux (Noeud
                 ↪  ((NonTerminal FunctionPar, s),
                 ↪  l));
                convert_to_abstract_aux
```

```
                  (Noeud ((NonTerminal Comma_FunctionPar_star, s1), l1));
              ] )
        | Noeud
            ( (NonTerminal Comma_FunctionPar_star, _),
              [
                Noeud ((Terminal Comma, _), []);
                Noeud ((NonTerminal FunctionPar, s), l);
                Noeud
                  ( (NonTerminal Comma_FunctionPar_star, _),
                    [ Noeud ((Terminal E, _), []) ] );
              ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal FunctionPar, s), l))
```

```
    | Noeud
        ( (NonTerminal Comma_FunctionPar_star, _),
          [
            Noeud ((Terminal Comma, _), []);
            Noeud ((NonTerminal FunctionPar, s), l);
            Noeud ((NonTerminal Comma_FunctionPar_star, s1), l1);
          ] ) ->
        Noeud
          ( ToFlatten,
            [
              convert_to_abstract_aux (Noeud ((NonTerminal FunctionPar, s), l));
              convert_to_abstract_aux
```

```
                    (Noeud ((NonTerminal Comma_FunctionPar_star, s1), l1));
                ] )
        | Noeud
            ( (NonTerminal FunctionPar, _),
              [ Noeud ((NonTerminal DummyArgName, s), l) ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal DummyArgName, s), l))
        | Noeud
            ( (NonTerminal EndFunctionStmt, _),
              [
                Noeud ((Terminal EndFunction, _), []);
                Noeud ((NonTerminal EndName_opt, _), _);
                Noeud ((Terminal EOS, s), l);
```

```
          ] ) ->
        convert_to_abstract_aux (Noeud ((Terminal EOS, s), l))
    | Noeud
        ( (NonTerminal SubroutineSubprogram, _),
          [
            Noeud ((Terminal Subroutine, _), []);
            Noeud ((NonTerminal SubroutineName, s), l);
            Noeud ((NonTerminal SubroutineRange, s1), l1);
          ] ) ->
        Noeud
          ( Syntax Subroutine,
            convert_to_abstract_aux (Noeud ((NonTerminal SubroutineName, s), l))
```

```
                    :: flatten
                         (convert_to_abstract_aux
                            (Noeud ((NonTerminal
                             ↪  SubroutineRange, s1), l1)))
                         [] )
      | Noeud
          ( (NonTerminal SubroutineRange, _),
            [
              Noeud ((NonTerminal
              ↪  SubroutineParList_opt, s), l);
              Noeud ((Terminal EOS, s1), l1);
              Noeud ((NonTerminal BodyConstruct_star,
              ↪  s2), l2);
              Noeud ((NonTerminal EndSubroutineStmt,
              ↪  s3), l3);
            ] ) ->
          let n = ref [] in
```

```
let n2 = ref [] in
(match l with
| [ Noeud ((Terminal E, _), []) ] -> ()
| _ ->
    n :=
      [
        convert_to_abstract_aux
          (Noeud ((NonTerminal SubroutineParList_opt, s), l));
      ]);
(match l2 with
| [ Noeud ((Terminal E, _), []) ]
| [
    Noeud ((Terminal LParenthesis, _), []);
    Noeud
```

```
                ( (NonTerminal
                 ↪  SubroutinePar_Comma_SubroutinePar_star
                 ↪  _),
                  [ Noeud ((Terminal E, _), []) ] );
              Noeud ((Terminal RParenthesis, _), []);
            ] ->
              ()
          | _ ->
              n2 :=
                [
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal
                     ↪  BodyConstruct_star, s2),
                     ↪  l2));
                ]);
          Noeud
            ( ToFlatten,
```

```
                flatten
                  (Noeud (ToFlatten, !n))
                  (convert_to_abstract_aux (Noeud ((Terminal EOS, s1), l1))
                  :: flatten
                      (Noeud (ToFlatten, !n2))
                      [
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal EndSubroutineStmt, s3), l3));
                      ]) )
      | Noeud
          ( (NonTerminal SubroutineParList_opt, _),
            [
              Noeud ((Terminal LParenthesis, _), []);
              Noeud
```

```
                ((NonTerminal
                 ↪  SubroutinePar_Comma_SubroutinePar_sta
                 ↪  s), l);
              Noeud ((Terminal RParenthesis, _), []);
            ] ) ->
          convert_to_abstract_aux
            (Noeud ((NonTerminal
             ↪  SubroutinePar_Comma_SubroutinePar_star_op
             ↪  s), l))
      | Noeud
          ( (NonTerminal
           ↪  SubroutinePar_Comma_SubroutinePar_star_opt,
           ↪  _),
            [
              Noeud ((NonTerminal SubroutinePar, s),
               ↪  l);
              Noeud
```

```
                ( (NonTerminal Comma_SubroutinePar_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] ) ->
          convert_to_abstract_aux (Noeud ((NonTerminal SubroutinePar, s), l))
      | Noeud
          ( (NonTerminal SubroutinePar_Comma_SubroutinePar_star_opt, _),
            [
              Noeud ((NonTerminal SubroutinePar, s), l);
              Noeud ((NonTerminal Comma_SubroutinePar_star, s1), l1);
            ] ) ->
          Noeud
```

```
          ( ToFlatten,
            [
              convert_to_abstract_aux
                (Noeud ((NonTerminal SubroutinePar,
                ↪  s), l));
              convert_to_abstract_aux
                (Noeud ((NonTerminal
                ↪  Comma_SubroutinePar_star, s1),
                ↪  l1));
            ] )
    | Noeud
        ( (NonTerminal Comma_SubroutinePar_star,
          ↪  _),
          [
            Noeud ((Terminal Comma, _), []);
            Noeud ((NonTerminal SubroutinePar, s),
            ↪  l);
```

```
                Noeud
                  ( (NonTerminal
                  ↪  Comma_SubroutinePar_star, _),
                    [ Noeud ((Terminal E, _), []) ] );
              ] ) ->
          convert_to_abstract_aux (Noeud
           ↪  ((NonTerminal SubroutinePar, s), l))
      | Noeud
          ( (NonTerminal Comma_SubroutinePar_star,
           ↪  _),
              [
                Noeud ((Terminal Comma, _), []);
                Noeud ((NonTerminal SubroutinePar, s),
                 ↪  l);
                Noeud ((NonTerminal
                 ↪  Comma_SubroutinePar_star, s1), l1);
              ] ) ->
```

```
            Noeud
              ( ToFlatten,
                [
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal SubroutinePar, s), l));
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal Comma_SubroutinePar_star, s1), l1));
                ] )
      | Noeud
          ( (NonTerminal SubroutinePar, _),
            [ Noeud ((NonTerminal DummyArgName, s), l) ] ) ->
          convert_to_abstract_aux (Noeud ((NonTerminal DummyArgName, s), l))
```

```
    | Noeud
        ( (NonTerminal EndSubroutineStmt, _),
          [
            Noeud ((Terminal EndSubroutine, _), []);
            Noeud ((NonTerminal EndName_opt, _), _);
            Noeud ((Terminal EOS, s), l);
          ] ) ->
        convert_to_abstract_aux (Noeud ((Terminal EOS, s), l))
    | Noeud
        ( (NonTerminal MainProgram, _),
          [
            Noeud ((NonTerminal ProgramStmt, s), l);
```

```
                Noeud ((NonTerminal MainRange, s1),
                 ↪  l1);
              ] ) ->
            Noeud
              ( Syntax Program,
                flatten
                  (Noeud
                     ( ToFlatten,
                       [
                         convert_to_abstract_aux
                           (Noeud ((NonTerminal
                            ↪  ProgramStmt, s), l));
                         convert_to_abstract_aux
                           (Noeud ((NonTerminal
                            ↪  MainRange, s1), l1));
                       ] ))
                  [] )
```

```
      | Noeud
          ( (NonTerminal Contains_Function, _),
            [
              Noeud ((Terminal Contains, _), []);
              Noeud ((Terminal EOS, s), l);
              Noeud
                ( (NonTerminal
                ↪  FunctionSubprogram_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] ) ->
          convert_to_abstract_aux (Noeud ((Terminal
          ↪  EOS, s), l))
      | Noeud
          ( (NonTerminal Contains_Function, _),
            [
              Noeud ((Terminal Contains, _), []);
              Noeud ((Terminal EOS, s), l);
```

```
              Noeud ((NonTerminal FunctionSubprogram_star, s1), l1);
            ] ) ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux (Noeud ((Terminal EOS, s), l));
                convert_to_abstract_aux
                  (Noeud ((NonTerminal FunctionSubprogram_star, s1), l1));
              ] )
      | Noeud
          ( (NonTerminal FunctionSubprogram_star, _),
            [
              Noeud ((Terminal Recursive, _), []);
```

```
                    Noeud ((NonTerminal FunctionSubprogram, s), l);
                    Noeud
                      ( (NonTerminal FunctionSubprogram_star, _),
                        [ Noeud ((Terminal E, _), []) ] );
                  ] )
        | Noeud
              ( (NonTerminal FunctionSubprogram_star, _),
                [
                    Noeud ((NonTerminal FunctionSubprogram, s), l);
                    Noeud
                      ( (NonTerminal FunctionSubprogram_star, _),
                        [ Noeud ((Terminal E, _), []) ] );
                  ] ) ->
```

```
            convert_to_abstract_aux (Noeud ((NonTerminal FunctionSubprogram, s), l))
        | Noeud
            ( (NonTerminal FunctionSubprogram_star, _),
              [
                Noeud ((NonTerminal FunctionSubprogram, s), l);
                Noeud ((NonTerminal FunctionSubprogram_star, s1), l1);
              ] )
        | Noeud
            ( (NonTerminal FunctionSubprogram_star, _),
              [
                Noeud ((Terminal Recursive, _), []);
                Noeud ((NonTerminal FunctionSubprogram, s), l);
```

```
                Noeud ((NonTerminal FunctionSubprogram_star, s1), l1);
              ] ) ->
            Noeud
              ( ToFlatten,
                [
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal FunctionSubprogram, s), l));
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal FunctionSubprogram_star, s1), l1));
                ] )
        | Noeud
            ( (NonTerminal ProgramStmt, _),
              [
```

```
                  Noeud ((Terminal Program, _), []);
                  Noeud ((NonTerminal ProgramName, s),
                   ↪  l);
                  Noeud ((Terminal EOS, s1), l1);
                ] ) ->
            Noeud
              ( ToFlatten,
                [
                  convert_to_abstract_aux (Noeud
                   ↪  ((NonTerminal ProgramName, s),
                   ↪  l));
                  convert_to_abstract_aux (Noeud
                   ↪  ((Terminal EOS, s1), l1));
                ] )
        | Noeud
            ( (NonTerminal MainRange, _),
```

```
                [ Noeud ((NonTerminal
                ↪  Contains_Function_opt_EndProgramStmt,
                ↪  s), l) ]
              ) ->
              convert_to_abstract_aux
                (Noeud ((NonTerminal
                ↪  Contains_Function_opt_EndProgramStmt,
                ↪  s), l))
          | Noeud
              ( (NonTerminal MainRange, _),
                [
                  Noeud ((NonTerminal BodyConstruct, s),
                   ↪  l);
                  Noeud
                    ( (NonTerminal BodyConstruct_star,
                     ↪  _),
                      [ Noeud ((Terminal E, _), []) ] );
```

```
                  Noeud ((NonTerminal Contains_Function_opt_EndProgramStmt, s1), l1);
                ] ) ->
              Noeud
                ( ToFlatten,
                  [
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal BodyConstruct, s), l));
                    convert_to_abstract_aux
                      (Noeud
                         ((NonTerminal Contains_Function_opt_EndProgram
                         s1), l1));
                  ] )
          | Noeud
```

```
          ( (NonTerminal MainRange, _),
            [
              Noeud ((NonTerminal BodyConstruct, s),
               ↪  l);
              Noeud ((NonTerminal BodyConstruct_star,
               ↪  s2), l2);
              Noeud ((NonTerminal
               ↪  Contains_Function_opt_EndProgramStmt,
               ↪  s1), l1);
            ] ) ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal BodyConstruct,
                   ↪  s), l));
                Noeud
```

```
                     ( ToFlatten,
                       [
                         convert_to_abstract_aux
                           (Noeud ((NonTerminal
                           ↪   BodyConstruct_star, s2),
                           ↪   l2));
                       ] );
                 convert_to_abstract_aux
                   (Noeud
                      ((NonTerminal
                      ↪   Contains_Function_opt_EndProgramS
                      ↪   s1), l1));
               ] )
      | Noeud
          ( (NonTerminal BodyConstruct_star, _),
            [
```

```
                  Noeud ((NonTerminal BodyConstruct, s),
                   ↪  l);
                  Noeud
                    ( (NonTerminal BodyConstruct_star,
                     ↪  _),
                      [ Noeud ((Terminal E, _), []) ] );
              ] ) ->
              Noeud
                ( ToFlatten,
                  [
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal BodyConstruct,
                       ↪  s), l));
                  ] )
        | Noeud
            ( (NonTerminal BodyConstruct_star, _),
              [
```

```
                Noeud ((NonTerminal BodyConstruct, s), l);
                Noeud ((NonTerminal BodyConstruct_star, s1), l1);
              ] ) ->
            Noeud
              ( ToFlatten,
                [
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal BodyConstruct, s), l));
                  Noeud
                    ( ToFlatten,
                      [
                        convert_to_abstract_aux
```

```
                    (Noeud ((NonTerminal BodyConstruct_star, s1), l1));
                ] );
            ] )
    | Noeud
        ( (NonTerminal Contains_Function_opt_EndProgramStmt, _),
          [ Noeud ((NonTerminal EndProgramStmt, s), l) ] ) ->
        convert_to_abstract_aux (Noeud ((NonTerminal EndProgramStmt, s), l))
    | Noeud
        ( (NonTerminal Contains_Function_opt_EndProgramStmt, _),
```

```
            [
              Noeud ((NonTerminal Contains_Function,
               ↪  s1), l1);
              Noeud ((NonTerminal EndProgramStmt, s),
               ↪  l);
            ] ) ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal
                   ↪  Contains_Function, s1), l1));
                convert_to_abstract_aux
                  (Noeud ((NonTerminal
                   ↪  EndProgramStmt, s), l));
              ] )
      | Noeud
```

```
          ( (NonTerminal EndProgramStmt, _),
            [
              Noeud ((Terminal EndProgram, _), []);
              Noeud ((NonTerminal EndName_opt, _),
               ↪  _);
              Noeud ((Terminal EOS, s), []);
            ] ) ->
          convert_to_abstract_aux (Noeud ((Terminal
          ↪  EOS, s), []))
      | Noeud
          ( (NonTerminal BodyConstruct, _),
            [ Noeud ((NonTerminal
            ↪  SpecificationPartConstruct, s), l) ]
            ↪  ) ->
          Noeud
            ( ToFlatten,
              [
```

```
                convert_to_abstract_aux
                  (Noeud ((NonTerminal SpecificationPartConstruct, s), l));
              ] )
        | Noeud
            ( (NonTerminal BodyConstruct, _),
              [ Noeud ((NonTerminal ExecutableConstruct, s), l) ] ) ->
            convert_to_abstract_aux
              (Noeud ((NonTerminal ExecutableConstruct, s), l))
        | Noeud
            ( (NonTerminal SpecificationPartConstruct, _),
              [ Noeud ((NonTerminal DeclarationConstruct, s), l) ] ) ->
```

