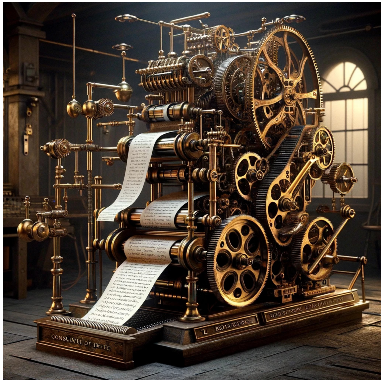
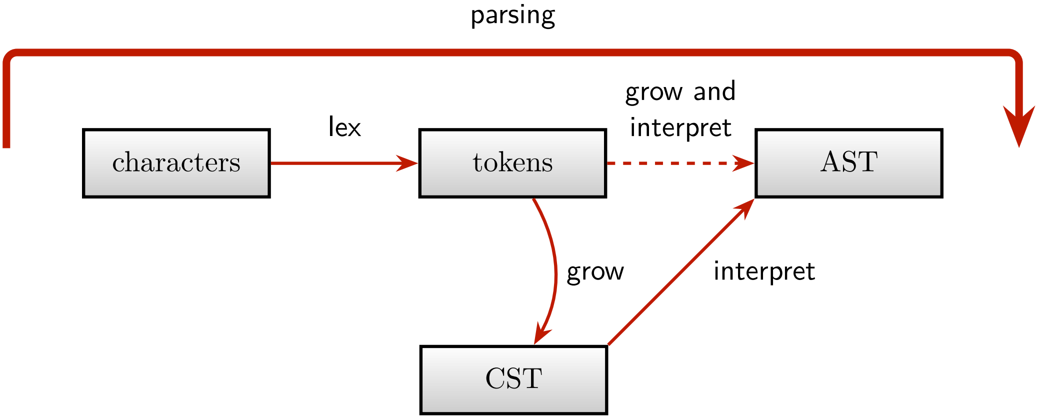


