CMSC 330: Organization of Programming Languages

Lets, Tuples, Records

Let Expressions

- Syntax
  - **`let x = e1 in e2`**
  - ***`x`*** is a *bound variable*
  - ***`e1`*** is the *binding expression*
  - ***`e2`*** is the *body expression*

- **`let`** expressions bind *local* variables
  - Different from **`let`** *definitions*, which are at the top-level

Let Expressions

- Syntax
  - `let x = e1 in e2`

- Evaluation
  - e1 ⇒ v1
  - e2{v1/x}

```
let z = 3+4 in 3*z

21
```

Let Expressions

- Syntax
  - **`let` *`x`* `=` *`e1`* `in` *`e2`***
- Type checking
  - If *`e1`* : *`t1`* and
  - If assuming *`x`* : *`t1`* implies *`e2`* : *`t`*
  - Then (**`let` *`x`* `=` *`e1`* `in` *`e2`***) : *`t`*

Example

What is the type of **`let z = 3+4 in 3*z`** ?

- **`3+4`** : **`int`**
- Assuming **`z`** : **`int`**, we have **`3*z`** : **`int`**
- So the type of **`let z = 3+4 in 3*z`** is **`int`**

Let Definitions vs. Let Expressions

- At the top-level, we write
  - `let x = e;;` (* no `in e2` part *)
  - This is called a let *definition*, not a let *expression*
    - Because it doesn't, itself, evaluate to anything

- Omitting in means "from now on":

```
# let pi = 3.14;;
(* pi is now bound in the rest of the top-level scope *)
```

Let Expressions: Scope

- In **`let x = e1 in e2`**, var **`x`** is *not* visible outside of **`e2`**

```
let pi = 3.14 in pi *. 3.0 *. 3.0;;
print_float pi;;
```

error: `pi` not bound

bind `pi` (only) in body of `let`
(which is `pi *. 3.0 *. 3.0`)

```
{
  float pi = 3.14;

  pi * 3.0 * 3.0;
}
pi; /* pi unbound! */
```

Examples – Scope of Let bindings

- `x;;` (* Unbound value x *)
- `let x = 1 in x + 1;;` (* 2 *)
- `let x = x in x + 1;;` (* Unbound value x *)
- `(let x = 1 in x + 1);;` `x;;`(* Unbound value x *)
- let x = 4 in (let x = x + 1 in x) ;; (* 5 *)

Nested Let Expressions

```
let res =
   (let area =
      (let pi = 3.14 in
       let r = 3.0 in
       pi *. r *. r) in
   area /. 2.0);;
```

Similar scoping possibilities C and Java

```
float res;
{ float area;
  { float pi = 3.14
    float r = 3.0;
    area = pi * r * r;
  }
  res = area / 2.0;
}
```

Let Expressions in Functions

- You can use let inside of functions for local vars

```
let area d =
  let pi = 3.14 in
  let r = d /. 2.0 in
  pi *. r *. r
```

Shadowing Names

- Shadowing is rebinding a name in an inner scope to have a different meaning
  - May or may not be allowed by the language

C

```
int i;

void f(float i) {
  {
    char *i = NULL;
    ...
  }
}
```

```
let x = 10 in
    let z =
       let x = 20 in
       x*2 in
    x+z.  (* 50 *)
```

Shadowing, by the Semantics

- What if ***e2*** is also a **`let`** for ***x*** ?
  - Substitution will **stop** at the ***e2*** of a shadowing ***x***

Example

```
let x = 3+4 in let x = 3*x in x+1
- let x = 7 in let x = 3*x in x+1
- let x = 3*7 in x+1
- let x = 21 in x+1
- 21+1
- 22
```

Will *not* be substituted, since it is shadowed by the inner let

Quiz 1: What does this evaluate to?

```
let x = 2 in
let y = x + x in
y * x
```

A. 4

B. 6

C. 8

D. Error

Quiz 1: What does this evaluate to?

```
let x = 2 in
let y = x + x in
y * x
```

A. 4

B. 6

C. 8

D. Error

Quiz 2: What does this evaluate to?

```
let x = 5 in
x = 3
```

A. 3

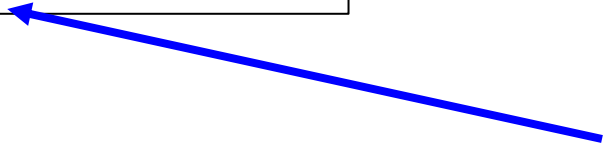
B. 2

C. true

D. false

Quiz 2: What does this evaluate to?

```
let x = 2 in
x = 3
```



This expression is checking whether **x** is equal to **3**

A. 3

B. 2

C. true

D. false

Quiz 3: What does this evaluate to?

```
let y = 3 in
let x = y+2 in
let y = 6 in
x+y
```