```
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal DeclarationConstruct, s), l));
              ] )
      | Noeud
          ( (NonTerminal DeclarationConstruct, _),
            [ Noeud ((NonTerminal TypeDeclarationStmt, s), l) ] ) ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal TypeDeclarationStmt, s), l));
```

```
                ] )
      | Noeud
          ( (NonTerminal TypeDeclarationStmt, _),
            [
              Noeud
                ((NonTerminal TypeSpec, _), [ Noeud
                ↪  ((Terminal Double, _), []) ]);
              Noeud ((NonTerminal
              ↪  Comma_AttrSpec_star, _), l1);
              Noeud ((NonTerminal
              ↪  TypeDecl_Assignment, s), l);
              Noeud ((Terminal EOS, s2), []);
            ] ) ->
          (match l1 with
          | [ Noeud ((Terminal E, _), []) ]
          | [
              Noeud ((Terminal Comma, _), []);
```

```
                Noeud
                  ( (NonTerminal AttrSpec, _),
                    [ Noeud ((NonTerminal
                     ↪  Intent_in_out, _), _) ] );
                Noeud
                  ( (NonTerminal Comma_AttrSpec_star,
                  ↪  _),
                    [ Noeud ((Terminal E, _), []) ] );
              ] ->
                ()
            | _ -> failwith "TypeDeclarationStmt 1");
            Noeud
              ( ToFlatten,
                [
                  Noeud
                    ( Syntax Double_precision,
                      [
```

```
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal
                          ↪  TypeDecl_Assignment, s),
                          ↪  l));
                      ] );
                  convert_to_abstract_aux (Noeud
                  ↪  ((Terminal EOS, s2), []));
                ] )
    | Noeud
        ( (NonTerminal TypeDeclarationStmt, _),
          [
            Noeud
              ( (NonTerminal TypeSpec, _),
                [
                  Noeud ((Terminal Integer, _),
                  ↪  []);
                  Noeud
```

```
                    ( (NonTerminal KindSelector_opt, _),
                      [ Noeud ((Terminal E, _), []) ] );
                ] );
          Noeud ((NonTerminal Comma_AttrSpec_star, _), l1);
          Noeud ((NonTerminal TypeDecl_Assignment, s), l);
          Noeud ((Terminal EOS, s2), []);
        ] ) ->
      (match l1 with
      | [ Noeud ((Terminal E, _), []) ]
      | [
          Noeud ((Terminal Comma, _), []);
          Noeud
            ( (NonTerminal AttrSpec, _),
```

```
                    [ Noeud ((NonTerminal
                     ↪  Intent_in_out, _), _) ] );
               Noeud
                 ( (NonTerminal Comma_AttrSpec_star,
                 ↪  _),
                   [ Noeud ((Terminal E, _), []) ] );
             ] ->
               ()
           | _ -> failwith "TypeDeclarationStmt 2");
           Noeud
             ( ToFlatten,
               [
                 Noeud
                   ( Syntax Integer,
                     flatten
                       (convert_to_abstract_aux
```

```
                                (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
                            [] );
                        convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
                    ] )
        | Noeud
            ( (NonTerminal TypeDeclarationStmt, _),
              [
                Noeud
                  ( (NonTerminal TypeSpec, _),
                    [ Noeud ((Terminal Character, _), []) ] );
                Noeud ((NonTerminal Comma_AttrSpec_star, s1), l1);
```

```
            Noeud ((NonTerminal TypeDecl_Assignment, s), l);
            Noeud ((Terminal EOS, s2), []);
          ] ) ->
        let n1 = ref [] in
        (match l1 with
        | [ Noeud ((Terminal E, _), []) ]
        | [
            Noeud ((Terminal Comma, _), []);
            Noeud
              ( (NonTerminal AttrSpec, _),
                [ Noeud ((NonTerminal Intent_in_out, _), _) ] );
            Noeud
              ( (NonTerminal Comma_AttrSpec_star, _),
                [ Noeud ((Terminal E, _), []) ] );
```

```
      ] ->
        ()
    | _ ->
        n1 :=
          [
            convert_to_abstract_aux
              (Noeud ((NonTerminal Comma_AttrSpec_star, s1), l1));
          ]);
  Noeud
    ( ToFlatten,
      [
        Noeud
          ( Syntax Character,
            flatten
              (Noeud (ToFlatten, !n1))
```

```
                      (flatten
                         (convert_to_abstract_aux
                            (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
                         []) );
                convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
            ] )
    | Noeud
        ( (NonTerminal Comma_AttrSpec_star, _),
          [
            Noeud ((NonTerminal Intent_in_out, _), _);
            Noeud ((NonTerminal Comma_AttrSpec_star, s), l);
          ] ) ->
```

```
          convert_to_abstract_aux
            (Noeud ((NonTerminal Comma_AttrSpec_star, s), l))
      | Noeud
          ( (NonTerminal Comma_AttrSpec_star, _),
            [
              Noeud ((Terminal Parameter, _), []);
              Noeud ((NonTerminal Comma_AttrSpec_star, _), _);
              (* the rest must be intent_in_out if not empty. either way, nothing to be done *)
            ] ) ->
          Noeud (Syntax Constant, [])
      | Noeud
          ( (NonTerminal TypeDeclarationStmt, _),
            [
```

```
            Noeud
              ( (NonTerminal TypeSpec, _),
                [
                  Noeud ((Terminal Complex, _), []);
                  Noeud
                    ( (NonTerminal KindSelector_opt, _),
                      [ Noeud ((Terminal E, _), []) ] );
                ] );
            Noeud ((NonTerminal Comma_AttrSpec_star, _), l1);
            Noeud ((NonTerminal TypeDecl_Assignment, s), l);
            Noeud ((Terminal EOS, s2), []);
          ] ) ->
```

```
          (match l1 with
          | [ Noeud ((Terminal E, _), []) ]
          | [
              Noeud ((Terminal Comma, _), []);
              Noeud
                ( (NonTerminal AttrSpec, _),
                  [ Noeud ((NonTerminal Intent_in_out, _), _) ] );
              Noeud
                ( (NonTerminal Comma_AttrSpec_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] ->
              ()
          | _ -> failwith "TypeDeclarationStmt 3");
          Noeud
            ( ToFlatten,
```

```
                [
                  Noeud
                    ( Syntax Complex,
                      flatten
                        (convert_to_abstract_aux
                          (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
                        [] );
                  convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
                ] )
        | Noeud
            ( (NonTerminal TypeDeclarationStmt, _),
              [
                Noeud
                  ( (NonTerminal TypeSpec, _),
```

```
                [
                  Noeud ((Terminal Logical, _), [] );
                  Noeud
                    ( (NonTerminal KindSelector_opt, _),
                      [ Noeud ((Terminal E, _), []) ] );
                ] );
          Noeud ((NonTerminal Comma_AttrSpec_star, _), l1);
          Noeud ((NonTerminal TypeDecl_Assignment, s), l);
          Noeud ((Terminal EOS, s2), []);
        ] ) ->
      (match l1 with
      | [ Noeud ((Terminal E, _), []) ]
```

```
| [
    Noeud ((Terminal Comma, _), []);
    Noeud
      ( (NonTerminal AttrSpec, _),
        [ Noeud ((NonTerminal Intent_in_out, _), _) ] );
    Noeud
      ( (NonTerminal Comma_AttrSpec_star, _),
        [ Noeud ((Terminal E, _), []) ] );
  ] ->
    ()
| _ -> failwith "TypeDeclarationStmt 4");
Noeud
  ( ToFlatten,
    [
      Noeud
```

```
                  ( Syntax Logical,
                    flatten
                      (convert_to_abstract_aux
                        (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
                      [] );
                convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
              ] )
    | Noeud
        ( (NonTerminal TypeDeclarationStmt, _),
          [
            Noeud
              ( (NonTerminal TypeSpec, _),
                [
                  Noeud ((Terminal Real, _), []);
```

```
                  Noeud
                    ( (NonTerminal
                     ↪  KindSelector_opt, _),
                      [ Noeud ((Terminal E, _), [])
                       ↪  ] );
              ] );
         Noeud ((NonTerminal
          ↪  Comma_AttrSpec_star, _), l1);
         Noeud ((NonTerminal
          ↪  TypeDecl_Assignment, s), l);
         Noeud ((Terminal EOS, s2), []);
     ] ) ->
   (match l1 with
   | [ Noeud ((Terminal E, _), []) ]
   | [
         Noeud ((Terminal Comma, _), []);
         Noeud
```

```
                  ( (NonTerminal AttrSpec, _),
                    [ Noeud ((NonTerminal Intent_in_out, _), _) ] );
                Noeud
                  ( (NonTerminal Comma_AttrSpec_star, _),
                    [ Noeud ((Terminal E, _), []) ] );
              ] ->
                ()
            | _ -> failwith "TypeDeclarationStmt 5");
            Noeud
              ( ToFlatten,
                [
                  Noeud
                    ( Syntax Real,
                      flatten
                        (convert_to_abstract_aux
```

```
                        (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
                     [] );
                 convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
               ] )
    | Noeud
        ( (NonTerminal TypeDeclarationStmt, _),
          [
            Noeud
              ( (NonTerminal TypeSpec, _),
                [
                  Noeud ((Terminal Integer, _), []);
                  Noeud ((NonTerminal KindSelector_opt, s1), l1);
```

```
                  ] );
              Noeud ((NonTerminal
               ↪  Comma_AttrSpec_star, _), l3);
              Noeud ((NonTerminal
               ↪  TypeDecl_Assignment, s), l);
              Noeud ((Terminal EOS, s2), []);
          ] ) ->
        (match l3 with
        | [ Noeud ((Terminal E, _), []) ]
        | [
              Noeud ((Terminal Comma, _), []);
              Noeud
                ( (NonTerminal AttrSpec, _),
                  [ Noeud ((NonTerminal
                   ↪  Intent_in_out, _), _) ] );
              Noeud
```

```
                ( (NonTerminal Comma_AttrSpec_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] ->
              ()
        | _ -> failwith "TypeDeclarationStmt 6");
        Noeud
          ( ToFlatten,
            [
              Noeud
                ( Syntax Integer,
                  Noeud
                    ( Syntax Size,
                      [
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal KindSelector_opt, s1), l1));
```

```
                         ] )
                    :: flatten
                         (convert_to_abstract_aux
                            (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
                         [] );
                 convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
               ] )
      | Noeud
          ( (NonTerminal TypeDeclarationStmt, _),
            [
              Noeud
                ( (NonTerminal TypeSpec, _),
                  [
```

```
                    Noeud ((Terminal Complex, _), []);
                    Noeud ((NonTerminal KindSelector_opt, s1), l1);
                  ] );
              Noeud ((NonTerminal Comma_AttrSpec_star, _), l3);
              Noeud ((NonTerminal TypeDecl_Assignment, s), l);
              Noeud ((Terminal EOS, s2), []);
          ] ) ->
        (match l3 with
        | [ Noeud ((Terminal E, _), []) ]
        | [
              Noeud ((Terminal Comma, _), []);
              Noeud
                ( (NonTerminal AttrSpec, _),
```

```
                [ Noeud ((NonTerminal Intent_in_out, _), _) ] );
            Noeud
              ( (NonTerminal Comma_AttrSpec_star, _),
                [ Noeud ((Terminal E, _), []) ] );
          ] ->
            ()
        | _ -> failwith "TypeDeclarationStmt 7");
        Noeud
          ( ToFlatten,
            [
              Noeud
                ( Syntax Complex,
                  Noeud
                    ( Syntax Size,
                      [
```

```
                                        convert_to_abstract_aux
                                           (Noeud ((NonTerminal KindSelector_opt, s1), l1));
                                     ] )
                              :: flatten
                                   (convert_to_abstract_aux
                                       (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
                                     [] );
                     convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
                  ] )
        | Noeud
             ( (NonTerminal TypeDeclarationStmt, _),
               [
```

```
                Noeud
                  ( (NonTerminal TypeSpec, _),
                    [
                      Noeud ((Terminal Logical, _), [] );
                      Noeud ((NonTerminal KindSelector_opt, s1), l1);
                    ] );
                Noeud ((NonTerminal Comma_AttrSpec_star, _), l3);
                Noeud ((NonTerminal TypeDecl_Assignment, s), l);
                Noeud ((Terminal EOS, s2), []);
              ] ) ->
            (match l3 with
            | [ Noeud ((Terminal E, _), []) ]
            | [
```

```
                  Noeud ((Terminal Comma, _), []);
                  Noeud
                    ( (NonTerminal AttrSpec, _),
                      [ Noeud ((NonTerminal
                      ↪  Intent_in_out, _), _) ] );
                  Noeud
                    ( (NonTerminal Comma_AttrSpec_star,
                    ↪  _),
                      [ Noeud ((Terminal E, _), []) ] );
                ] ->
                  ()
              | _ -> failwith "TypeDeclarationStmt 8");
              Noeud
                ( ToFlatten,
                  [
                    Noeud
                      ( Syntax Logical,
```

```
                    Noeud
                      ( Syntax Size,
                        [
                          convert_to_abstract_aux
                            (Noeud ((NonTerminal KindSelector_opt, s1), l1));
                        ] )
                    :: flatten
                         (convert_to_abstract_aux
                            (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
                         [] );
                convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
              ] )
```

```
      | Noeud
          ( (NonTerminal TypeDeclarationStmt, _),
            [
              Noeud
                ( (NonTerminal TypeSpec, _),
                  [
                    Noeud ((Terminal Real, _), []);
                    Noeud ((NonTerminal
                     ↪  KindSelector_opt, s1), l1);
                  ] );
              Noeud ((NonTerminal
               ↪  Comma_AttrSpec_star, _), l3);
              Noeud ((NonTerminal
               ↪  TypeDecl_Assignment, s), l);
              Noeud ((Terminal EOS, s2), []);
            ] ) ->
          (match l3 with
```

```
        | [ Noeud ((Terminal E, _), []) ]
        | [
            Noeud ((Terminal Comma, _), []);
            Noeud
              ( (NonTerminal AttrSpec, _),
                [ Noeud ((NonTerminal Intent_in_out, _), _) ] );
            Noeud
              ( (NonTerminal Comma_AttrSpec_star, _),
                [ Noeud ((Terminal E, _), []) ] );
          ] ->
            ()
        | _ -> failwith "TypeDeclarationStmt 9");
        Noeud
          ( ToFlatten,
            [
```

```
Noeud
  ( Syntax Real,
    Noeud
      ( Syntax Size,
        [
          convert_to_abstract_aux
            (Noeud ((NonTerminal KindSelector_opt, s1), l1));
        ] )
    :: flatten
         (convert_to_abstract_aux
            (Noeud ((NonTerminal TypeDecl_Assignment, s), l)))
         [] );
```

```
              convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
            ] )
      | Noeud ((NonTerminal AttrSpec, _), [ Noeud ((Terminal Parameter, _), []) ])
        ->
          Noeud (Syntax Constant, [])
      | Noeud
          ( (NonTerminal Comma_EntityDecl_star, _),
            [
              Noeud ((Terminal Comma, _), []);
              Noeud ((NonTerminal EntityDecl, s), l);
              Noeud
                ( (NonTerminal Comma_EntityDecl_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] )
```