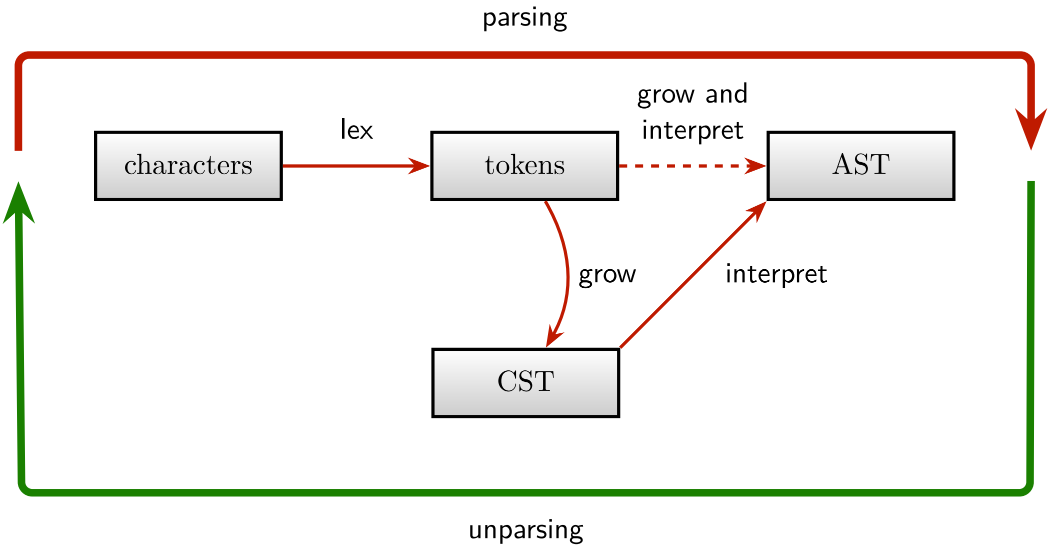
# Correct, Fast LR(1) Unparsing


François Pottier



JFLA 2024


parsing
lex
grow and interpret
characters
tokens
AST
grow
interpret
CST


parsing
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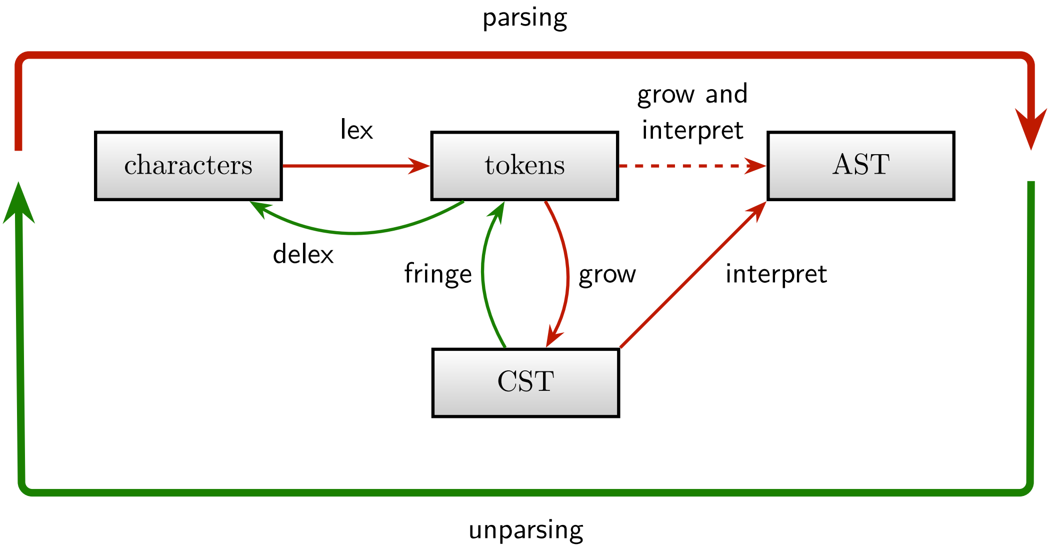
unparsing


parsing
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grow
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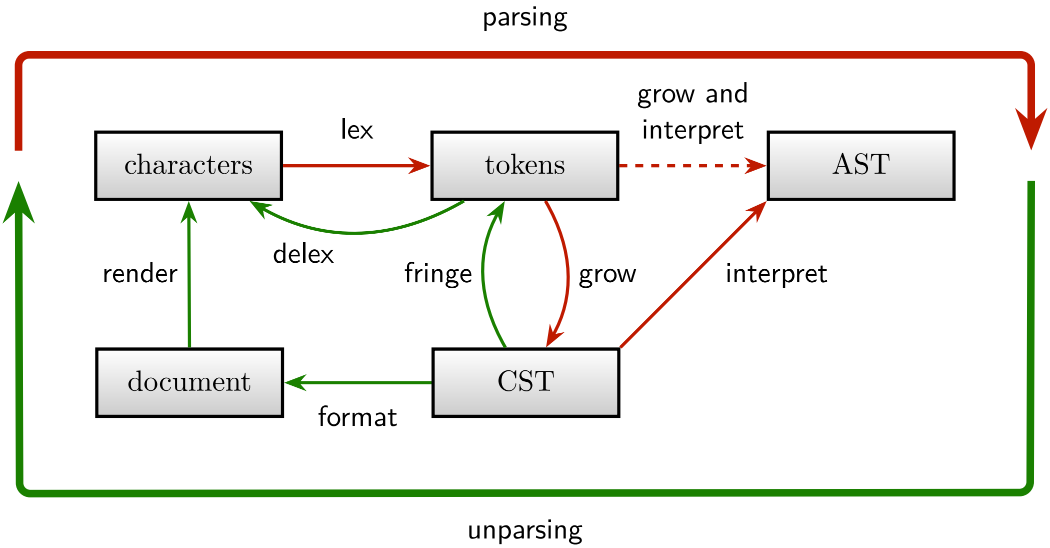
CST
unparsing


