CS 3110

Expressions

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Review

Previously in 3110:

- What is a functional language?
- Why learn to program in a functional language?

Today:

- Five aspects of a language
- Expressions, values, definitions

Question

Did you bring an iClicker today?

A. Yes
B. No
C. I plead the 5th

No worries: Attendance point tracking starts in lecture on Thursday; in section, on Monday

Five aspects of learning a PL

1. Syntax: How do you write language constructs?
2. Semantics: What do programs mean? (Type checking, evaluation rules)
3. Idioms: What are typical patterns for using language features to express your computation?
4. Libraries: What facilities does the language (or a third-party project) provide as "standard"? (E.g., file access, data structures)
5. Tools: What do language implementations provide to make your job easier? (E.g., top-level, debugger, GUI editor, …)

- All are essential for good programmers to understand
- Breaking a new PL down into these pieces makes it easier to learn

Our Focus

We focus on semantics and idioms for OCaml

- Semantics is like a meta-tool: it will help you learn languages
- Idioms will make you a better programmer in those languages

Libraries and tools are a secondary focus: throughout your career you'll learn new ones on the job every year

Syntax is almost always boring

- A fact to learn, like "Cornell was founded in 1865"
- People obsess over subjective preferences {yawn}
- Class rule: We don't complain about syntax

Expressions

- Primary building block of OCaml programs
- Akin to statements or commands in imperative languages

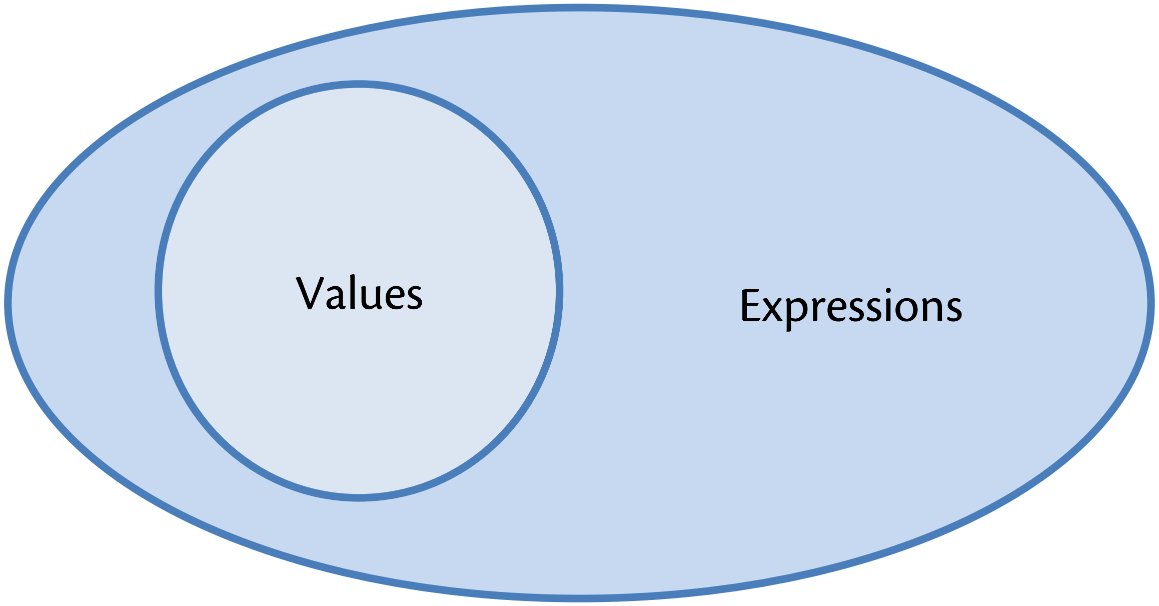
Expressions

Every kind of expression has:

- **Syntax**
- **Semantics:**
  - **Type-checking rules (*static semantics)*:** produce a type or fail with an error message
  - **Evaluation rules (*dynamic semantics*):** produce a *value*
    - (or exception or infinite loop)
    - Used only on expressions that type-check

Values

A **value** is an expression that does not need any further evaluation



Demo

IF EXPRESSIONS

Demo

`if` expressions

Syntax:

```
if e1
```

Write ==> to indicate evaluation
Pronounce as "evaluates to"

Evaluation:

- if `e1` evaluates to `true`, and if `e2` evaluates to `v`, then `if e1 then e2 else e3` evaluates to `v`
- if `e1` evaluates to `fals`
  then `if e1 then e`

Write colon to indicate type of expression
Pronounce colon as "has type"

Type checking:

if `e1` has type `bool` and `e2` has type `t` and `e3` has type `t`
then `if e1 then e2 else e3` has type `t`

`if` expressions

Syntax:

```
if e1 then e2 else e3
```

Evaluation:

- if `e1 ==> true` and `e2 ==> v`,
  then `if e1 then e2 else e3 ==> v`
- if `e1 ==> false` and `e3 ==> v`,
  then `if e1 then e2 else e3 ==> v`

Type checking:

if `e1 : bool` and `e2 : t` and `e3 : t`
then `if e1 then e2 else e3 : t`

`if` expressions

Syntax:

```
if e1 then e2 else e3
```

Evaluation:

- if `e1 ==> true` and `e2 ==> v`,
  then `(if e1 then e2 else e3) ==> v`
- if `e1 ==> false` and `e3 ==> v`,
  then `(if e1 then e2 else e3) ==> v`

Type checking:

if `e1 : bool` and `e2 : t` and `e3 : t`
then `(if e1 then e2 else e3) : t`

Type inference and annotation

- OCaml compiler infers types
  - Compilation fails with type error if it can't
  - Hard part of language design: guaranteeing compiler can infer types when program is correctly written

- You can manually annotate types anywhere
  - Replace `e` with `(e : t)`
  - Useful for resolving type errors

Demo

LET DEFINITIONS

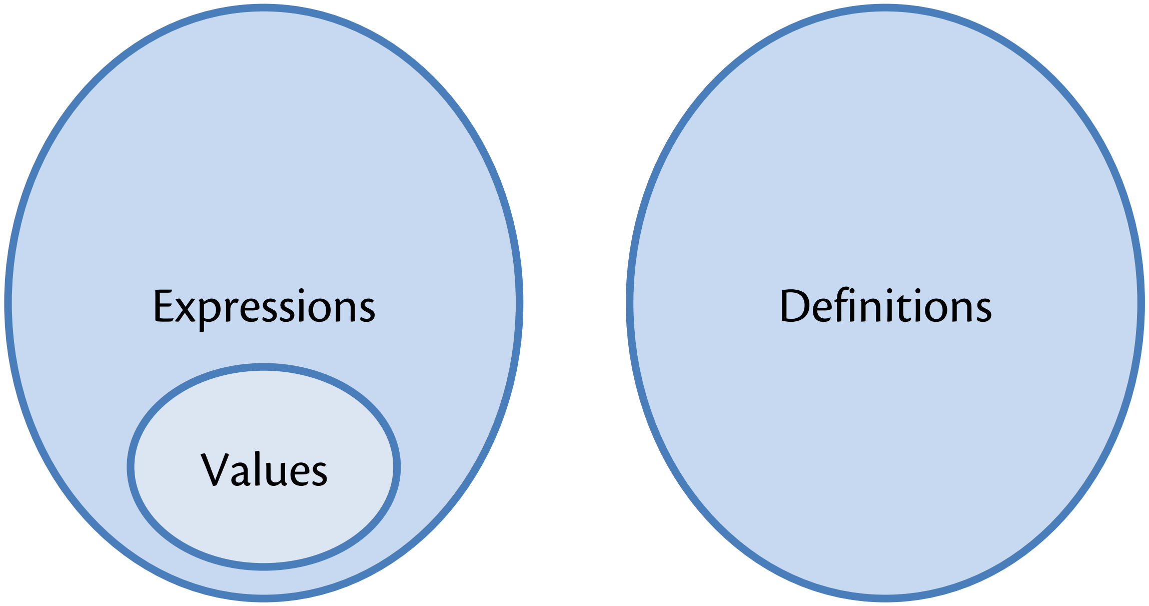
Demo

Definitions

A **definition** gives a name to a value

Definitions are not expressions, or vice-versa

But definitions syntactically contain expressions



`let` definitions

Syntax:

```
let x = e
```

where **`x`** is an *identifier*

Evaluation:

- Evaluate **`e`** to a value **`v`**
- Bind **`v`** to **`x`**: henceforth, **`x`** will evaluate to **`v`** (under the hood: there is a memory location named **`x`** that contains **`v`**)
- But the definition does not evaluate to a value

LET EXPRESSIONS

Demo

`let` expressions

Syntax:

```
   let x = e1 in e2
```

`x` is an *identifier*

`e1` is the *binding expression*

`e2` is the *body expression*

`let x = e1 in e2` is itself an expression

`let` expressions

```
let x = e1 in e2
```

Evaluation:

- Evaluate `e1` to a value `v1`
- Substitute `v1` for `x` in `e2`, yielding a new expression `e2'`
- Evaluate `e2'` to `v2`
- Result of evaluation is `v2`

Example

`let` expressions

```
let x = e1 in e2
```

Type-checking:

If `e1:t1` and `x:t1` and `e2:t2`

then `(let x = e1 in e2) : t2`

This type-checking rule was stated incorrectly during lecture; it has been fixed.

VARIABLE EXPRESSIONS

Variable expressions

How to evaluate just

```
x
```

?

`let` definitions in toplevel

```
let x = e
```

is implicitly, "**`in`** *rest of what you type*"

E.g., you type:

```
let a="big";;
let b="red";;
let c=a^b;;
```

Toplevel understands as

```
let a="big" in
let b="red" in
let c=a^b in...
```

Variable expressions

How to evaluate just

```
x
```

?

Answer: substitution from that giant nested **`let`** expression

Upcoming events

- [Thu] A0 released

This is expressive.

THIS IS 3110

WHAT ABOUT IMMUTABILITY?

Seems like variable can mutate…

```
let x = 1;;
let x = 2;;
x;;
```

But really it's just nested scopes

```
let x = 1 in
  let x = 2 in
    x
```

Allocate memory that will always be 1

Allocate memory that will always be 2

Which piece of memory does name mean?
Innermost scope, as you would expect.

See section on Scope in textbook for full details, including
Principle of Name Irrelevance