```
    | Noeud
        ( (NonTerminal TypeDecl_Assignment, _),
          [
            Noeud ((Terminal Colon, _), []);
            Noeud ((Terminal Colon, _), []);
            Noeud ((NonTerminal EntityDecl, s), l);
            Noeud
              ( (NonTerminal Comma_EntityDecl_star,
              ↪  _),
                [ Noeud ((Terminal E, _), []) ] );
          ] ) ->
        convert_to_abstract_aux (Noeud
         ↪  ((NonTerminal EntityDecl, s), l))
    | Noeud
        ( (NonTerminal Comma_EntityDecl_star, _),
          [
            Noeud ((Terminal Comma, _), []);
```

```
                Noeud ((NonTerminal EntityDecl, s), l);
                Noeud ((NonTerminal Comma_EntityDecl_star, s2), l2);
              ] )
        | Noeud
            ( (NonTerminal TypeDecl_Assignment, _),
              [
                Noeud ((Terminal Colon, _), []);
                Noeud ((Terminal Colon, _), []);
                Noeud ((NonTerminal EntityDecl, s), l);
                Noeud ((NonTerminal Comma_EntityDecl_star, s2), l2);
              ] ) ->
            Noeud
              ( ToFlatten,
                [
```

```
                convert_to_abstract_aux (Noeud ((NonTerminal EntityDecl, s), l));
                Noeud
                  ( ToFlatten,
                    [
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal Comma_EntityDecl_star, s2), l2));
                    ] );
              ] )
      | Noeud
          ( (NonTerminal Comma_ObjectName_star, _),
            [
              Noeud ((Terminal Comma, _), []);
              Noeud ((NonTerminal ObjectName, s), l);
```

```
                Noeud
                  ( (NonTerminal Comma_ObjectName_star, _),
                    [ Noeud ((Terminal E, _), []) ] );
              ] )
        | Noeud
            ( (NonTerminal TypeDecl_Assignment, _),
              [
                Noeud ((NonTerminal ObjectName, s), l);
                Noeud
                  ( (NonTerminal Comma_ObjectName_star, _),
                    [ Noeud ((Terminal E, _), []) ] );
              ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal ObjectName, s), l))
        | Noeud
```

```
          ( (NonTerminal Comma_ObjectName_star, _),
            [
              Noeud ((Terminal Comma, _), []);
              Noeud ((NonTerminal ObjectName, s), l);
              Noeud ((NonTerminal Comma_ObjectName_star, s1), l1);
            ] )
      | Noeud
          ( (NonTerminal TypeDecl_Assignment, _),
            [
              Noeud ((NonTerminal ObjectName, s), l);
              Noeud ((NonTerminal Comma_ObjectName_star, s1), l1);
            ] ) ->
          Noeud
            ( ToFlatten,
              [
```

```
                convert_to_abstract_aux (Noeud ((NonTerminal ObjectName, s), l));
                convert_to_abstract_aux
                  (Noeud ((NonTerminal Comma_ObjectName_star, s1), l1));
              ] )
      | Noeud
          ( (NonTerminal EntityDecl, _),
            [
              Noeud ((NonTerminal ObjectName, s), l);
              Noeud
                ( (NonTerminal Asterisk_CharLength_opt, _),
                  [ Noeud ((Terminal E, _), []) ] );
              Noeud
```

```
                ((NonTerminal Equal_Expr_opt, _), [ Noeud ((Terminal E, _), []) ]);
            ] ) ->
          convert_to_abstract_aux (Noeud ((NonTerminal ObjectName, s), l))
      | Noeud
          ( (NonTerminal EntityDecl, _),
            [
              Noeud
                ((NonTerminal ObjectName, _), [ Noeud ((Terminal Ident, s), []) ]);
              Noeud
                ( (NonTerminal Asterisk_CharLength_opt, _),
                  [
                    Noeud ((Terminal Asterisk, _), []);
```

```
                  Noeud ((NonTerminal CharLength, s1), l1);
                ] );
              Noeud
                ((NonTerminal Equal_Expr_opt, _), [ Noeud ((Terminal E, _), []) ]);
          ] ) ->
        Noeud
          ( ToFlatten,
            [
              Noeud
                ( Syntax Size,
                  [
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal CharLength, s1), l1));
                  ] );
```

```
                Noeud (Name s, []);
              ] )
      | Noeud
          ( (NonTerminal EntityDecl, _),
            [
              Noeud
                ((NonTerminal ObjectName, _), [ Noeud ((Terminal Ident, s), []) ]);
              Noeud
                ( (NonTerminal Asterisk_CharLength_opt, _),
                  [ Noeud ((Terminal E, _), []) ] );
              Noeud
                ( (NonTerminal Equal_Expr_opt, _),
                  [
                    Noeud ((Terminal Equal, _), []);
                    Noeud ((NonTerminal Expr, s2), l2);
```

```
                ] );
          ] ) ->
        Noeud
          ( Operateur Assignation,
            [
              Noeud (Name s, []);
              convert_to_abstract_aux (Noeud ((NonTerminal Expr, s2), l2));
            ] )
      | Noeud
        ( (NonTerminal EntityDecl, _),
          [
            Noeud
              ((NonTerminal ObjectName, _), [ Noeud ((Terminal Ident, s), []) ]);
            Noeud
              ( (NonTerminal Asterisk_CharLength_opt, _),
```

```
                [
                  Noeud ((Terminal Asterisk, _), []);
                  Noeud ((NonTerminal CharLength, s1), l1);
                ] );
            Noeud
              ( (NonTerminal Equal_Expr_opt, _),
                [
                  Noeud ((Terminal Equal, _), []);
                  Noeud ((NonTerminal Expr, s2), l2);
                ] );
        ] ) ->
    Noeud
      ( Operateur Assignation,
        [
```

```
                Noeud
                  ( Syntax Size,
                    [
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal CharLength, s1), l1));
                    ] );
                Noeud (Name s, []);
                convert_to_abstract_aux (Noeud ((NonTerminal Expr, s2), l2));
              ] )
      | Noeud
          ( (NonTerminal CharLength, _),
            [
              Noeud ((Terminal LParenthesis, _), []);
              Noeud ((NonTerminal TypeParamValue, s), l);
```

```
                Noeud ((Terminal RParenthesis, _), []);
              ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal TypeParamValue, s), l))
        | Noeud
            ( (NonTerminal CharLength, _),
              [ Noeud ((NonTerminal ScalarIntLiteralConstant, s), l) ] ) ->
            convert_to_abstract_aux
              (Noeud ((NonTerminal ScalarIntLiteralConstant, s), l))
        | Noeud
            ( (NonTerminal TypeParamValue, _),
              [ Noeud ((NonTerminal Expr_Or_Asterisk, s), l) ] ) ->
```

```
            convert_to_abstract_aux (Noeud ((NonTerminal Expr_Or_Asterisk, s), l))
        | Noeud
            ( (NonTerminal Expr_Or_Asterisk, _),
              [ Noeud ((Terminal Asterisk, _), []) ] ) ->
            Noeud (Syntax Any, [])
        | Noeud
            ((NonTerminal Expr_Or_Asterisk, _), [ Noeud ((NonTerminal Expr, s), l) ])
          ->
            convert_to_abstract_aux (Noeud ((NonTerminal Expr, s), l))
        | Noeud
            ( (NonTerminal KindSelector_opt, _),
              [
                Noeud ((Terminal LParenthesis, _), []);
```

```
                Noeud ((NonTerminal Expr, s), l);
                Noeud ((Terminal RParenthesis, _), []);
              ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal Expr, s), l))
        | Noeud ((NonTerminal ExecutableConstruct, _), l) -> (
            match l with
            | [ Noeud ((NonTerminal ActionStmt, s1), l1) ] ->
                Noeud
                  ( ToFlatten,
                    [
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal ActionStmt, s1), l1));
                    ] )
```

```
| [ Noeud ((NonTerminal DoConstruct, s1), l1) ] ->
    Noeud
      ( ToFlatten,
        [
          convert_to_abstract_aux
            (Noeud ((NonTerminal DoConstruct, s1), l1));
        ] )
| [ Noeud ((NonTerminal IfConstruct, s1), l1) ] ->
    Noeud
      ( ToFlatten,
        [
          convert_to_abstract_aux
            (Noeud ((NonTerminal IfConstruct, s1), l1));
```

```
                    ] )
          | [
           Noeud
             ( (NonTerminal ReturnStmt, _),
               [ Noeud ((Terminal Return, _), []);
                 ↪  Noeud ((Terminal EOS, s), l) ]
             );
          ] ->
              Noeud
                ( ToFlatten,
                    [
                      Noeud (Syntax Return, []);
                      convert_to_abstract_aux (Noeud
                       ↪  ((Terminal EOS, s), l));
                    ] )
          | _ -> failwith "ExecutableConstruct")
      | Noeud
```

```
          ( (NonTerminal ActionStmt, _),
            [ Noeud ((NonTerminal AssignmentStmt, s), l) ] ) ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal AssignmentStmt, s), l));
              ] )
      | Noeud
          ((NonTerminal ActionStmt, _), [ Noeud ((NonTerminal PrintStmt, s), l) ])
        ->
          Noeud
            ( ToFlatten,
```

```
                [ convert_to_abstract_aux (Noeud
                ↪  ((NonTerminal PrintStmt, s), l)) ]
             )
      | Noeud
          ( (NonTerminal AssignmentStmt, _),
            [
              Noeud ((NonTerminal Name, s), l);
              Noeud ((Terminal Equal, _), []);
              Noeud ((NonTerminal Expr, s1), l1);
              Noeud ((Terminal EOS, s2), []);
            ] ) ->
          Noeud
            ( ToFlatten,
              [
                Noeud
                  ( Operateur Assignation,
                    [
```

```
                    convert_to_abstract_aux (Noeud ((NonTerminal Name, s), l));
                    convert_to_abstract_aux (Noeud ((NonTerminal Expr, s1), l1));
                  ] );
              convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
            ] )
    | Noeud
        ( (NonTerminal PrintStmt, _),
          [
            Noeud ((Terminal Print, _), []);
            Noeud ((NonTerminal FormatIdentifier, _), _);
            Noeud
```

```
                ( (NonTerminal Comma_OutputItemList_opt, _),
                  [ Noeud ((Terminal E, _), []) ] );
            Noeud ((Terminal EOS, s2), []);
          ] ) ->
        Noeud
          ( ToFlatten,
            [
              Noeud (Syntax Print, [ Noeud (Chaine "", []) ]);
              convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
            ] )
      | Noeud
        ( (NonTerminal PrintStmt, _),
          [
            Noeud ((Terminal Print, _), []);
```

```
            Noeud ((NonTerminal FormatIdentifier, _), _);
            Noeud ((NonTerminal Comma_OutputItemList_opt, s), l);
            Noeud ((Terminal EOS, s2), []);
          ] ) ->
        Noeud
          ( ToFlatten,
            [
              Noeud
                ( Syntax Print,
                  flatten
                    (convert_to_abstract_aux
                       (Noeud ((NonTerminal Comma_OutputItemList_opt, s), l)))
                    [] );
```

```
          convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []));
        ] )
| Noeud
    ( (NonTerminal Comma_OutputItemList_opt, _),
      [
        Noeud ((Terminal Comma, _), []);
        Noeud ((NonTerminal OutputItemList, s), l);
      ] ) ->
    convert_to_abstract_aux (Noeud ((NonTerminal OutputItemList, s), l))
| Noeud
    ( (NonTerminal Comma_OutputItem_star, _),
      [
        Noeud ((Terminal Comma, _), []);
```

```
            Noeud ((NonTerminal OutputItem, s), l);
            Noeud
              ( (NonTerminal Comma_OutputItem_star, _),
                [ Noeud ((Terminal E, _), []) ] );
          ] )
    | Noeud
        ( (NonTerminal OutputItemList, _),
          [
            Noeud ((NonTerminal OutputItem, s), l);
            Noeud
              ( (NonTerminal Comma_OutputItem_star, _),
                [ Noeud ((Terminal E, _), []) ] );
          ] ) ->
        convert_to_abstract_aux (Noeud ((NonTerminal OutputItem, s), l))
```

```
      | Noeud
         ( (NonTerminal Comma_OutputItem_star, _),
           [
             Noeud ((Terminal Comma, _), []);
             Noeud ((NonTerminal OutputItem, s), l);
             Noeud ((NonTerminal Comma_OutputItem_star, s1), l1);
           ] )
      | Noeud
         ( (NonTerminal OutputItemList, _),
           [
             Noeud ((NonTerminal OutputItem, s), l);
             Noeud ((NonTerminal Comma_OutputItem_star, s1), l1);
           ] ) ->
         Noeud
           ( ToFlatten,
```

```
                 [
                   convert_to_abstract_aux (Noeud ((NonTerminal OutputItem, s), l));
                   convert_to_abstract_aux
                     (Noeud ((NonTerminal Comma_OutputItem_star, s1), l1));
                 ] )
      | Noeud ((NonTerminal OutputItem, _), [ Noeud ((NonTerminal Expr, s), l) ])
        ->
          convert_to_abstract_aux (Noeud ((NonTerminal Expr, s), l))
      | Noeud
          ( (NonTerminal DoConstruct, _),
```

```
          [ Noeud ((NonTerminal BlockDoConstruct, s), l) ] ) ->
        convert_to_abstract_aux (Noeud ((NonTerminal BlockDoConstruct, s), l))
    | Noeud
        ( (NonTerminal BlockDoConstruct, _),
          [
            Noeud ((Terminal Do, _), []);
            Noeud ((NonTerminal LoopControl_opt, _), l);
            Noeud
              ( (NonTerminal ExecutionPartConstruct_star, _),
                [ Noeud ((Terminal E, _), []) ] );
            Noeud ((NonTerminal EndDoStmt, _), _);
          ] ) -> (
        match l with
```

```
            | [ Noeud ((Terminal EOS, s), []) ] ->
                Noeud
                  ( Syntax While,
                    [
                      Noeud (Booleen true, []);
                      convert_to_abstract_aux (Noeud ((Terminal EOS, s), []));
                    ] )
            | [
              Noeud ((NonTerminal LoopControl, s1), l1); Noeud ((Terminal EOS, s), []);
            ] -> (
                match l1 with
                | Noeud ((Terminal While, _), _) :: _ ->
                    Noeud
                      ( Syntax While,
```

```
                    flatten
                      (convert_to_abstract_aux
                         (Noeud ((NonTerminal
                          ↪  LoopControl, s1),
                          ↪  l1)))
                      [
                        convert_to_abstract_aux
                         ↪  (Noeud ((Terminal EOS,
                         ↪  s), []));
                      ] )
          | Noeud ((NonTerminal VariableName, _),
          ↪  _) :: _ ->
              Noeud
                ( Syntax For,
                    flatten
                      (convert_to_abstract_aux
```

```
                                (Noeud ((NonTerminal LoopControl, s1), l1)))
                              [
                                convert_to_abstract_aux (Noeud ((Terminal EOS, s), []));
                              ] )
                | _ -> failwith "BlockDoConstruct 1")
            | _ -> failwith "BlockDoConstruct 2")
    | Noeud
        ( (NonTerminal BlockDoConstruct, _),
          [
            Noeud ((Terminal Do, _), []);
            Noeud ((NonTerminal LoopControl_opt, _), l);
```