A. 8

B. 11

C. 13

D. 14

Quiz 3: What does this evaluate to?

```
let y = 3 in
let x = y+2 in
let y = 6 in
x+y
```

A. 8

B. 11

C. 13

D. 14

Tuples

- Constructed using `(e1, …, en)`
- Deconstructed using pattern matching
  - Patterns involve parens and commas, e.g., `(p1, p2, …)`
- Tuples are similar to C structs
  - But without field labels
  - Allocated on the heap
- Tuples can be heterogenous
  - Unlike lists, which must be homogenous
  - `(1, ["string1";"string2"])` is a valid tuple

Tuple Types

- Tuple types use **`*`** to separate components
  - Type joins types of its components
- Examples
  - `(1, 2) :`
  - `(1, "string", 3.5) :`
  - `(1, ["a"; "b"], 'c') :`
  - `[(1,2)] :`
  - `[(1, 2); (3, 4)] :`
  - `[(1,2); (1,2,3)] :`

Tuple Types

- Tuple types use **`*`** to separate components
  - Type joins types of its components
- Examples
  - `(1, 2) :` **`int * int`**
  - `(1, "string", 3.5) :` **`int * string * float`**
  - `(1, ["a"; "b"], 'c') :` **`int * string list * char`**
  - `[(1,2)] :` **`(int * int) list`**
  - `[(1, 2); (3, 4)] :` **`(int * int) list`**
  - `[(1,2); (1,2,3)] :` ***`error`***

Because the first list element has type int * int, but the second has type int * int * int – list elements must all be of the same type

Pattern Matching Tuples

```
let plus3 t =
  match t with
  (x, y, z) -> x + y + z;;
plus3 : int*int*int -> int = <fun>


let plus3' (x, y, z) = x + y + z;;
plusThree' : int*int*int -> int = <fun>
```

Tuples Are A Fixed Size

- This OCaml definition
  - ```
    let foo x = match x with
      (a, b) -> a + b
    | (a, b, c) -> a + b + c
    ```

  has a type error. Why?

- Tuples of different size have different types
  - `(a, b) has type: 'a * 'b`
  - `(a, b, c) has type: 'a * 'b * 'c`
    ```

Quiz 4: What does this evaluate to?

```
let get a b = (a+b,0) in
get 1 2
```

A. (3,0)

B. (2,0)

C. 3

D. type error

Quiz 4: What does this evaluate to?

```
let get a b = (a+b,0) in
get 1 2
```

A. (3,0)

B. (2,0)

C. 3

D. type error

Quiz 5: What does this evaluate to?

```
let get (a,b) y = a+y in
get (2,1) 1
```

A. 3

B. type error

C. 2

D. 1

Quiz 5: What does this evaluate to?

```
let get (a,b) y = a+y in
get (2,1) 1
```

A. 3

B. type error

C. 2

D. 1

Records

- Records: identify elements by name
  - Elements of a tuple are identified by position

- Define a record type before defining record values

```
type date = { month: string; day: int; year: int }
```

- Define a record value

```
# let today = { day=16; year=2017; month="f"^"eb" };;

today : date = { day=16; year=2017; month="feb" };;
```

Destructing Records

```
type date = { month: string; day: int; year: int }
let today = { day=16; year=2017; month="feb" };;
```

- Access by field name or pattern matching

```
today.month;; (* feb *)

let { year } = today in (* binds year to 2017 *)
let { month=_; day=d } = today in
…
```

Quiz 6: What is the type of **`shift`**?

```
type point = {x:int; y:int}

let shift { x = px } = [px]::[]
```

A. `point -> int list`

B. `int -> int list`

C. `point -> point list`

D. `point -> int list list`

Quiz 6: What is the type of `shift`?

```
type point = {x:int; y:int}

let shift { x = px } = [px]::[]
```

A. `point -> int list`

B. `int -> int list`

C. `point -> point list`

D. `point -> int list list`