parsing
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grow
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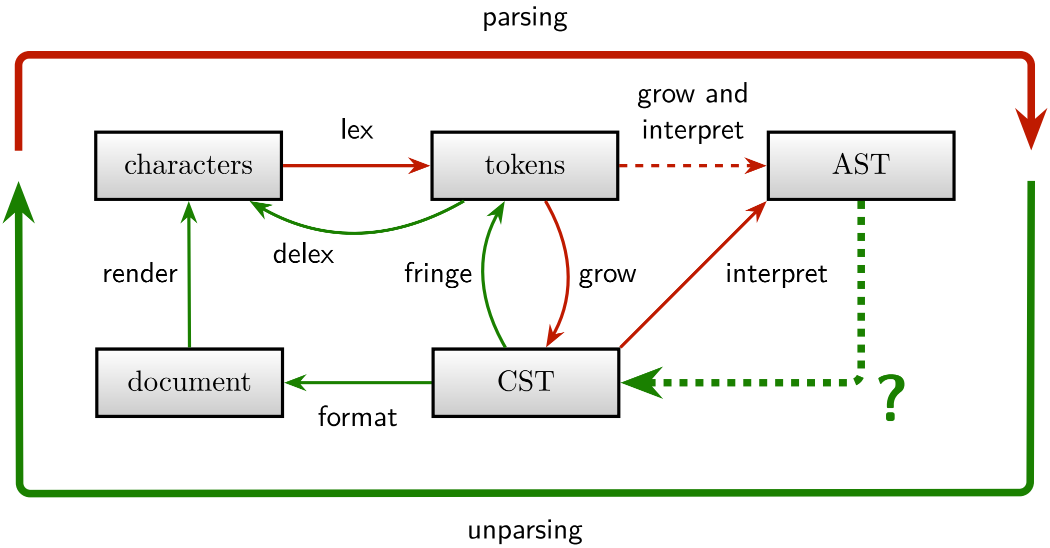
document
CST
format
unparsing


parsing
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Can we **automatically generate** a translation of ASTs to CSTs?

## From ASTs Back to CSTs

Can we **automatically generate** a translation of ASTs to CSTs?

- **No!** Semantic actions are arbitrary OCaml code, so cannot (in general) be inverted.

Can we **let the user** write a translation of ASTs to CSTs?

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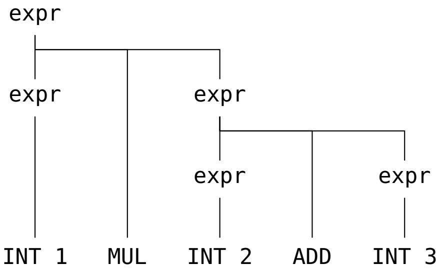
- **No!** Semantic actions are arbitrary OCaml code, so cannot (in general) be inverted.

Can we **let the user** write a translation of ASTs to CSTs?

- **No!** Some CSTs are **not viable** and must be avoided.

# Not All CSTs Are Viable

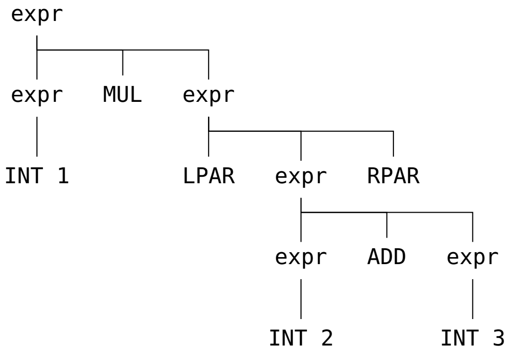



This CST is **not viable**: it does not satisfy $\mathit{grow}(\mathit{fringe}(c)) = c$.