```
          Noeud ((NonTerminal ExecutionPartConstruct_star, s1), l1);
          Noeud ((NonTerminal EndDoStmt, _), _);
        ] ) -> (
      match l with
      | [ Noeud ((Terminal EOS, s), []) ] ->
          Noeud
            ( Syntax While,
              [
                Noeud (Booleen true, []);
                convert_to_abstract_aux (Noeud ((Terminal EOS, s), []));
                convert_to_abstract_aux
                  (Noeud ((NonTerminal ExecutionPartConstruct_star, s1), l1));
```

```
                ] )
        | [
         Noeud ((NonTerminal LoopControl, s2), l2);
          ↪  Noeud ((Terminal EOS, s), []);
        ] -> (
            match l2 with
            | Noeud ((Terminal While, _), _) :: _
            ↪  ->
                Noeud
                  ( Syntax While,
                    flatten
                      (Noeud
                        ( ToFlatten,
                          [

                              ↪  convert_to_abstract_au
```

```
                (Noeud ((NonTerminal LoopControl, s2), l2));
              convert_to_abstract_au
                (Noeud ((Terminal EOS, s), []));
              Noeud
                ( ToFlatten,
                  flatten
                    (convert_to_abst
                      (Noeud
                        ( ( NonTermina
                              Exec
```

```
                                                s1 ),
                                              l1 )))
                                       [] );
                               ] ))
                   [] )
        | Noeud ((NonTerminal VariableName, _),
        ↪  _) :: _ ->
          Noeud
            ( Syntax For,
              flatten
                (Noeud
                   ( ToFlatten,
                     [

                       ↪  convert_to_abstract_au
```

```
                    (Noeud ((NonTerminal
                     ↪  LoopControl,
                     ↪  s2), l2));

                  ↪  convert_to_abstract_au
                    (Noeud ((Terminal
                     ↪  EOS, s), []));
                  Noeud
                    ( ToFlatten,
                      flatten

                         ↪  (convert_to_abst
                           (Noeud
                              ( (
                              ↪  NonTermina

                                    ↪  Exec
```

```
                                                                    s1 ),
                                                                 l1 )))
                                                       [] );
                                            ] ))
                                  [] )
                     | _ -> failwith "BlockDoConstruct 3")
                | _ -> failwith "BlockDoConstruct 4")
      | Noeud
          ( (NonTerminal LoopControl, _),
            [
              Noeud ((Terminal While, _), []);
              Noeud ((Terminal LParenthesis, _), []);
              Noeud ((NonTerminal Expr, s), l);
              Noeud ((Terminal RParenthesis, _), []);
            ] ) ->
          convert_to_abstract_aux (Noeud
          ↪  ((NonTerminal Expr, s), l))
```

```
      | Noeud
          ( (NonTerminal LoopControl, _),
            [
              Noeud ((NonTerminal VariableName, s), l);
              Noeud ((Terminal Equal, _), []);
              Noeud ((NonTerminal IntRealDpExpression, s1), l1);
              Noeud ((Terminal Comma, _), []);
              Noeud ((NonTerminal IntRealDpExpression, s2), l2);
              Noeud ((NonTerminal Comma_IntRealDpExpression_opt, _), l3);
            ] ) -> (
          match l3 with
          | [ Noeud ((Terminal E, _), []) ] ->
```

```
          Noeud
            ( ToFlatten,
              [
                Noeud
                  ( Operateur Assignation,
                    [
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal VariableName, s), l));
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal IntRealDpExpression, s1), l1));
                    ] );
                convert_to_abstract_aux
```

```
                          (Noeud ((NonTerminal IntRealDpExpression, s2), l2));
                       Noeud (Syntax Step, [ Noeud (Integer "1", []) ]);
                     ] )
             | [
              Noeud ((Terminal Comma, _), _);
              Noeud ((NonTerminal IntRealDpExpression, s4), l4);
             ] ->
                 Noeud
                   ( ToFlatten,
                     [
                       Noeud
                         ( Operateur Assignation,
                           [
```

```
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal VariableName, s), l));
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal IntRealDpExpression, s1), l1));
                  ] );
            convert_to_abstract_aux
              (Noeud ((NonTerminal IntRealDpExpression, s2), l2));
            Noeud
              ( Syntax Step,
                [
                    convert_to_abstract_aux
```

```
                                (Noeud ((NonTerminal IntRealDpExpression, s4), l4));
                            ] );
                        ] )
            | _ -> failwith "LoopControl")
        | Noeud
            ( (NonTerminal IntRealDpExpression, _),
              [ Noeud ((NonTerminal Expr, s), l) ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal Expr, s), l))
        | Noeud
            ( (NonTerminal IfConstruct, _),
              [
                Noeud ((NonTerminal IfThenStmt, _), l);
```

```
                Noeud ((NonTerminal ExecutionPartConstruct_star, s1), l1);
                Noeud
                  ((NonTerminal ElseIfStmt_ExecutionPartConstruct_sta
                  s2), l2);
                Noeud
                  ((NonTerminal ElseStmt_ExecutionPartConstruct_star_
                  s3), l3);
                Noeud
                  ( (NonTerminal EndIfStmt, _),
                    [
                      Noeud ((Terminal EndIf, _), []); Noeud ((Terminal EOS, s4), []);
```

```
                  ] );
              ] ) -> (
          let next =
            ref [ convert_to_abstract_aux (Noeud ((Terminal EOS, s4), [])) ]
          in
          let inner = ref [] in
          (match l3 with
          | [ Noeud ((Terminal E, _), []) ] -> ()
          | _ ->
              next :=
                convert_to_abstract_aux
                  (Noeud
                     ( (NonTerminal ElseStmt_ExecutionPartConstruct_
                     s3),
                       l3 ))
```

```
                :: !next);
          (match l2 with
          | [ Noeud ((Terminal E, _), []) ] -> ()
          | _ ->
              next :=
                convert_to_abstract_aux
                  (Noeud
                     ( ( NonTerminal
                     ↪   ElseIfStmt_ExecutionPartConstruct
                         s2 ),
                       l2 ))
                :: !next);
          (match l1 with
          | [ Noeud ((Terminal E, _), []) ] -> ()
          | _ ->
              inner :=
                flatten
```

```
                (convert_to_abstract_aux
                   (Noeud ((NonTerminal ExecutionPartConstruct_star, s1), l1)))
                !inner);
        match l with
        | [
         Noeud ((Terminal If, _), []);
         Noeud ((Terminal LParenthesis, _), []);
         Noeud ((NonTerminal ScalarLogicalExpr, s), l);
         Noeud ((Terminal RParenthesis, _), []);
         Noeud ((Terminal Then, _), []);
         Noeud ((Terminal EOS, s5), []);
        ] ->
            Noeud
              ( ToFlatten,
```

```
                    Noeud
                      ( Syntax If,
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal ScalarLogicalExpr, s), l))
                        :: flatten
                             (convert_to_abstract_aux
                                (Noeud ((Terminal EOS, s5), [])))
                             !inner )
                    :: !next )
          | _ -> failwith "IfConstruct")
      | Noeud
          ( (NonTerminal ElseIfStmt_ExecutionPartConstruct_star_star _),
```

```
            [
              Noeud ((NonTerminal ElseIfStmt, s), l);
              Noeud ((NonTerminal ExecutionPartConstruct_star, s1), l1);
            ] ) -> (
          let inner = ref [] in
          (match l1 with
          | [ Noeud ((Terminal E, _), []) ] -> ()
          | _ ->
              inner :=
                flatten
                  (convert_to_abstract_aux
                     (Noeud ((NonTerminal ExecutionPartConstruct_star, s1), l1)))
                  !inner);
```

```
        match l with
        | [
         Noeud ((Terminal Else, _), []);
         Noeud ((Terminal If, _), []);
         Noeud ((Terminal LParenthesis, _), []);
         Noeud ((NonTerminal ScalarLogicalExpr,
          ↪  s1), l1);
         Noeud ((Terminal RParenthesis, _), []);
         Noeud ((Terminal Then, _), []);
         Noeud ((Terminal EOS, s2), []);
        ] ->
            Noeud
              ( Syntax Else_if,
                convert_to_abstract_aux
                  (Noeud ((NonTerminal
                   ↪  ScalarLogicalExpr, s1), l1))
                :: convert_to_abstract_aux (Noeud
                ↪  ((Terminal EOS, s2), []))
```

```
                    :: !inner )
            | _ -> failwith
            ↪  "ElseIfStmt_ExecutionPartConstruct_star_sta
        | Noeud
            ( (NonTerminal ExecutionPartConstruct_star,
            ↪  _),
              [
                Noeud ((NonTerminal
                ↪  ExecutionPartConstruct, s), l);
                Noeud
                  ( (NonTerminal
                  ↪  ExecutionPartConstruct_star, _),
                    [ Noeud ((Terminal E, _), []) ] );
              ] ) ->
            convert_to_abstract_aux
              (Noeud ((NonTerminal
              ↪  ExecutionPartConstruct, s), l))
```

```
      | Noeud
          ( (NonTerminal ExecutionPartConstruct_star,
          ↪  _),
            [
              Noeud ((NonTerminal
              ↪  ExecutionPartConstruct, s), l);
              Noeud ((NonTerminal
              ↪  ExecutionPartConstruct_star, s1),
              ↪  l1);
            ] ) ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal
                  ↪  ExecutionPartConstruct, s),
                  ↪  l));
```

```
                convert_to_abstract_aux
                  (Noeud ((NonTerminal
                  ↪  ExecutionPartConstruct_star,
                  ↪  s1), l1));
              ] )
      | Noeud
          ( (NonTerminal
          ↪  ElseStmt_ExecutionPartConstruct_star_opt,
          ↪  _),
            [
              Noeud ((NonTerminal ElseStmt, _), l);
              Noeud ((NonTerminal
              ↪  ExecutionPartConstruct_star, s1),
              ↪  l1);
            ] ) -> (
          let inner = ref [] in
          (match l1 with
```

```
            | [ Noeud ((Terminal E, _), []) ] -> ()
            | _ ->
                inner :=
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal ExecutionPartConstruct_star, s1), l1))
                  :: !inner);
        match l with
        | [ Noeud ((Terminal Else, _), []); Noeud ((Terminal EOS, s2), []) ] ->
            Noeud
              ( Syntax Else,
                convert_to_abstract_aux (Noeud ((Terminal EOS, s2), []))
                :: !inner )
```

```
          | _ -> failwith "ElseStmt_ExecutionPartConstruct_star_opt")
      | Noeud
          ( (NonTerminal ExecutionPartConstruct, _),
            [ Noeud ((NonTerminal ExecutableConstruct, s), l) ] ) ->
          Noeud
            ( ToFlatten,
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal ExecutableConstruct, s), l));
              ] )
      | Noeud
          ( (NonTerminal ScalarLogicalExpr, _),
            [ Noeud ((NonTerminal Expr, s), l) ] ) ->
```

```
        convert_to_abstract_aux (Noeud ((NonTerminal Expr, s), l))
    | Noeud
        ( (NonTerminal ScalarIntLiteralConstant, _),
          [ Noeud ((Terminal Icon, s), l) ] ) ->
        Noeud (Integer s, [])
    | Noeud ((NonTerminal Expr, _), [ Noeud ((NonTerminal Level5Expr, s), l) ])
      ->
        convert_to_abstract_aux (Noeud ((NonTerminal Level5Expr, s), l))
    | Noeud
        ( (NonTerminal EquivOp_EquivOperand_star, _),
          [
            Noeud ((NonTerminal EquivOp, _), _);
```

```
            Noeud ((NonTerminal EquivOperand, s), l);
            Noeud
              ( (NonTerminal EquivOp_EquivOperand_star, _),
                [ Noeud ((Terminal E, _), []) ] );
          ] )
    | Noeud
        ( (NonTerminal Level5Expr, _),
          [
            Noeud ((NonTerminal EquivOperand, s), l);
            Noeud
              ( (NonTerminal EquivOp_EquivOperand_star, _),
                [ Noeud ((Terminal E, _), []) ] );
          ] ) ->
```

```
            convert_to_abstract_aux (Noeud ((NonTerminal EquivOperand, s), l))
        | Noeud
            ( (NonTerminal EquivOp_EquivOperand_star, _),
              [
                Noeud ((NonTerminal EquivOp, _), _);
                Noeud ((NonTerminal EquivOperand, s), l);
                Noeud ((NonTerminal EquivOp_EquivOperand_star, s1), l1);
              ] )
        | Noeud
            ( (NonTerminal Level5Expr, _),
              [
```

```
          Noeud ((NonTerminal EquivOperand, s), l);
          Noeud ((NonTerminal EquivOp_EquivOperand_star, s1), l1);
        ] ) -> (
      match l1 with
      | Noeud
          ((NonTerminal EquivOp, _), [ Noeud ((Terminal Equivalent, _), []) ])
        :: _ ->
          Noeud
            ( OperateurLogique Equivalent,
              [
                convert_to_abstract_aux
                  (Noeud ((NonTerminal EquivOperand, s), l));
```

```
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal EquivOp_EquivOperand_star, s1), l1));
                ] )
        | Noeud
            ( (NonTerminal EquivOp, _),
              [ Noeud ((Terminal NotEquivalent, _), []) ] )
          :: _ ->
            Noeud
              ( OperateurLogique NonEquivalent,
                [
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal EquivOperand, s), l));
                  convert_to_abstract_aux
```

```
                    (Noeud ((NonTerminal EquivOp_EquivOperand_star, s1), l1));
                ] )
        | _ -> failwith "Level5Expr")
    | Noeud
        ( (NonTerminal OrOp_OrOperand_star, _),
          [
            Noeud ((Terminal OrOp, _), []);
            Noeud ((NonTerminal OrOperand, s), l);
            Noeud
              ( (NonTerminal OrOp_OrOperand_star, _),
                [ Noeud ((Terminal E, _), []) ] );
          ] )
    | Noeud
        ( (NonTerminal EquivOperand, _),
```

```
                [
                  Noeud ((NonTerminal OrOperand, s), l);
                  Noeud
                    ( (NonTerminal OrOp_OrOperand_star, _),
                      [ Noeud ((Terminal E, _), []) ] );
                ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal OrOperand, s), l))
        | Noeud
            ( (NonTerminal OrOp_OrOperand_star, _),
              [
                Noeud ((Terminal OrOp, _), []);
                Noeud ((NonTerminal OrOperand, s), l);
                Noeud ((NonTerminal OrOp_OrOperand_star, s2), l2);
              ] )
```

```
    | Noeud
        ( (NonTerminal EquivOperand, _),
          [
            Noeud ((NonTerminal OrOperand, s), l);
            Noeud ((NonTerminal OrOp_OrOperand_star, s2), l2);
          ] ) ->
        Noeud
          ( OperateurLogique Ou,
            [
              convert_to_abstract_aux (Noeud ((NonTerminal OrOperand, s), l));
              convert_to_abstract_aux
                (Noeud ((NonTerminal OrOp_OrOperand_star, s2), l2));
            ] )
    | Noeud
```

