编程语言的设计原理

Design Principles of Programming Languages

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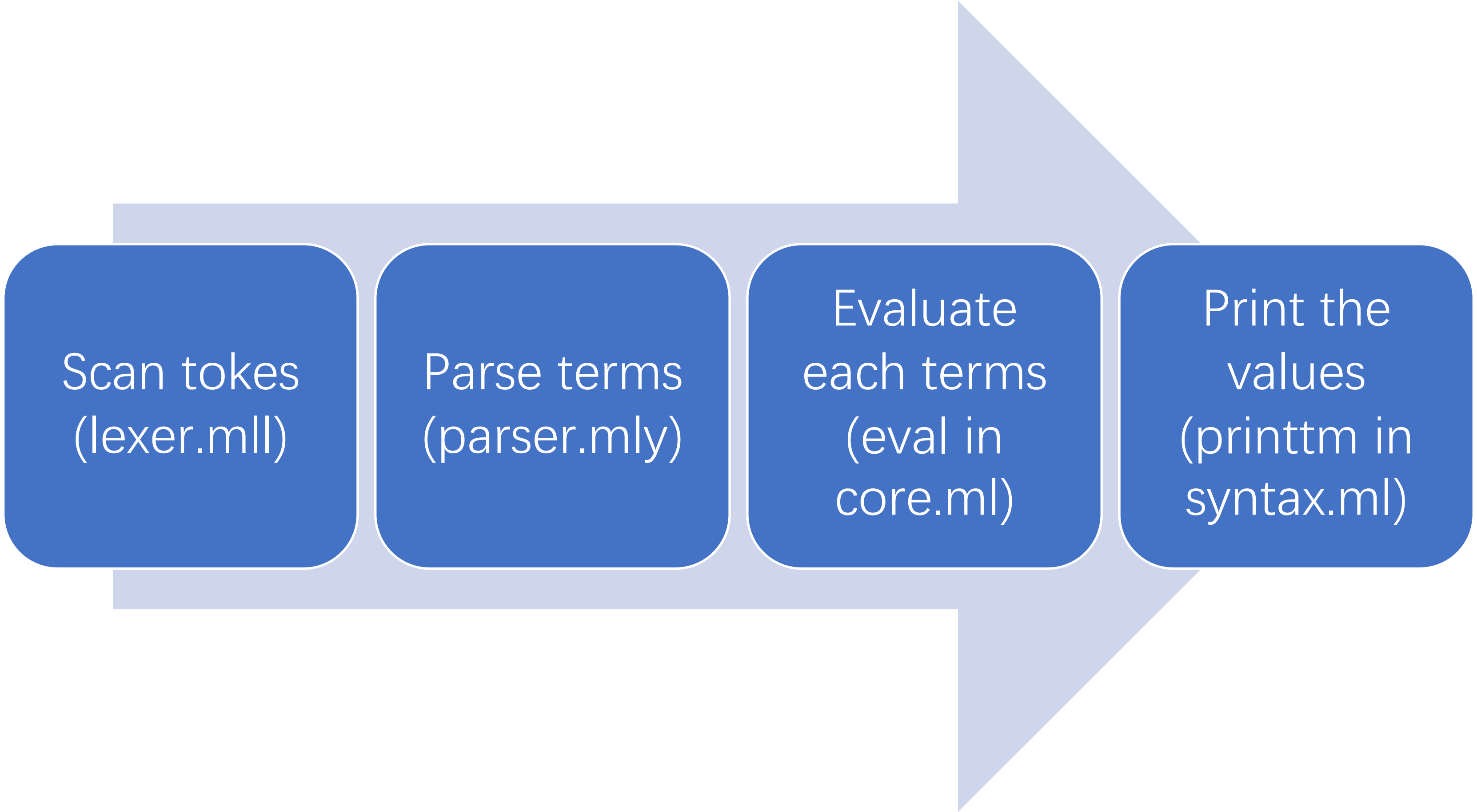
Practice in Class

arith, fullsimple, fullref

Structure of package

main.ml drives the whole process



Structure of package

syntax. ml defines the terms

```
type term =
    TmTrue of info
  | TmFalse of info
  | TmIf of info * term * term * term
  | TmZero of info
  | TmSucc of info * term
  | TmPred of info * term
  | TmIsZero of info * term
```

Info:

a data type recording *the position* of the term in the source file

Structure of package

```
let rec isnumericval t = match t with
    TmZero(_) → true
    | TmSucc(_,t1) → isnumericval t1
    | _ → false
```

Structure of package

- eval in core.ml

```
let rec eval t =
  try let t' = eval1 t
      in eval t'
  with NoRuleApplies → t
```

- eval1: perform a single step reduction

Some abbreviations

- UCID = upper case identifier
- LCID = lower case identifier
- ty = type
- tm = term
- LCURLY = “{“
- RCURLY = “}”
- USCORE = “_”

Commands

- Each line of the source file is parsed *as a command*
  - type command = | Eval of info * term
  - New commands will be added later

- Main routine for each file

```
let process_file f =
    alreadyImported := f :: !alreadyImported;
    let cmds = parseFile f in
    let g c =
        open_hvbox 0;
        let results = process_command c in
      print_flush();
      results
in
  List.iter g cmds
```

Homework for 3/9

- Please get familiar with OCaml and its utilities
- Please download the implementation package of the TAPL, and digest the source codes in archives of *arith*, *tyarith*, *untype*.
- Please give your implementation for Chap. 4
  – Submit your code as a compressed file with one of the above names
  – Your submission should contain file test.f that contains exactly the expressions to be tested
  – TA will perform the following two commands to verify your submission:
    - make
    - ./f test.f