In other words, parsing `1*2+3` does not produce this tree.

In other words, the parser cannot construct this tree.

One should **never** attempt to print this tree!




Here is a **viable** CST whose fringe is `1*(2+3)`.

It represents **the same AST** as the previous non-viable tree.

This is the CST that we wish to print! **Parentheses** are necessary in this example.

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Can we **let the user** write a translation of ASTs to CSTs?

- No. Guaranteeing that a viable tree is obtained
  can be **difficult** and **error-prone**.
  Maintaining this guarantee as the parser evolves
  seems difficult as well.

## From ASTs Back to CSTs

To escape this conundrum, we propose to **split** this step:

- **let the user** translate an AST to (a description of) a **set** of possible CSTs;
- **generate and/or provide** an algorithm that selects a viable CST among this set.

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Thus,

- the user deals with the problem of **inverting the semantic actions**;
- the user indicates **where parentheses may be inserted**;
- the tool decides **where to actually insert parentheses**.

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Thus,

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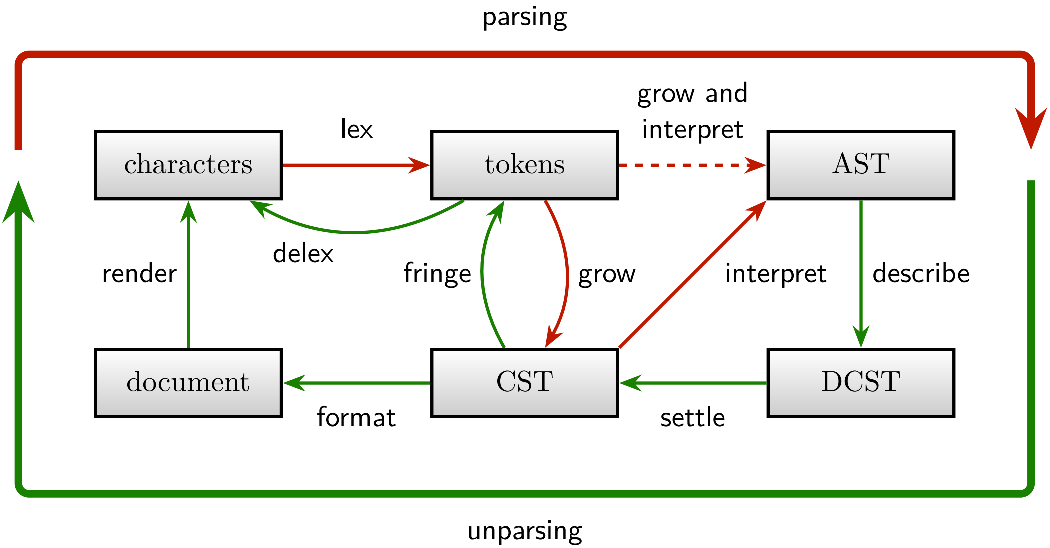
A DCST resembles a CST but can contain binary **disjunction** nodes. It is usually a **DAG**.

# The Big Picture



Menhir can now:

- generate **abstract types of DCSTs**
  and **a DCST construction API**
  so the user can translate ASTs to DCSTs.
- generate **abstract types of CSTs**
  and **a CST deconstruction API**
  so the user can translate CSTs to documents or strings.
- provide a **translation of DCSTs to CSTs**
  whose correctness is guaranteed,
  even if the grammar has conflicts and uses `%left`, `%right`, `%nonassoc`, `%prec`.

Only **viable CSTs** can ever be constructed.

**Two** DCST-to-CST translations have been implemented:

- one is fast but **incomplete**: in certain (unlikely?) situations, it can fail to find a viable CST even though there exists one.
- the other is complete but can be 15x **slower**, due to memoization.

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This new facility has **no known users** yet...