```
           ( (NonTerminal AndOp_AndOperand_star, _),
             [
               Noeud ((Terminal AndOp, _), []);
               Noeud ((NonTerminal AndOperand, s), l);
               Noeud
                 ( (NonTerminal AndOp_AndOperand_star,
                 ↪  _),
                   [ Noeud ((Terminal E, _), []) ] );
             ] )
       | Noeud
           ( (NonTerminal OrOperand, _),
             [
               Noeud ((NonTerminal AndOperand, s), l);
               Noeud
                 ( (NonTerminal AndOp_AndOperand_star,
                 ↪  _),
                   [ Noeud ((Terminal E, _), []) ] );
```

```
                ] ) ->
              convert_to_abstract_aux (Noeud ((NonTerminal AndOperand, s), l))
          | Noeud
              ( (NonTerminal AndOp_AndOperand_star, _),
                [
                  Noeud ((Terminal AndOp, _), []);
                  Noeud ((NonTerminal AndOperand, s1), l1);
                  Noeud ((NonTerminal AndOp_AndOperand_star, s2), l2);
                ] )
          | Noeud
              ( (NonTerminal OrOperand, _),
                [
                  Noeud ((NonTerminal AndOperand, s1), l1);
```

```
                Noeud ((NonTerminal AndOp_AndOperand_star, s2), l2);
              ] ) ->
          Noeud
            ( OperateurLogique Et,
              [
                convert_to_abstract_aux (Noeud ((NonTerminal AndOperand, s1), l1));
                convert_to_abstract_aux
                  (Noeud ((NonTerminal AndOp_AndOperand_star, s2), l2));
              ] )
      | Noeud
          ( (NonTerminal AndOperand, _),
            [
```

```
                Noeud ((NonTerminal NotOp_opt, _), [ Noeud ((Terminal E, _), []) ]);
                Noeud ((NonTerminal Level4Expr, s), l);
              ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal Level4Expr, s), l))
        | Noeud
            ( (NonTerminal AndOperand, _),
              [
                Noeud
                  ((NonTerminal NotOp_opt, _), [ Noeud ((Terminal NotOp, _), []) ]);
                Noeud ((NonTerminal Level4Expr, s), l);
              ] ) ->
            Noeud
              ( OperateurLogique Non,
```

```
              [ convert_to_abstract_aux (Noeud ((NonTerminal Level4Expr, s), l)) ]
            )
      | Noeud
          ( (NonTerminal RelOp_Level3Expr_star, _),
            [
              Noeud ((NonTerminal RelOp, _), _);
              Noeud ((NonTerminal Level3Expr, s), l);
              Noeud
                ( (NonTerminal RelOp_Level3Expr_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] )
      | Noeud
          ( (NonTerminal Level4Expr, _),
            [
              Noeud ((NonTerminal Level3Expr, s), l);
```

```
                  Noeud
                    ( (NonTerminal RelOp_Level3Expr_star,
                    ↪  _),
                      [ Noeud ((Terminal E, _), []) ] );
                ] ) ->
            convert_to_abstract_aux (Noeud
            ↪  ((NonTerminal Level3Expr, s), l))
        | Noeud
            ( (NonTerminal RelOp_Level3Expr_star, _),
              [
                  Noeud ((NonTerminal RelOp, _), _);
                  Noeud ((NonTerminal Level3Expr, s), l);
                  Noeud ((NonTerminal
                  ↪  RelOp_Level3Expr_star, s1), l1);
              ] )
        | Noeud
            ( (NonTerminal Level4Expr, _),
```

```
          [
            Noeud ((NonTerminal Level3Expr, s), l);
            Noeud ((NonTerminal RelOp_Level3Expr_star, s1), l1);
          ] ) -> (
        match l1 with
        | [ Noeud ((Terminal E, _), []) ] ->
            convert_to_abstract_aux (Noeud ((NonTerminal Level3Expr, s), l))
        | Noeud ((NonTerminal RelOp, _), [ Noeud ((Terminal IsEqual, _), []) ])
          :: _ ->
            Noeud
              ( Comparateur Egal,
                [
                  convert_to_abstract_aux
```

```
                        (Noeud ((NonTerminal Level3Expr, s), l));
                    convert_to_abstract_aux
                        (Noeud ((NonTerminal RelOp_Level3Expr_star, s1), l1));
                  ] )
        | Noeud ((NonTerminal RelOp, _), [ Noeud ((Terminal NotEqual, _), []) ])
          :: _ ->
            Noeud
              ( Comparateur NonEgal,
                [
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal Level3Expr, s), l));
                  convert_to_abstract_aux
```

```
                        (Noeud ((NonTerminal
                         ↪  RelOp_Level3Expr_star, s1),
                         ↪  l1));
                   ] )
          | Noeud
              ((NonTerminal RelOp, _), [ Noeud
              ↪  ((Terminal StrictLess, _), []) ])
            :: _ ->
              Noeud
                ( Comparateur StrictPlusPetit,
                  [
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal
                       ↪  Level3Expr, s), l));
                    convert_to_abstract_aux
```

```
                    (Noeud ((NonTerminal RelOp_Level3Expr_star, s1), l1));
                ] )
        | Noeud ((NonTerminal RelOp, _), [ Noeud ((Terminal LessEqual, _), []) ])
          :: _ ->
            Noeud
              ( Comparateur PlusPetit,
                [
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal Level3Expr, s), l));
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal RelOp_Level3Expr_star, s1), l1));
```

```
                    ] )
            | Noeud
                ((NonTerminal RelOp, _), [ Noeud
                ↪   ((Terminal StrictGreater, _), [])
                ↪   ])
              :: _ ->
                Noeud
                  ( Comparateur StrictPlusGrand,
                    [
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal
                        ↪   Level3Expr, s), l));
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal
                        ↪   RelOp_Level3Expr_star, s1),
                        ↪   l1));
                    ] )
```

```
              | Noeud
                  ((NonTerminal RelOp, _), [ Noeud ((Terminal GreaterEqual, _), []) ])
                :: _ ->
                  Noeud
                    ( Comparateur PlusGrand,
                      [
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal Level3Expr, s), l));
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal RelOp_Level3Expr_star, s1), l1));
                      ] )
              | _ -> failwith "Level4Expr")
          | Noeud
```

```
            ((NonTerminal Level3Expr, _), [ Noeud
             ↪  ((NonTerminal Level2Expr, s), l) ])
          ->
            convert_to_abstract_aux (Noeud
             ↪  ((NonTerminal Level2Expr, s), l))
        | Noeud
            ( (NonTerminal
             ↪  AddOp_Sign_opt_AddOperand_star, _),
              [
                Noeud ((NonTerminal AddOp, _), _);
                Noeud ((NonTerminal
                 ↪  Sign_opt_AddOperand, s), l);
                Noeud
                  ( (NonTerminal
                  ↪  AddOp_Sign_opt_AddOperand_star,
                  ↪  _),
                    [ Noeud ((Terminal E, _), []) ] );
```

```
                ] )
        | Noeud
            ( (NonTerminal Level2Expr, _),
              [
                Noeud ((NonTerminal
                 ↪  Sign_opt_AddOperand, s), l);
                Noeud
                  ( (NonTerminal
                   ↪  AddOp_Sign_opt_AddOperand_star,
                   ↪  _),
                    [ Noeud ((Terminal E, _), []) ] );
              ] ) ->
            convert_to_abstract_aux
              (Noeud ((NonTerminal Sign_opt_AddOperand,
               ↪  s), l))
        | Noeud
```

```
            ( (NonTerminal
            ↪  AddOp_Sign_opt_AddOperand_star, _),
              [
                Noeud ((NonTerminal AddOp, _), _);
                Noeud ((NonTerminal
                 ↪  Sign_opt_AddOperand, s), l);
                Noeud ((NonTerminal
                 ↪  AddOp_Sign_opt_AddOperand_star,
                 ↪  s2), l2);
              ] )
        | Noeud
            ( (NonTerminal Level2Expr, _),
              [
                Noeud ((NonTerminal
                 ↪  Sign_opt_AddOperand, s), l);
```

```
            Noeud ((NonTerminal AddOp_Sign_opt_AddOperand_star, s2), l2);
          ] ) -> (
        match l2 with
        | Noeud
            ( (NonTerminal AddOp, _),
              [
                Noeud ((NonTerminal Sign, _), [ Noeud ((Terminal Plus, _), []) ]);
              ] )
          :: _ ->
            Noeud
              ( Operateur Plus,
                [
                  convert_to_abstract_aux
```

```
                    (Noeud ((NonTerminal Sign_opt_AddOperand, s), l));
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal AddOp_Sign_opt_AddOperand_star, s2), l2));
                ] )
        | Noeud
            ( (NonTerminal AddOp, _),
              [
                Noeud
                  ((NonTerminal Sign, _), [ Noeud ((Terminal Minus, _), []) ]);
              ] )
          :: _ ->
            Noeud
```

```
                  ( Operateur Moins,
                    [
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal Sign_opt_AddOperand, s), l));
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal AddOp_Sign_opt_AddOperand_star, s2), l2));
                    ] )
              | _ -> failwith "Level2Expr")
      | Noeud
          ( (NonTerminal Sign_opt_AddOperand, _),
            [
              Noeud ((NonTerminal Sign_opt, _), [ Noeud ((Terminal E, _), []) ]);
```

```
                Noeud ((NonTerminal AddOperand, s), l);
              ] ) ->
            convert_to_abstract_aux (Noeud ((NonTerminal AddOperand, s), l))
        | Noeud
            ( (NonTerminal Sign_opt_AddOperand, _),
              [
                Noeud
                  ( (NonTerminal Sign_opt, _),
                    [
                      Noeud
                        ((NonTerminal Sign, _), [ Noeud ((Terminal Plus, _), []) ]);
                    ] );
                Noeud ((NonTerminal AddOperand, s), l);
              ] ) ->
```

```
        Noeud
          ( Operateur Plus,
            [ convert_to_abstract_aux (Noeud ((NonTerminal AddOperand, s), l)) ]
          )
    | Noeud
        ( (NonTerminal Sign_opt_AddOperand, _),
          [
            Noeud
              ( (NonTerminal Sign_opt, _),
                [
                  Noeud
                    ((NonTerminal Sign, _), [ Noeud ((Terminal Minus, _), []) ]);
                ] );
            Noeud ((NonTerminal AddOperand, s), l);
```

```
            ] ) ->
          Noeud
            ( Operateur Moins,
              [ convert_to_abstract_aux (Noeud ((NonTerminal AddOperand, s), l)) ]
            )
      | Noeud
          ( (NonTerminal MultOp_MultOperand_star, _),
            [
              Noeud ((NonTerminal MultOp, _), _);
              Noeud ((NonTerminal MultOperand, s), l);
              Noeud
                ( (NonTerminal MultOp_MultOperand_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] )
```

```
      | Noeud
          ( (NonTerminal AddOperand, _),
            [
              Noeud ((NonTerminal MultOperand, s), l);
              Noeud
                ( (NonTerminal MultOp_MultOperand_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] ) ->
          convert_to_abstract_aux (Noeud ((NonTerminal MultOperand, s), l))
      | Noeud
          ( (NonTerminal MultOp_MultOperand_star, _),
            [
              Noeud ((NonTerminal MultOp, _), _);
```

```
                Noeud ((NonTerminal MultOperand, s), l);
                Noeud ((NonTerminal MultOp_MultOperand_star, s2), l2);
              ] )
      | Noeud
          ( (NonTerminal AddOperand, _),
            [
                Noeud ((NonTerminal MultOperand, s), l);
                Noeud ((NonTerminal MultOp_MultOperand_star, s2), l2);
              ] ) -> (
          match l2 with
          | Noeud ((NonTerminal MultOp, _), [ Noeud ((Terminal Asterisk, _), []) ])
            :: _ ->
```

```
                Noeud
                  ( Operateur Fois,
                    [
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal
                        ↪  MultOperand, s), l));
                      convert_to_abstract_aux
                        (Noeud ((NonTerminal
                        ↪  MultOp_MultOperand_star,
                        ↪  s2), l2));
                    ] )
            | Noeud ((NonTerminal MultOp, _), [ Noeud
            ↪  ((Terminal Divise, _), []) ])
              :: _ ->
                Noeud
                  ( Operateur Division,
                    [
```

```
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal MultOperand, s), l));
                        convert_to_abstract_aux
                          (Noeud ((NonTerminal MultOp_MultOperand_star, s2), l2));
                    ] )
            | _ -> failwith "AddOperand")
        | Noeud
            ( (NonTerminal PowerOp_Level1Expr_star, _),
              [
                Noeud ((Terminal PowerOp, _), []);
                Noeud ((NonTerminal Level1Expr, s), l);
                Noeud
                  ( (NonTerminal PowerOp_Level1Expr_star, _),
```

```
                [ Noeud ((Terminal E, _), []) ] );
            ] )
      | Noeud
          ( (NonTerminal MultOperand, _),
            [
              Noeud ((NonTerminal Level1Expr, s), l);
              Noeud
                ( (NonTerminal
                ↪  PowerOp_Level1Expr_star, _),
                [ Noeud ((Terminal E, _), []) ] );
            ] ) ->
          convert_to_abstract_aux (Noeud
          ↪  ((NonTerminal Level1Expr, s), l))
      | Noeud
          ( (NonTerminal PowerOp_Level1Expr_star, _),
            [
              Noeud ((Terminal PowerOp, _), []);
```

```
                Noeud ((NonTerminal Level1Expr, s), l);
                Noeud ((NonTerminal
                 ↪  PowerOp_Level1Expr_star, s2), l2);
              ] )
        | Noeud
            ( (NonTerminal MultOperand, _),
              [
                Noeud ((NonTerminal Level1Expr, s), l);
                Noeud ((NonTerminal
                 ↪  PowerOp_Level1Expr_star, s2), l2);
              ] ) ->
            Noeud
              ( Operateur Puissance,
                [
                  convert_to_abstract_aux (Noeud
                   ↪  ((NonTerminal Level1Expr, s),
                   ↪  l));
```

```
                    convert_to_abstract_aux
                      (Noeud ((NonTerminal PowerOp_Level1Expr_star, s2), l2));
                ] )
        | Noeud
            ((NonTerminal Level1Expr, _), [ Noeud ((NonTerminal Primary, s), l) ])
          ->
            convert_to_abstract_aux (Noeud ((NonTerminal Primary, s), l))
        | Noeud ((NonTerminal Primary, _), l) -> (
            match l with
            | [ Noeud ((Terminal Icon, s), []) ] -> Noeud (Integer s, [])
            | [ Noeud ((Terminal Rcon, s), []) ] -> Noeud (Floating s, [])
```

```
          | [ Noeud ((Terminal Dcon, s), []) ] ->
          ↪  Noeud (Double s, [])
          | [
           Noeud ((NonTerminal Name, _), [ Noeud
            ↪  ((Terminal Ident, s), []) ]);
           Noeud
             ( (NonTerminal FunctionReference_opt,
              ↪  _),
               [ Noeud ((Terminal E, _), []) ] );
          ] ->
             Noeud (Name s, [])
          | [
           Noeud ((NonTerminal Name, _), [ Noeud
            ↪  ((Terminal Ident, s), []) ]);
           Noeud
             ( (NonTerminal FunctionReference_opt,
              ↪  _),
```

```
                [
                  Noeud ((Terminal LParenthesis, _), []);
                  Noeud
                    ( ( NonTerminal
                          FunctionArg_Comma_FunctionArg
                        _ ),
                      [ Noeud ((Terminal RParenthesis, _), []) ] );
                ] );
          ] ->
            Noeud (Syntax Call, [ Noeud (Name s, []) ])
          | [
              Noeud ((NonTerminal Name, _), [ Noeud ((Terminal Ident, s), []) ]);
```