Exercise arith.simple_use

- Using arith to write the following equation
  - Return five if two is not zero, otherwise return nine
  - Hint: read the code in *parser.mly*

Exercise arith.size

- Make the *evaluation* computes *the size of a term* (3.3.2) instead of reducing the term, and test it on the original test.f
  - Hint:
    - pr: string->unit   prints a string to the screen
    - string_of_int : int->string   converts an integer into a string
    - Remember to change both .ml and .mli files

Big-step vs small-step

- Big-step is usually easier to understand
  - called “natural semantics” in some articles
- Big-step often leads to *simpler proof*
- Big-step cannot describe computations that *do not produce a value*
  - Non-terminating computation
  - “Stuck” computation

Exercise arith.big-step

- Change the evaluation to use *big-step semantics*, and compute the following expressions:
  - true;
  - if false then true else false;
  - if 0 then 1 else 2;
  - if true then (succ false) else 2;
  - 0;
  - succ (pred 0);
  - iszero (pred (succ (succ 0)));

fullsimple

- Implementing all extensions in Chapter 11
- Allow different types of command:
  - Evaluation: type-checking and reducing a term
  - Bindings
    - Variable binding: a:Int;
    - Type variable binding: T;
    - Term abbreviation binding: t = succ 0;
    - Type abbreviation binding: T = Nat -> Nat;
- Types can be used without declaration (uninterpreted types)

```
x:X
(lambda a:X. a) x
```

Review: nameless representation

- What is the nameless representation of the following term?

$$\lambda x.\ x\ (\lambda y.\ x\ y)$$

$$\lambda.\ 0\ (\lambda.\ 1\ 0)$$

Fullsimple, terms

```
type term =
    TmVar of info * int * int
    | TmAbs of info * string * ty * term
    | TmApp of info * term * term
    | …
```

- Using *nameless representation of terms*
- The *second int* for TmVar is used for debugging
  - = the number of items in the context
- The "*string*" in TmAbs is used for printing

Example: printing terms

```
and printtm_ATerm outer ctx t = match t with
    | TmVar(fi, x, n) ->
        if ctxlength ctx = n then
            pr (index2name fi ctx x)
        else
            pr ("[bad index: " ^ …
   | TmAbs(fi, x, tyT1, t2) ->
        (let (ctx',x') = (pickfreshname ctx x) in
            obox(); pr "lambda ";
             pr x'; pr ":"; printty_Type false ctx tyT1; pr "."; …
             printtm_Term outer ctx' t2; …
```

Review: context

- What contexts are used in our course?
  – Mapping names to integers in nameless representation
  – Σ: mapping variables to types
- Can be combined into one
- New contexts in the implementation
  – Type variable binding: marking type variables
  – Term abbreviation binding: Mapping variables to terms (and their types)
  – Type abbreviation binding: Mapping type variables to terms

```
type binding =
    NameBind
  | TyVarBind
  | VarBind of ty
  | TmAbbBind of term * (ty option) |
  TyAbbBind of ty

  type context = (string * binding) list
```

Auxiliary functions for nameless representation

- name2index

  info->context ->string->int

  return the index of a name

- index2name

  info->context ->int->string

  inverse of the above

- pickfreshname

  context->string ->(context, string)

  generate a fresh name using the second parameter as hint

```
type binding =
    ~~NameBind~~
    | TyVarBind
    | VarBind of ty
    | TmAbbBind of term * (ty option) |
    TyAbbBind of ty

    type context = (string * binding) list
```

Exercise fullsimple.nameless

- Construct a term *t* that is evaluated a term *t'* in fullsimple, where *t'* is different from *t* via only alpha-renaming (i.e., no beta-reduction)

Exercise fullsimple.match

- Add pattern matching for *tuples*, and test on the following expressions
  - let {x, y, z} = {true, 1, {2}} in z;
  - let {x, y, z} = {true, 1, {2}} in (lambda x:Nat. x) y;
  - let {x, y, z} = let x = 1 in {true, x, {2}} in z;
  - lambda x:Nat. let {x, y} = {true, 1} in x;
  - let x = 0 in let {y, z} = {1, 2} in x;
  - let {y, z} = {1, 2} in let y = 3 in y;
- Part of the code is already provided to you in the following two pages

Partial code for fullsimple.match

- Adding the following line to “type term =”   in syntax.ml
  - | TmPLet of info * string list * term * term
- Adding the following lines after line 235 in parser.mly
  - | LET Pattern EQ Term IN Term

    { fun ctx -> TmPLet($1, $2, $4 ctx, $6 (List.fold_left (fun x y -> addname x y) ctx $2)) }
  - Pattern :

    LCURLY MetaVars RCURLY

    { $2 }

    | LCURLY RCURLY

    { [] }
- Add the following line to tminfo in syntax.ml
  - | TmPLet(fi,_,_,_) -> fi

Partial code for fullsimple.match

- Adding the following lines to “printtm_Term” in syntax.ml

```
| TmPLet(fi, xs, t1, t2) ->
obox0();
 pr "let {";
 let rec print xs =
 match xs with
      x::x'::rest -> pr x; pr ","; print (x'::rest);
      | x::[] -> pr x;
      | [] -> pr ""; in
 print xs;
 pr "} = ";
 printtm_Term false ctx t1;
 print_space(); pr "in"; print_space();
 let ctx' = List.fold_left (fun ctx x -> addname ctx x) ctx xs in
 printtm_Term false ctx' t2;
 cbox()
```