# How Unparsing Is Used, and How It Works

Here are **abstract syntax trees** for arithmetic expressions:

```
type binop = BAdd | BMul          (* Binary operators *)
type expr =                       (* Expressions *)
  | EConst of int
  | EBinOp of expr * binop * expr
type main = expr
```

AST.ml

As usual, the tokens are defined first:

```
%token<int> INT                  (* Tokens *)
%token      ADD  "+"
%token      MUL  "*"
%token      LPAR "("
%token      RPAR ")"
%token      EOL
```

parser.mly

Then, **precedence declarations** are provided:

```
%left       ADD                    (* Priority levels: weakest to strongest *)
%left       MUL
```

parser.mly

Then, an **unstratified** syntax of expressions is given:

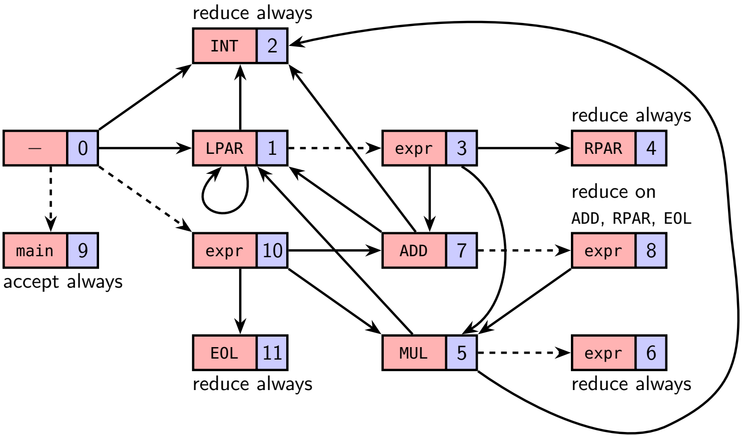
```
%inline op:
| ADD                              { BAdd }                [@name add]
| MUL                              { BMul }                [@name mul]

expr:
| LPAR; e = expr; RPAR             { e }                   [@name paren]
| i = INT                          { EConst i }            [@name const]
| e1 = expr; op = op; e2 = expr { EBinOp (e1, op, e2) }

main:
| e = expr; EOL                    { e }                   [@name eol]
```

parser.mly

The `[@name]` attributes influence the generated CST and DCST APIs.




A shift/reduce conflict on `MUL` in state 8 is resolved in favor of shifting.

A shift/reduce conflict on `ADD` in state 6 is resolved in favor of reduction.

The generated parser contains this submodule:

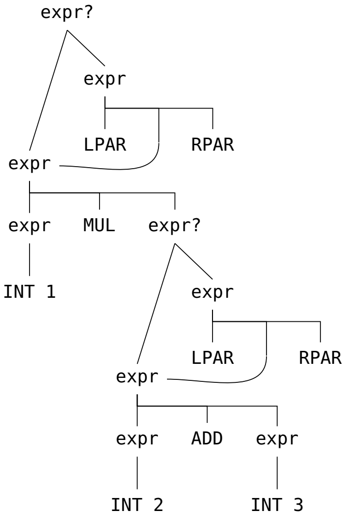
```
module DCST : sig
  type expr
  type main
  val expr_choice: expr -> expr -> expr        (* Constructors for [expr] *)
  val paren: expr -> expr
  val const: (int) -> expr
  val add: expr -> expr -> expr
  val mul: expr -> expr -> expr
  val main_choice: main -> main -> main        (* Constructors for [main] *)
  val eol: expr -> main
end                                                                parser.mli
```