```
        Noeud ((NonTerminal FunctionReference_opt, s1), l1);
      ] ->
          Noeud
            ( Syntax Call,
              Noeud (Name s, [])
              :: flatten
                   (convert_to_abstract_aux
                      (Noeud ((NonTerminal FunctionReference_opt, s1), l1)))
                   [] )
      | [
        Noeud ((NonTerminal Scon, _), [ Noeud ((Terminal SconSingle, s), []) ]);
      ] ->
          Noeud (Chaine s, [])
```

```
        | [
         Noeud ((NonTerminal Scon, _), [ Noeud ((Terminal SconDouble, s), []) ]);
        ] ->
            Noeud (Chaine s, [])
        | [
         Noeud
           ((NonTerminal LogicalConstant, _), [ Noeud ((Terminal True, _), []) ]);
        ] ->
            Noeud (Booleen true, [])
        | [
         Noeud
           ( (NonTerminal LogicalConstant, _),
             [ Noeud ((Terminal False, _), []) ] );
        ] ->
            Noeud (Booleen false, [])
```

```
          | [
           Noeud ((Terminal LParenthesis, _), []);
           Noeud ((NonTerminal Expr, s), l);
           Noeud ((Terminal RParenthesis, _), []);
          ] ->
              Noeud
                ( ToFlatten,
                  [
                    Noeud (Parentheseouvrante, []);
                    convert_to_abstract_aux (Noeud
                     ↪  ((NonTerminal Expr, s), l));
                    Noeud (Parenthesefermante, []);
                  ] )
          | _ -> failwith "Primary")
      | Noeud
          ( (NonTerminal FunctionReference_opt, _),
            [
```

```
            Noeud ((Terminal LParenthesis, _), []);
            Noeud
              ( ( NonTerminal
              ↪  FunctionArg_Comma_FunctionArg_star_opt
                  s ),
                l );
          ] ) ->
        convert_to_abstract_aux
          (Noeud
             ( ( NonTerminal
             ↪  FunctionArg_Comma_FunctionArg_star_opt_
                 s ),
               l ))
    | Noeud
        ( (NonTerminal
        ↪  FunctionArg_Comma_FunctionArg_star_opt_RPare
        ↪  _),
```

```
                [
                  Noeud ((NonTerminal FunctionArg, s),
                   ↪  l);
                  Noeud
                    ( (NonTerminal
                     ↪  Comma_FunctionArg_star, _),
                      [ Noeud ((Terminal E, _), []) ] );
                  Noeud ((Terminal RParenthesis, _), []);
                ] ) ->
            convert_to_abstract_aux (Noeud
             ↪  ((NonTerminal FunctionArg, s), l))
        | Noeud
            ( (NonTerminal
             ↪  FunctionArg_Comma_FunctionArg_star_opt_RPare
             ↪  _),
              [
```

```
                Noeud ((NonTerminal FunctionArg, s), l);
                Noeud ((NonTerminal Comma_FunctionArg_star, s1), l1);
                Noeud ((Terminal RParenthesis, _), []);
              ] ) ->
            Noeud
              ( ToFlatten,
                [
                  convert_to_abstract_aux (Noeud ((NonTerminal FunctionArg, s), l));
                  convert_to_abstract_aux
                    (Noeud ((NonTerminal Comma_FunctionArg_star, s1), l1));
                ] )
```

```
      | Noeud
          ( (NonTerminal Comma_FunctionArg_star, _),
            [
              Noeud ((Terminal Comma, _), []);
              Noeud ((NonTerminal FunctionArg, s), l);
              Noeud
                ( (NonTerminal Comma_FunctionArg_star, _),
                  [ Noeud ((Terminal E, _), []) ] );
            ] ) ->
          convert_to_abstract_aux (Noeud ((NonTerminal FunctionArg, s), l))
      | Noeud
          ( (NonTerminal Comma_FunctionArg_star, _),
            [
              Noeud ((Terminal Comma, _), []);
```

```
          Noeud ((NonTerminal FunctionArg, s), l);
          Noeud ((NonTerminal Comma_FunctionArg_star, s1), l1);
        ] ) ->
      Noeud
        ( ToFlatten,
          [
            convert_to_abstract_aux (Noeud ((NonTerminal FunctionArg, s), l));
            convert_to_abstract_aux
              (Noeud ((NonTerminal Comma_FunctionArg_star, s1), l1));
          ] )
```

```
    | Noeud ((NonTerminal FunctionArg, _), [ Noeud
    ↪  ((NonTerminal Expr, s), l) ])
      ->
        convert_to_abstract_aux (Noeud
         ↪  ((NonTerminal Expr, s), l))
    | Noeud ((NonTerminal Name, _), [ Noeud
    ↪  ((Terminal Ident, s), []) ])
    | Noeud ((NonTerminal ArrayName, _), [ Noeud
    ↪  ((Terminal Ident, s), []) ])
    | Noeud ((NonTerminal ComponentName, _), [
    ↪  Noeud ((Terminal Ident, s), []) ])
    | Noeud ((NonTerminal EndName, _), [ Noeud
    ↪  ((Terminal Ident, s), []) ])
    | Noeud ((NonTerminal DummyArgName, _), [ Noeud
    ↪  ((Terminal Ident, s), []) ])
    | Noeud ((NonTerminal FunctionName, _), [ Noeud
    ↪  ((Terminal Ident, s), []) ])
```

```
    | Noeud
        ((NonTerminal ImpliedDoVariable, _), [ Noeud ((Terminal Ident, s), []) ])
    | Noeud ((NonTerminal ProgramName, _), [ Noeud ((Terminal Ident, s), []) ])
    | Noeud
        ((NonTerminal SubroutineName, _), [ Noeud ((Terminal Ident, s), []) ])
    | Noeud
        ((NonTerminal SubroutineNameUse, _), [ Noeud ((Terminal Ident, s), []) ])
    | Noeud ((NonTerminal VariableName, _), [ Noeud ((Terminal Ident, s), []) ])
    | Noeud ((NonTerminal ObjectName, _), [ Noeud ((Terminal Ident, s), []) ])
      ->
       Noeud (Name s, [])
```

```
    | Noeud ((Terminal EOS, s), []) ->
      Noeud (ToFlatten, convert_comments (Noeud (Commentaire s, [])))
    | _ ->
      (let string_of_symbol (s : symbol) : string =
         match s with
         | Terminal x -> string_of_terminal x
         | NonTerminal x -> string_of_non_terminal x
       in
       match t with
       | Noeud ((s, _), Noeud ((x, _), _) :: _) ->
           prerr_string (string_of_symbol s);
           prerr_char ' ';
           prerr_string (string_of_symbol x);
```

```
                prerr_newline ()
            | Noeud ((s, _), _) ->
                prerr_string (string_of_symbol s);
                prerr_newline ());
          failwith "is not implemented yet"
    in
    link_return_function (convert_to_abstract_aux t)
    ↪  None
```

```
open Automates

let syntax_automate_det = {
```

```
    nodes = [244; 243; 242; 241; 240; 239; 238; 237;
     ↪  236; 235; 234; 233; 232; 231; 230; 229; 228;
     ↪  227; 226; 225; 224; 223; 222; 221; 220; 219;
     ↪  218; 217; 216; 215; 214; 213; 212; 211; 210;
     ↪  209; 208; 207; 206; 205; 204; 203; 202; 201;
     ↪  200; 199; 198; 197; 196; 195; 194; 193; 192;
     ↪  191; 190; 189; 188; 187; 186; 185; 184; 183;
     ↪  182; 181; 180; 179; 178; 177; 176; 175; 174;
     ↪  173; 172; 171; 170; 169; 168; 167; 166; 165;
     ↪  164; 163; 162; 161; 160; 159; 158; 157; 156;
     ↪  155; 154; 153; 152; 151; 150; 149; 148; 147;
     ↪  146; 145; 144; 143; 142; 141; 140; 139; 138;
     ↪  137; 136; 135; 134; 133; 132; 131; 130; 129;
     ↪  128; 127; 126; 125; 124; 123; 122; 121; 120;
     ↪  119; 118; 117; 116; 115; 114; 113; 112; 111;
     ↪  110; 109; 108; 107; 106; 105; 104; 103; 102;
     ↪  101; 100; 99; 98; 97; 96; 95; 94; 93; 92; 91;
     ↪  90; 89; 88; 87; 86; 85; 84; 83; 82; 81; 80;
```

```
    debut = 0;
```

```
fin = [|None; Some EOS; Some Space; None; None;
    None; Some LParenthesis; Some RParenthesis;
    Some Asterisk; Some Plus; Some Comma; Some
    Minus; None; Some Divise; Some Icon; Some
    Colon; Some StrictLess; Some Equal; Some
    StrictGreater; Some Ident; Some Ident; Some
    Ident; Some Ident; Some Ident; Some Ident;
    Some Ident; Some Ident; Some Ident; Some
    Ident; Some Ident; Some Ident; Some Ident;
    Some Ident; Some Ident; Some Ident; Some
    While; Some Ident; Some Ident; Some Then;
    Some Ident; Some Ident; Some Ident; Some
    Ident; Some Ident; Some Ident; Some Ident;
    Some Ident; Some Subroutine; Some Ident; Some
    Ident; Some Ident; Some Ident; Some Ident;
    Some Ident; Some Ident; Some Return; Some
    Ident; Some Ident; Some Result; Some Ident;
    Some Ident; Some Ident; Some Ident; Some
```

```
  transitions = [|
    [|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; 1;
     ↪ -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
     ↪ -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; 2;
     ↪ 3; 4; -1; -1; -1; -1; 5; 6; 7; 8; 9; 10;
     ↪ 11; 12; 13; 14; 14; 14; 14; 14; 14; 14; 14;
     ↪ 14; 14; 15; -1; 16; 17; 18; -1; -1; 19; 19;
     ↪ 20; 21; 22; 23; 19; 19; 24; 19; 19; 25; 19;
     ↪ 19; 26; 27; 19; 28; 29; 30; 19; 19; 31; 19;
     ↪ 19; 19; -1; -1; -1; -1; -1; -1; 19; 19; 20;
     ↪ 21; 22; 23; 19; 19; 24; 19; 19; 25; 19; 19;
     ↪ 26; 27; 19; 28; 29; 30; 19; 19; 31; 19; 19;
     ↪ 19; -1; -1; -1; -1; -1|];
```

```
        [|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; 1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  244; 3; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1|];
```

```
    [|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
    ↪  -1; -1; -1; -1; -1; -1; -1|];
```

```
    [|3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 244; 3; 3; 3;
    ↪  3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3;
    ↪  3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3;
    ↪  3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3;
    ↪  3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3;
    ↪  3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3;
    ↪  3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3;
    ↪  3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3;
    ↪  3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3; 3;
    ↪  3; 3|];
```

```
[|4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4; 4; 4; 4; 4; 243; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4; 4;
↪  4|];
```

```
    [|5; 5; 5; 5; 5; 5; 5; 5; 5; 5; 5; 5; 5; 5; 5;
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↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1|];
```

```
      [|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; 239; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; 239; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1|];
```

```
        [|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; 240; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1|];
```

```
[|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1|];
```

```
[|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
↪  -1; -1; -1; -1; -1; -1; -1|];
```

```
      [|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; 5; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
       ↪  -1; -1; -1; -1; -1; -1; -1|];
```

```
        [|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; 4; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
         ↪  -1; -1; -1; -1; -1; -1; -1|];
```

```
        [|-1; -1; -1; -1; -1; -1; -1; -1; -1; -1; 1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  244; 3; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1; -1; -1; -1;
        ↪  -1; -1; -1; -1; -1; -1; -1; -1|]
    |]
}
```

```
open Environnement
open Abstract_tokens
open Bibliotheques
open Convert_to_abstract
open LL1
open Traduction

(** Renvoie les imports nécessaires contenus dans
↪  [l] *)
let rec generate_library_imports (l : libs) :
↪  string =
  match l with
  | [] -> ""
  | name :: q -> "#include <" ^ name ^ ".h>\n" ^
  ↪  generate_library_imports q

(** Renvoie le format de string dans les printf
↪  pour afficher la variable ou la
```

```
    fonction [n] à l'aide de [env] *)
let generate_format_string_of_name (n : string) (env : environnement) : string =
  match Hashtbl.find_opt env n with
  | Some (Syntax Real) -> "%f "
  | Some (Syntax Integer) -> "%d "
  | Some (Syntax Logical) -> "%d "
  | _ -> failwith "La variable n'est pas dans l'environnement"

(** Renvoie le format de string dans les printf pour afficher les éléments de
    [l] en s'aidant des types dans [env] *)
let rec generate_format_string (l : ast list) (env : environnement) : string =
  match l with
  | [] -> ""
```

```
    | Noeud (Chaine _, []) :: q -> "%s " ^ generate_format_string q env
    | Noeud (Integer _, []) :: q -> "%d " ^ generate_format_string q env
    | Noeud (Floating _, []) :: q -> "%f " ^ generate_format_string q env
    | Noeud (Booleen _, []) :: q -> "%d " ^ generate_format_string q env
    | Noeud (Name n, []) :: q ->
      generate_format_string_of_name n env ^ generate_format_string q env
    | Noeud (Syntax Call, Noeud (Name n, []) :: _) :: _ ->
      generate_format_string_of_name n env
    | Noeud (s, _) :: _ ->
      print_token s;
      failwith " type non def"
```

```ocaml

(** renvoie la chaîne associée au type de [var] dans [env] *)
let str_of_env_type (env : environnement) (var : string) : string =
  match Hashtbl.find_opt env var with
   | Some (Syntax Integer) -> "int"
   | Some (Syntax Real) -> "float"
   | Some t ->
       print_token t;
       failwith "type non supporté"
   | None -> failwith "var not found in environnement"

(** Applique la fonction [f] au dernier élément de la liste [l] *)
```

```
let rec map_to_last (f : 'a -> 'a) (l : 'a list) : 'a list =
  match l with
  | [] -> failwith "impossible to map to last"
  | e :: [] -> if e = L [] then failwith "e= []" else [ f e ]
  | e :: q -> e :: map_to_last f q

(** ajoute un point-virgule à la fin de [s] si elle n'en a pas déjà *)
let rec add_semi_colon (s : string_or_string_list) : string_or_string_list =
  match s with
  | S s -> if String.ends_with s ~suffix:";" then S s else S (s ^ ";")
  | L l -> L (map_to_last add_semi_colon l)

```

```
(** Renvoie le type de la fonction d'ast [a] à l'aide de l'environnement [env] *)
let get_function_return_type (a : ast) (env : environnement) :
    string_or_string_list =
  match a with
  | Noeud (Syntax Function, l) -> (
      let ret = last_of_list l in
      match ret with
      | Noeud (Syntax Return, [ Noeud (Name var_name, []) ]) ->
          S (str_of_env_type env var_name)
      | _ -> failwith "type de retour non pris en charge")
  | _ -> failwith "Cette fonction prend en paramètre un Noeud(Function)"
```

