Design Principles of Programming Languages

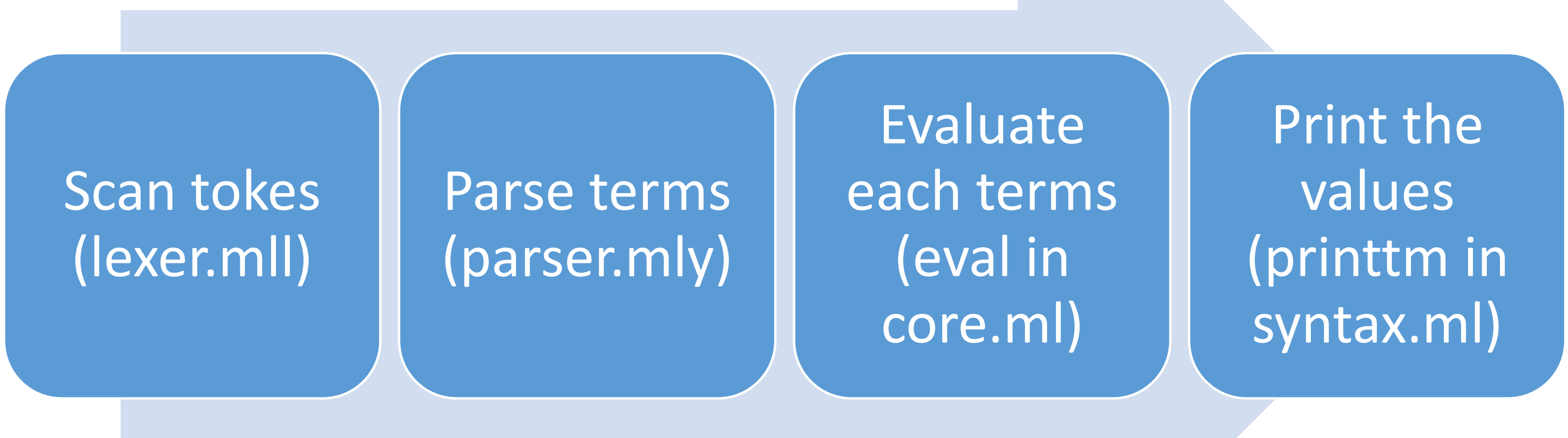
Practice

arith, fullsimple, fullref

Zhenjiang Hu, Haiyan Zhao, Yingfei Xiong
Peking University, Spring Term

Structure of arith

Main.ml drives the whole process.



Syntax.ml defines the terms.

Syntax.ml

```
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

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

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
```

Exercise arith.simple_use

- Using arith to write the following equation
  - Return five if two is 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

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

Exercise arith.big-step

- Change the evaluation to use big-step semantics, and compare the results with small-step semantics on 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)));
- What does the comparison reveal?

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

fullsimple

- Implement 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
- All can be combined into one

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

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

Only used in printing as a placeholder

Queried by index

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 for fullsimple.rec_fix

- Define plus using fix and test the following expressions
  - plus 10 105;
  - plus 0 1;
  - plus 0 0;
  - plus 2 0;

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.natlist

- Try the following term in fullsimple and explain why it cannot be typed

  NatList = <nil:Unit, cons:{Nat,NatList}>;

  nil = <nil=unit> as NatList;

  cons = lambda n:Nat. lambda l:NatList. <cons={n,l}> as NatList;

Exercise fullref.rec_no_fix

- Write plus without using fix or letrec in fullref

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()
```

Homework

- Please use the associated code to finish the exercises
- If an exercise asks for a program in the defined language, submit the program.
- If an exercise asks for modifying the interpreter
  - Submit all code
  - Your submission should contain file test.f which contains the expressions required by the exercise
  - TA will perform the following two commands to verify your submission:
    - make
    - ./f test.f
- Please submit a compressed file where each problem in a separate folder
- You do not need to hand in fullsimple.nameless and fullsimple.natlist