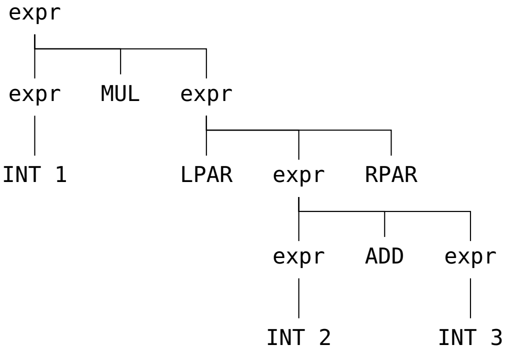
The user exploits the DCST construction API as follows:

```
let possibly_paren (e : DCST.expr) : DCST.expr =
  DCST.expr_choice e (DCST.paren e)            (* [e] is shared: a DAG is built *)

let rec expr (e : AST.expr) : DCST.expr =
  possibly_paren @@                  (* at every node, parentheses may be inserted *)
  match e with
  | EConst i             -> DCST.const i
  | EBinOp (e1, BAdd, e2) -> DCST.add (expr e1) (expr e2)
  | EBinOp (e1, BMul, e2) -> DCST.mul (expr e1) (expr e2)

and main       : AST.main -> DCST.main = function
  | e                    -> DCST.eol (expr e)                          AST2DCST.ml
```


expr?
expr
LPAR
RPAR
expr
expr
MUL
expr?
INT 1
expr
LPAR
RPAR
expr
expr
ADD
expr
INT 2
INT 3


expr
expr
MUL
expr
INT 1
LPAR
expr
RPAR
expr
ADD
expr
INT 2
INT 3

The generated parser contains this submodule:

```
module Settle : sig
  val main: DCST.main -> CST.main option
end
```

parser.mli

## DCST to CST Conversion: Key Insights

Suppose you have access to the parse tables.

To **check** that a CST is viable, **run the parser** on its fringe.
Verify that the parser succeeds and produces this tree.

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At disjunction nodes, choose a viable child:

- by trying both children and **backtracking** (complete; **exponentially slow**), or
- by trying both children and **memoizing** shared subgoals (complete; **slow**), or
- by **committing** to the first child if it seems **apparently viable** (**incomplete**; fast).

The generated parser contains this submodule:

```
module CST : sig
  type expr
  type main
  class virtual ['r] reduce : object
    method virtual zero : 'r             (* Document construction methods *)
    method virtual cat : 'r -> 'r -> 'r
    method virtual text : string -> 'r
    method visit_expr : expr -> 'r       (* Visitor methods *)
    method case_paren : expr -> 'r
    method case_add : expr -> expr -> 'r
    method case_mul : expr -> expr -> 'r
      (* ... more visitor methods and case methods ... *)
  end
end                                                                        parser.mli
```

The user instantiates (just) the virtual methods:

```
class print = object
  inherit [string] CST.reduce
  method zero = ""
  method cat = (^)
  method text s = s
  method visit_INT i = Printf.sprintf "%d" i
  method visit_EOL = "\n"
end

let main (m : CST.main) : string =
  (new print)#visit_main m
```

CST2String.ml

This code makes no decisions regarding parenthesization. It is **just a printer**.

This kind of output is produced:

```
65*((22+38)*69+(24+58))+(84*70+(20+63*83*97+49*(70+0))*(93+89)*(12*15+85+21))
```

The user instantiates the virtual methods and overrides a few other methods:

```
open PPrint
class print = object (self)
  inherit [document] CST.reduce as super
  method! visit_ADD = space ^^ plus ^^ break 1
  method! visit_MUL = space ^^ star ^^ break 1
  method! visit_expr e = group (super#visit_expr e)
  method! case_paren e = nest 2 (lparen ^^ self#visit_expr e) ^^ rparen
    (* ... a few more methods ... *)
end

let main (m : CST.main) : document =
  (new print)#visit_main m
```

CST2Document.ml

Again, this code makes no decisions regarding parenthesization.

This kind of output is produced:

```
65 *
( (22 + 38) * 69 +
  (24 + 58)
) +
( 84 * 70 +
  ( 20 +
    63 * 83 * 97 +
    49 * (70 + 0)
  ) *
  (93 + 89) *
  ( 12 * 15 + 85 +
    21
  )
)
```

À **vous** de jouer!