```
(** parcourt la liste des fils pour trouver les définitions des paramètres *)
let rec get_function_param_list (l : ast list) (env : environnement) :
    string_or_string_list * ast list =
  match l with

  | Noeud (Name nom, []) :: Noeud(Name n,[]) :: q ->
      let sosl, q2 = get_function_param_list (Noeud(Name n,[]) :: q) env in
      (L [ S (str_of_env_type env nom); S " "; S nom; S ", "; sosl ], q)

  | Noeud (Name nom, []) ::  q -> L [ S (str_of_env_type env nom); S " "; S nom ], q
  | l1 -> (S "", l)
```

```ocaml

(** convertit l'arbre de syntaxe abstrait [ast] à l'aide de l'environnement
    [env] et l'indente de [n_tab] en un string_or_string_list *)
let rec convert_ast_to_C_sosl (ast : ast list) (env : environnement)
    (nb_tab : int) : string_or_string_list =
  match ast with
  | [] -> S ""
  | [ Noeud (ProgramRoot, l) ] -> convert_ast_to_C_sosl l env nb_tab
  | Noeud (Syntax Program, Noeud (Name nom, []) :: l1) :: q ->
      L
        [
          Traduction.tabs_to_string nb_tab;
```

```
            S "// ";
            S nom;
            S "\n";
            Traduction.tabs_to_string nb_tab;
            S "void main(void){";
            convert_ast_to_C_sosl l1 env (nb_tab +
            ↪  1);
            S "}";
          ]
    | Noeud (Commentaire c, []) :: q ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "//";
            S c;
            convert_ast_to_C_sosl q env nb_tab;
          ]
```

```
    | Noeud (Syntax Print, l2) :: q ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "printf(\"";
            S (generate_format_string l2 env);
            S "\"";
            L
              (List.rev
                 (List.fold_left
                    (fun acc x ->
                      convert_ast_to_C_sosl [ x ] env nb_tab :: S ", " :: acc)
                    [] l2));
            S ");";
            convert_ast_to_C_sosl q env nb_tab;
          ]
```

```
(* définit le type des variables *)
| Noeud (Syntax Real, l) :: q ->
   let s = convert_ast_to_C_sosl l env 0 in
   let s = add_semi_colon s in
   L
     [
       Traduction.tabs_to_string nb_tab;
       S "float ";
       s;
       convert_ast_to_C_sosl q env nb_tab;
     ]
| Noeud (Syntax Integer, l) :: q ->
   let s = convert_ast_to_C_sosl l env 0 in
   let s = add_semi_colon s in
   L
     [
       Traduction.tabs_to_string nb_tab;
```

```
                S "int ";
                s;
                convert_ast_to_C_sosl q env nb_tab;
              ]
   | Noeud (Syntax Logical, l) :: q ->
        let s = convert_ast_to_C_sosl l env 0 in
        let s = add_semi_colon s in
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "bool ";
            s;
            convert_ast_to_C_sosl q env nb_tab;
          ]
   | Noeud (Syntax Double_precision, l) :: q ->
        let s = convert_ast_to_C_sosl l env 0 in
        let s = add_semi_colon s in
```

```
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "long ";
            s;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (Syntax Character, Noeud (Syntax Constant, []) :: l) :: q ->
        let s = convert_ast_to_C_sosl l env 0 in
        let s = add_semi_colon s in
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "const char ";
            s;
            convert_ast_to_C_sosl q env nb_tab;
```

```
        ]
    | Noeud (Syntax Character, l) :: q ->
        let s = convert_ast_to_C_sosl l env 0 in
        let s = add_semi_colon s in
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "char ";
            s;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (Operateur Assignation, Noeud (Name s, []) :: l) :: q ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S s;
```

```
      S " = ";
      convert_ast_to_C_sosl l env 0;
      S ";";
      convert_ast_to_C_sosl q env nb_tab;
     ]
  | Noeud (Syntax Size, l) :: q ->
    L
     [
      Traduction.tabs_to_string nb_tab;
      S "[";
      convert_ast_to_C_sosl l env 0;
      S "] ";
      convert_ast_to_C_sosl q env nb_tab;
     ]
  | Noeud (Operateur Assignation, Noeud (Syntax
  ↪  Size, l1) :: l) :: q ->
    L
```

```
            [
              Traduction.tabs_to_string nb_tab;
              convert_ast_to_C_sosl [ Noeud (Syntax
               ↪  Size, l1) ] env 0;
              convert_ast_to_C_sosl
                (Noeud (Operateur Assignation, l) :: q)
                env nb_tab;
            ]
    | Noeud (Syntax Any, []) :: q ->
     ↪  convert_ast_to_C_sosl q env 0
    | Noeud (Name s, []) :: q -> L [ S s;
     ↪  convert_ast_to_C_sosl q env nb_tab ]
    | Noeud (Operateur Plus, elem :: l) :: q ->
        L
            [
              convert_ast_to_C_sosl [ elem ] env
               ↪  nb_tab;
```

```
              S " + ";
              convert_ast_to_C_sosl l env nb_tab;
              convert_ast_to_C_sosl q env nb_tab;
            ]

  (* opérateur unaire *)
  | Noeud (Operateur Moins, elem :: []) :: q ->
      L
        [
          S " -";
          convert_ast_to_C_sosl [ elem ] env
           ↪ nb_tab;
          convert_ast_to_C_sosl q env nb_tab;
        ]

  | Noeud (Operateur Moins, elem :: l) :: q ->
      L
```

```
          [
            convert_ast_to_C_sosl [ elem ] env
            ↪ nb_tab;
            S " - ";
            convert_ast_to_C_sosl l env nb_tab;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (Operateur Fois, elem :: l) :: q ->
        L
          [
            convert_ast_to_C_sosl [ elem ] env
            ↪ nb_tab;
            S " * ";
            convert_ast_to_C_sosl l env nb_tab;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (Operateur Division, elem :: l) :: q ->
```

```
        L
          [
            convert_ast_to_C_sosl [ elem ] env nb_tab;
            S " / ";
            convert_ast_to_C_sosl l env nb_tab;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (Parentheseouvrante, []) :: q ->
        L [ S "("; convert_ast_to_C_sosl q env nb_tab ]
    | Noeud (Parenthesefermante, []) :: q ->
        L [ S ")"; convert_ast_to_C_sosl q env nb_tab ]
    | Noeud (OperateurLogique NonEquivalent, [ p1; p2 ]) :: q
    | Noeud (Comparateur NonEgal, [ p1; p2 ]) :: q ->
```

```
        L
          [
            convert_ast_to_C_sosl [ p1 ] env 0;
            S " != ";
            convert_ast_to_C_sosl [ p2 ] env 0;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (OperateurLogique Equivalent, [ p1; p2 ])
    ↪  :: q
    | Noeud (Comparateur Egal, [ p1; p2 ]) :: q ->
        L
          [
            convert_ast_to_C_sosl [ p1 ] env 0;
            S " == ";
            convert_ast_to_C_sosl [ p2 ] env 0;
            convert_ast_to_C_sosl q env nb_tab;
          ]
```

```
  | Noeud (Comparateur StrictPlusPetit, [ p1; p2 ]) :: q ->
      L
        [
          convert_ast_to_C_sosl [ p1 ] env 0;
          S " < ";
          convert_ast_to_C_sosl [ p2 ] env 0;
          convert_ast_to_C_sosl q env nb_tab;
        ]
  | Noeud (Comparateur PlusPetit, [ p1; p2 ]) :: q ->
      L
        [
          convert_ast_to_C_sosl [ p1 ] env 0;
          S " <= ";
          convert_ast_to_C_sosl [ p2 ] env 0;
          convert_ast_to_C_sosl q env nb_tab;
```

```
            ]
    | Noeud (Comparateur StrictPlusGrand, [ p1; p2 ])
    ↪   :: q ->
        L
          [
            convert_ast_to_C_sosl [ p1 ] env 0;
            S " > ";
            convert_ast_to_C_sosl [ p2 ] env 0;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (Comparateur PlusGrand, [ p1; p2 ]) :: q
    ↪   ->
        L
          [
            convert_ast_to_C_sosl [ p1 ] env 0;
            S " >= ";
            convert_ast_to_C_sosl [ p2 ] env 0;
```

```
                convert_ast_to_C_sosl q env nb_tab;
              ]
    | Noeud (OperateurLogique Et, [ p1; p2 ]) :: q ->
        L
          [
            convert_ast_to_C_sosl [ p1 ] env 0;
            S " && ";
            convert_ast_to_C_sosl [ p2 ] env 0;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (OperateurLogique Ou, [ p1; p2 ]) :: q ->
        L
          [
            convert_ast_to_C_sosl [ p1 ] env 0;
            S " || ";
            convert_ast_to_C_sosl [ p2 ] env 0;
            convert_ast_to_C_sosl q env nb_tab;
```

```
          ]
    | Noeud (OperateurLogique Non, [ p1; p2 ]) :: q
    ↪   ->
        L
          [
            convert_ast_to_C_sosl [ p1 ] env 0;
            S " ! ";
            convert_ast_to_C_sosl [ p2 ] env 0;
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (Operateur Puissance, [ p1; p2 ]) :: q ->
        L
          [
            S "pow((long)";
            convert_ast_to_C_sosl [ p1 ] env 0;
            S ", ";
            convert_ast_to_C_sosl [ p2 ] env 0;
```

```
        S "(long))";
        convert_ast_to_C_sosl q env nb_tab;
       ]
    | Noeud (Syntax If, condition :: instructions) :: q ->
      L
       [
        Traduction.tabs_to_string nb_tab;
        S "if (";
        convert_ast_to_C_sosl [ condition ] env nb_tab;
        S "){";
        convert_ast_to_C_sosl instructions env (nb_tab + 1);
        Traduction.tabs_to_string nb_tab;
        S "}";
        convert_ast_to_C_sosl q env nb_tab;
```

```
            ]
    | Noeud (Syntax Else_if, condition ::
    ↪  instructions) :: q ->
        L
            [
              Traduction.tabs_to_string nb_tab;
              S "else if (";
              convert_ast_to_C_sosl [ condition ] env
              ↪  nb_tab;
              S "){";
              convert_ast_to_C_sosl instructions env
              ↪  (nb_tab + 1);
              Traduction.tabs_to_string nb_tab;
              S "}";
              convert_ast_to_C_sosl q env nb_tab;
            ]
    | Noeud (Syntax Else, instructions) :: q ->
```

```
            L
              [
                Traduction.tabs_to_string nb_tab;
                S "else {";
                convert_ast_to_C_sosl instructions env
                 ↪  (nb_tab + 1);
                Traduction.tabs_to_string nb_tab;
                S "}";
                convert_ast_to_C_sosl q env nb_tab;
              ]
      | Noeud
          ( Syntax For,
            Noeud (Operateur Assignation, [ variable;
             ↪  valeur ])
            :: fin
            :: Noeud (Syntax Step, [ pas ])
            :: instructions )
```

```
      :: q ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "for (";
            convert_ast_to_C_sosl
              [ Noeud (Operateur Assignation, [ variable; valeur ]) ]
              env 0;
            S " ";
            convert_ast_to_C_sosl
              [ Noeud (Comparateur StrictPlusPetit, [ variable; fin ]) ]
              env 0;
            S "; ";
            convert_ast_to_C_sosl [ variable ] env 0;
            S "=";
```

```
          convert_ast_to_C_sosl
            [ Noeud (Operateur Plus, [ variable;
            ↪  pas ]) ]
            env 0;
          S ") {";
          convert_ast_to_C_sosl instructions env
          ↪  (nb_tab + 1);
          Traduction.tabs_to_string nb_tab;
          S "}";
          convert_ast_to_C_sosl q env nb_tab;
        ]
  | Noeud (Syntax While, condition :: instructions)
  ↪  :: q ->
      L
        [
          Traduction.tabs_to_string nb_tab;
          S "while (";
```

```
        convert_ast_to_C_sosl [ condition ] env 0;
        S "){";
        convert_ast_to_C_sosl instructions env (nb_tab + 1);
        Traduction.tabs_to_string nb_tab;
        S "}";
        convert_ast_to_C_sosl q env nb_tab;
      ]
| Noeud (Integer s, []) :: q -> L [ S s; convert_ast_to_C_sosl q env nb_tab ]
| Noeud (Floating s, []) :: q -> L [ S s; convert_ast_to_C_sosl q env nb_tab ]
| Noeud (Double s, []) :: q ->
    let d =
      String.fold_left
```

```
          (fun acc x -> if x = 'd' then acc ^ "e" else acc ^ String.make 1 x)
          "" s
      in
      L [ S d; convert_ast_to_C_sosl q env nb_tab ]
      (* convertit les d en e de fortran *)
  | Noeud (Booleen b, []) :: q ->
      L
        [
          S (if b then "true" else "false"); convert_ast_to_C_sosl q env nb_tab;
        ]
  | Noeud (Chaine s, []) :: q -> L [ S s; convert_ast_to_C_sosl q env nb_tab ]
  | Noeud (Syntax Function, Noeud (Name n, []) :: l) :: q ->
```

```
        let sosl, l2 = get_function_param_list l env
        ↪  in
        L
          [
            tabs_to_string nb_tab;
            get_function_return_type
              (Noeud (Syntax Function, Noeud (Name n,
              ↪  []) :: l))
              env;
            S " ";
            S n;
            S "(";
            sosl;
            S "){\n";
            convert_ast_to_C_sosl l2 env (nb_tab +
            ↪  1);
            tabs_to_string nb_tab;
```

```
                S "}\n";
              ]
    | Noeud (Syntax Call, Noeud (Name n, []) :: l) ::
    ↪  q ->
        L
          [
            S n;
            S "(";
            convert_ast_to_C_sosl l env 0;
            S ")";
            convert_ast_to_C_sosl q env nb_tab;
          ]
    | Noeud (Syntax Return, l) :: q ->
        L
          [
            tabs_to_string nb_tab;
            S "return ";
```

```
          convert_ast_to_C_sosl l env 0;
          S ";\n";
          convert_ast_to_C_sosl q env nb_tab;
        ]

  | Noeud (NewLine, []) :: q -> L [ S "\n"; convert_ast_to_C_sosl q env nb_tab ]
  | Noeud (t, _) :: q ->
      print_token t;
      failwith "La syntaxe donnée n'est pas encore prise en charge\n"

(** convertit l'arbre de syntaxe abstrait [ast] et ajoute les librairies
    nécessaires depuis [biblios] grace à [env] *)
let convert_ast_to_C (ast : ast list) (env : environnement)
```

```
    (biblios : Bibliotheques.libs) : string =
  generate_library_imports biblios
  ^ Traduction.string_of_string_or_string_list
  ↪  (convert_ast_to_C_sosl ast env 0)


```

```
open Environnement
open Abstract_tokens
open Bibliotheques
open Convert_to_abstract
open LL1
open Traduction

let rec convert_ast_to_Fortran_sosl (ast : ast list) (env : environnement)
    (nb_tab : int) : string_or_string_list =
  match ast with
  | [] -> S ""
  | [ Noeud (ProgramRoot, l) ] -> convert_ast_to_Fortran_sosl l env nb_tab
  | Noeud (Syntax Program, Noeud (Name nom, []) :: l1) :: q ->
      L
```

```
            [
              S "program ";
              S nom;
              convert_ast_to_Fortran_sosl l1 env
              ↪  (nb_tab + 1);
              S "end program\n";
              convert_ast_to_Fortran_sosl q env nb_tab;
            ]
    | Noeud (Commentaire c, []) :: q ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "!";
            S c;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (Syntax Print, l2) :: q ->
```

```
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "print *";
            L
              (List.rev
                (List.fold_left
                  (fun acc x ->
                    convert_ast_to_Fortran_sosl [ x ] env nb_tab
                    :: S ", " :: acc)
                  [] l2));
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    (* définit le type des variables *)
    | Noeud (Syntax Real, l) :: q ->
        let s = convert_ast_to_Fortran_sosl l env 0 in
```

```
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "real ::";
            s;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (Syntax Integer, l) :: q ->
        let s = convert_ast_to_Fortran_sosl l env 0
          ↪ in
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "integer ::";
            s;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
```

```
    | Noeud (Syntax Logical, l) :: q ->
        let s = convert_ast_to_Fortran_sosl l env 0
         ↪  in
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "logical ::";
            s;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (Syntax Double_precision, l) :: q ->
        let s = convert_ast_to_Fortran_sosl l env 0
         ↪  in
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "double precision ::";
```

```
                s;
                convert_ast_to_Fortran_sosl q env nb_tab;
            ]
  | Noeud (Operateur Assignation, Noeud (Name s, []) :: l) :: q ->
      L
        [
          Traduction.tabs_to_string nb_tab;
          S s;
          S " = ";
          convert_ast_to_Fortran_sosl l env 0;
          convert_ast_to_Fortran_sosl q env nb_tab;
        ]
  | Noeud (Name s, []) :: q ->
      L [ S s; convert_ast_to_Fortran_sosl q env nb_tab ]
  | Noeud (Operateur Plus, elem :: l) :: q ->
```

```
    L
      [
        convert_ast_to_Fortran_sosl [ elem ] env nb_tab;
        S " + ";
        convert_ast_to_Fortran_sosl l env nb_tab;
        convert_ast_to_Fortran_sosl q env nb_tab;
      ]
| Noeud (Operateur Moins, elem :: l) :: q ->
    L
      [
        convert_ast_to_Fortran_sosl [ elem ] env nb_tab;
        S " - ";
        convert_ast_to_Fortran_sosl l env nb_tab;
        convert_ast_to_Fortran_sosl q env nb_tab;
      ]
```

```
  | Noeud (Operateur Fois, elem :: l) :: q ->
    L
      [
        convert_ast_to_Fortran_sosl [ elem ] env
        ↪  nb_tab;
        S " * ";
        convert_ast_to_Fortran_sosl l env nb_tab;
        convert_ast_to_Fortran_sosl q env nb_tab;
      ]
  | Noeud (Operateur Division, elem :: l) :: q ->
    L
      [
        convert_ast_to_Fortran_sosl [ elem ] env
        ↪  nb_tab;
        S " / ";
        convert_ast_to_Fortran_sosl l env nb_tab;
        convert_ast_to_Fortran_sosl q env nb_tab;
```

```
        ]
    | Noeud (Parentheseouvrante, []) :: q ->
      L [ S "("; convert_ast_to_Fortran_sosl q env nb_tab ]
    | Noeud (Parenthesefermante, []) :: q ->
      L [ S ")"; convert_ast_to_Fortran_sosl q env nb_tab ]
    | Noeud (OperateurLogique NonEquivalent, [ p1; p2 ]) :: q ->
      L
        [
          convert_ast_to_Fortran_sosl [ p1 ] env 0;
          S " .neqv. ";
          convert_ast_to_Fortran_sosl [ p2 ] env 0;
          convert_ast_to_Fortran_sosl q env nb_tab;
        ]
    | Noeud (Comparateur NonEgal, [ p1; p2 ]) :: q ->
```

```
        L
          [
            convert_ast_to_Fortran_sosl [ p1 ] env 0;
            S " /= ";
            convert_ast_to_Fortran_sosl [ p2 ] env 0;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (OperateurLogique Equivalent, [ p1; p2 ])
    ↪   :: q ->
        L
          [
            convert_ast_to_Fortran_sosl [ p1 ] env 0;
            S " .eqv. ";
            convert_ast_to_Fortran_sosl [ p2 ] env 0;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (Comparateur Egal, [ p1; p2 ]) :: q ->
```

```
        L
          [
            convert_ast_to_Fortran_sosl [ p1 ] env 0;
            S " == ";
            convert_ast_to_Fortran_sosl [ p2 ] env 0;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (Comparateur StrictPlusPetit, [ p1; p2 ]) :: q ->
        L
          [
            convert_ast_to_Fortran_sosl [ p1 ] env 0;
            S " < ";
            convert_ast_to_Fortran_sosl [ p2 ] env 0;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (Comparateur PlusPetit, [ p1; p2 ]) :: q ->
```

```
      L
        [
          convert_ast_to_Fortran_sosl [ p1 ] env 0;
          S " <= ";
          convert_ast_to_Fortran_sosl [ p2 ] env 0;
          convert_ast_to_Fortran_sosl q env nb_tab;
        ]
  | Noeud (Comparateur StrictPlusGrand, [ p1; p2 ])
  ↪  :: q ->
      L
        [
          convert_ast_to_Fortran_sosl [ p1 ] env 0;
          S " > ";
          convert_ast_to_Fortran_sosl [ p2 ] env 0;
          convert_ast_to_Fortran_sosl q env nb_tab;
        ]
  | Noeud (Comparateur PlusGrand, [ p1; p2 ]) :: q
  ↪  ->
```

```
        L
          [
            convert_ast_to_Fortran_sosl [ p1 ] env 0;
            S " >= ";
            convert_ast_to_Fortran_sosl [ p2 ] env 0;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (OperateurLogique Et, [ p1; p2 ]) :: q ->
        L
          [
            convert_ast_to_Fortran_sosl [ p1 ] env 0;
            S " && ";
            convert_ast_to_Fortran_sosl [ p2 ] env 0;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (OperateurLogique Ou, [ p1; p2 ]) :: q ->
        L
```

```
            [
              convert_ast_to_Fortran_sosl [ p1 ] env 0;
              S " || ";
              convert_ast_to_Fortran_sosl [ p2 ] env 0;
              convert_ast_to_Fortran_sosl q env nb_tab;
            ]
    | Noeud (OperateurLogique Non, [ p1; p2 ]) :: q
    ↪   ->
          L
            [
              convert_ast_to_Fortran_sosl [ p1 ] env 0;
              S " ! ";
              convert_ast_to_Fortran_sosl [ p2 ] env 0;
              convert_ast_to_Fortran_sosl q env nb_tab;
            ]
    | Noeud (Operateur Puissance, [ p1; p2 ]) :: q ->
          L
```

```
          [
            convert_ast_to_Fortran_sosl [ p1 ] env 0;
            S "**";
            convert_ast_to_Fortran_sosl [ p2 ] env 0;
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (Syntax If, condition :: instructions)
      :: Noeud (Syntax Else_if, l)
      :: q ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "if (";
            convert_ast_to_Fortran_sosl [ condition ] env nb_tab;
            S ") do";
            convert_ast_to_Fortran_sosl instructions env (nb_tab + 1);
```

```
                Traduction.tabs_to_string nb_tab;
                convert_ast_to_Fortran_sosl
                  (Noeud (Syntax Else_if, l) :: q)
                  env nb_tab;
            ]
    | Noeud (Syntax If, condition :: instructions) ::
    ↪  Noeud (Syntax Else, l) :: q
      ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "if (";
            convert_ast_to_Fortran_sosl [ condition ]
            ↪  env nb_tab;
            S ") do";
            convert_ast_to_Fortran_sosl instructions
            ↪  env (nb_tab + 1);
```

```
        Traduction.tabs_to_string nb_tab;
        convert_ast_to_Fortran_sosl (Noeud (Syntax Else, l) :: q) env nb_tab;
      ]
| Noeud (Syntax If, condition :: instructions) :: q ->
    L
      [
        Traduction.tabs_to_string nb_tab;
        S "if (";
        convert_ast_to_Fortran_sosl [ condition ] env nb_tab;
        S ") do";
        convert_ast_to_Fortran_sosl instructions env (nb_tab + 1);
        Traduction.tabs_to_string nb_tab;
        S "end if";
```

```
              convert_ast_to_Fortran_sosl q env nb_tab;
            ]
    | Noeud (Syntax Else_if, condition :: instructions)
      :: Noeud (Syntax Else, l)
      :: q ->
        L
          [
              Traduction.tabs_to_string nb_tab;
              S "else if (";
              convert_ast_to_Fortran_sosl [ condition ] env nb_tab;
              S ")";
              convert_ast_to_Fortran_sosl instructions env (nb_tab + 1);
              Traduction.tabs_to_string nb_tab;
```

```
            convert_ast_to_Fortran_sosl (Noeud
             ↪  (Syntax Else, l) :: q) env nb_tab;
          ]
   | Noeud (Syntax Else_if, condition ::
   ↪  instructions)
     :: Noeud (Syntax Else_if, l)
     :: q ->
       L
         [
            Traduction.tabs_to_string nb_tab;
            S "else if (";
            convert_ast_to_Fortran_sosl [ condition ]
             ↪  env nb_tab;
            S ")";
            convert_ast_to_Fortran_sosl instructions
             ↪  env (nb_tab + 1);
            Traduction.tabs_to_string nb_tab;
```

```
        convert_ast_to_Fortran_sosl
          (Noeud (Syntax Else_if, l) :: q)
          env nb_tab;
      ]
| Noeud (Syntax Else_if, condition :: instructions) :: q ->
    L
      [
        Traduction.tabs_to_string nb_tab;
        S "else if (";
        convert_ast_to_Fortran_sosl [ condition ] env nb_tab;
        S ")";
        convert_ast_to_Fortran_sosl instructions env (nb_tab + 1);
        Traduction.tabs_to_string nb_tab;
        S "end if";
```

```
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
  | Noeud (Syntax Else, instructions) :: q ->
      L
        [
            Traduction.tabs_to_string nb_tab;
            S "else ";
            convert_ast_to_Fortran_sosl instructions
            ↪  env (nb_tab + 1);
            Traduction.tabs_to_string nb_tab;
            S "end if";
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
  | Noeud
      ( Syntax For,
        Noeud (Operateur Assignation, [ variable;
        ↪  valeur ])
```

```
          :: fin
          :: Noeud (Syntax Step, [ pas ])
          :: instructions )
      :: q ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "do ";
            convert_ast_to_Fortran_sosl
              [ Noeud (Operateur Assignation, [ variable; valeur ]) ]
              env 0;
            S ", ";
            convert_ast_to_Fortran_sosl [ fin ] env 0;
            S ", ";
            convert_ast_to_Fortran_sosl [ pas ] env 0;
```

```
            S "\n";
            convert_ast_to_Fortran_sosl instructions env (nb_tab + 1);
            Traduction.tabs_to_string nb_tab;
            S "end do";
            convert_ast_to_Fortran_sosl q env nb_tab;
          ]
    | Noeud (Syntax While, condition :: instructions) :: q ->
        L
          [
            Traduction.tabs_to_string nb_tab;
            S "do while (";
            convert_ast_to_Fortran_sosl [ condition ] env 0;
            S ")";
```

```
          convert_ast_to_Fortran_sosl instructions env (nb_tab + 1);
          Traduction.tabs_to_string nb_tab;
          S "end do";
          convert_ast_to_Fortran_sosl q env nb_tab;
        ]
  | Noeud (Integer s, []) :: q ->
      L [ S s; convert_ast_to_Fortran_sosl q env nb_tab ]
  | Noeud (Floating s, []) :: q ->
      L [ S s; convert_ast_to_Fortran_sosl q env nb_tab ]
  | Noeud (Double s, []) :: q ->
      L [ S s; convert_ast_to_Fortran_sosl q env nb_tab ]
      (* convertit les d en e de fortran *)
  | Noeud (Booleen b, []) :: q ->
```

```
      L
        [
          S (if b then "true" else "false");
          convert_ast_to_Fortran_sosl q env nb_tab;
        ]
  | Noeud (Chaine s, []) :: q ->
      L [ S s; convert_ast_to_Fortran_sosl q env nb_tab ]
  | Noeud (NewLine, []) :: q ->
      L [ S "\n"; convert_ast_to_Fortran_sosl q env nb_tab ]
  | _ -> failwith "La syntaxe donnée n'est pas encore prise en charge\n"

let convert_ast_to_Fortran (ast : ast list) (env : environnement) : string =
  Traduction.string_of_string_or_string_list
```

```
    (convert_ast_to_Fortran_sosl ast env 0)
```

```ocaml
open TraductionFortran
open TraductionC
open Det_automaton
open LL1
open Convert_to_abstract
open Environnement
open Automates
open Grammar

let transpile_Fortran_to_C (fortran_file_name :
↪  string) (c_file_name : string) :
    unit =
  let lexemes = exec_of_file syntax_automate_det
  ↪  fortran_file_name in
  let arbre_syntaxique = analyse_LL1 grammar
  ↪  lexemes in
  let arbre_syntaxique_abstrait =
  ↪  convert_to_abstract arbre_syntaxique in
```

```
  let env = create_env_from_ast
   ↪  arbre_syntaxique_abstrait in
  (* print_env env;  *)
  let code_C =
    convert_ast_to_C
      [ arbre_syntaxique_abstrait ]
      (env)
      []
  in
  let out_file = open_out c_file_name in
  output_string out_file code_C;
  close_out out_file

let transpile_Fortran_to_Fortran (fortran_file_name
 ↪   : string)
    (c_file_name : string) : unit =
  let lexemes = exec_of_file syntax_automate_det
   ↪  fortran_file_name in
```

```
  let arbre_syntaxique = analyse_LL1 grammar lexemes in
  let arbre_syntaxique_abstrait = convert_to_abstract arbre_syntaxique in
  let env = create_env_from_ast arbre_syntaxique_abstrait in

  let code_Fortran =
    convert_ast_to_Fortran
      [ arbre_syntaxique_abstrait ]
      (env)
  in
  let out_file = open_out c_file_name in
  output_string out_file code_Fortran;
  close_out out_file
```

```
open Transpileurs

let print_usage () =
  print_string "Usage : ";
  print_newline ();
  print_string Sys.argv.(0);
  print_string " -C <inupt_fortran_file> [-o <output_c_file>]";
  print_newline ();
  print_string Sys.argv.(0);
  print_string " -Fortran <inupt_fortran_file> [-o <output_fortran_file>]";
  print_newline ()

let output_file (len : int) : string =
  if len == 5 then
    if
```

```
      (* un nom de fichier de sortie est donné *)
      Sys.argv.(3) = "-o"
    then Sys.argv.(4)
    else (
      print_usage ();
      raise (Invalid_argument ""))
  else
    (* un nom de fichier de sortie n'est pas donné, on en donne un par défaut *)
    match Sys.argv.(1) with
    | "-Fortran" -> "out.f90"
    | "-C" -> "out.c"
    | _ ->
        print_usage ();
        raise (Invalid_argument "")

let main () =
```

```
  let len = Array.length Sys.argv in
  if len <> 3 && len <> 5 then print_usage ()
  else
    let input_file_name = Sys.argv.(2) in
    let output_file_name = output_file len in
    print_string ("Generating " ^ output_file_name ^ "...");
    print_newline ();
    if Sys.argv.(1) = "-C" then
      transpile_Fortran_to_C input_file_name output_file_name
    else transpile_Fortran_to_Fortran input_file_name output_file_name;
    print_string ("Finished generating " ^ output_file_name);
    print_newline ()

```

```
let _ = main ()
```