CSE 341 AB

Section 2
(4/11)

Questions?

Agenda

1. Intros

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3. Types!
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   b. Parametric Polymorphism
   c. Type Generality
   d. Equality Types

4. Variants
   e. Syntactic Sugar
   f. A Note on Patterns
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Intros

Please introduce yourself to someone you haven’t talked to yet!

E.g.

- What’s your name?
- Why are you taking 341?
- What do you do for fun?
- What’s your favorite programming language?

Syntactic Sugar

Sometimes we don't change our core language to add new language constructs.

```
x andalso y
```

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if x then y else false
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case x of
     true  => y
   | false => false
```

Syntactic Sugar

Sometimes we don’t change our core language to add new language constructs.

```
x orelse y

↓

if x then true else y

↓

case x of
    true  => true
  | false => y
```

Function Tracing

Function Tracing

- Function tracing is simplified (for now!).

- In Unit 3 we will look at a more complex, *but more accurate*, representation.

Function Tracing - Function Binding

When you visit a function binding, just map its name to `fn`.

```
fun foo (x: int) = x + 2;

foo 2
```

id	val
RES	
foo	fn

Function Tracing - Function Call

```
fun foo (x: int) = x + 2;

foo 2
```

id	val
RES	
foo	fn

Function Tracing - Function Call

Visit the left- and right-hand sides of the function call.

```
fun foo (x: int) = x + 2;

foo 2
```

id	val
RES	
foo	fn

<u>foo</u> 2

foo <u>2</u>

foo 2

Function Tracing - Function Call

Once we've determined the function we need to call, create a *new* environment!

Extend it with the arguments to `foo`.

```
fun foo (x: int) = x + 2;
```

```
foo 2
```

<u>foo</u> 2

foo <u>2</u>

foo 2

id	val
RES	
foo	fn

foo	
id	val
RES	
x	2

Function Tracing - Function Call

Evaluate the function body.

```
fun foo (x: int) = x + 2;

foo 2
```

```
x + 2
2 + 2
2 + 2
4
```

id	val
RES	
foo	fn

foo	
id	val
RES	
x	2

Function Tracing - Function Call

Save the result in RES.

```
fun foo (x: int) = x + 2;

foo 2
```

```
x + 2
2 + 2
2 + 2
4
```

id	val
RES	
foo	fn

foo	
id	val
RES	4
x	2

Function Tracing - Function Call

We now know the value of the original call.

Destroy the environment and pass the value back.

```
fun foo (x: int) = x + 2;
```

```
foo 2
```

```
x + 2
2 + 2
2 + 2
4
```

id	val
RES	4
foo	fn

foo	
id	val
RES	4
x	2

Function Tracing - But What About...

variables bound outside a function body?

```
val y = 2;
fun foo (x: int) = x + y;
val y = 3;
foo 2
```

Function Tracing - But What About...

nested functions?

```
fun foo (x: int) =
    let fun bar (y: int) = y * y
    in
        bar (x * x)
    end;
foo 2
```

Function Tracing - But What About...

Find out next week!

Types

Type Synonyms

```
datatype suit = Club | Diamond | Heart | Spade
datatype rank = Jack | Queen | King | Ace
      | Num of int

type card = suit * rank
```

A synonym doesn't add a new type name.
What's the type of `(Club, Jack)`? Try it out!

In a World Without Parametric Polymorphism...

```
fun append_ints (xs : int list, ys : int list) =
    case xs of
        []          => ys
      | x::xs       => x::append(xs, ys)
```

```
fun append_strings (xs : string list, ys : string list) =
    case xs of
        []          => ys
      | x::xs       => x::append(xs, ys)
```

The code is the same, but every new data type requires a new function!

(Notice that we only use the inputs' *structures*, not their *values*. This will become important in future weeks.)

What If… NOT VALID SML!!!

```
fun append ('a) (xs : 'a list, ys : 'a list) =
    case xs of
        []        => ys
      | x::xs     => x::append(xs, ys)
```

What If… NOT VALID SML!!!

```
fun append ('a) (xs : 'a list, ys : 'a list) =
    case xs of
        []        => ys
      | x::xs     => x::append(xs, ys)
```

```
append : forall 'a, 'a list * 'a list -> 'a list
```

What If… NOT VALID SML!!!

```
fun append ('a) (xs : 'a list, ys : 'a list) =
    case xs of
        []        => ys
      | x::xs     => x::append(xs, ys)
```

```
append : forall 'a, 'a list * 'a list -> 'a list
```

```
val append_ints = append(int)
val append_strings = append(string)
```

```
append_ints       : int list * int list -> int list
append_strings    : string list * string list -> string list
```

What If… NOT VALID SML!!!

```
fun append ('a) (xs : 'a list, ys : 'a list) =
    case xs of
        []        => ys
      | x::xs     => x::append(xs, ys)
```

```
append : forall 'a, 'a list * 'a list -> 'a list
```

```
val append_ints = append(int)
val append_strings = append(string)
```

Types in our expressions?!?! Take me back!

Luckily, SML has a restriction that means we don't have to write this way:
`forall` can only appear at the beginning of a type.

But it's useful to think about what's going on under the hood.

What If… VALID SML!!!

```
fun append      (xs : 'a list, ys : 'a list) =
    case xs of
        []       => ys
      | x::xs    => x::append(xs, ys)
```

```
append :             'a list * 'a list -> 'a list
```

What If… VALID SML!!!

```
fun append      (xs : 'a list, ys : 'a list) =
    case xs of
        []       => ys
      | x::xs    => x::append(xs, ys)
```

```
append :             'a list * 'a list -> 'a list
```

You can use `append` with any type of list *as long as both lists have the same type!*

SML will do the right thing under the hood and insert type arguments for you.

Type Generality

Types with 0 or more type parameters are called *type schemes*.

For now, to get a concrete type from a type scheme, replace ALL instances of a type parameter with a concrete type.

A type scheme, A, is **more general** than another type scheme, B, if every concrete instantiation of B is also one of A.

We write A $\sqsubseteq$ B.

Don’t worry, we will refine this in the coming weeks!

Type Generality Examples

```
'a = int
'a list * 'a list -> 'a list => int list * int list -> int list

'a = string
'a list * 'a list -> 'a list => string list * string list -> string list

'a = int, b' = bool
'a * 'b -> 'b => int * bool -> bool
```

```
'a list * 'a list -> 'a list ⊑ int list * int list -> int list

'a list * 'a list -> 'a list !⊑ int list * string list -> int list

'a list * 'b list -> 'a list ⊑ 'a list * 'a list -> 'a list
```

Equality Types

Write a list contains function…

Equality Types

- The double quoted variable arises from use of the = operator
- We can use = on most types like int, bool, string, tuples (that contain only “equality types”)
- Functions and real are not ”equality types”
- Generality rules work the same, except substitution must be some type which can be compared with =

!!! You can ignore warnings about “calling polyEqual”

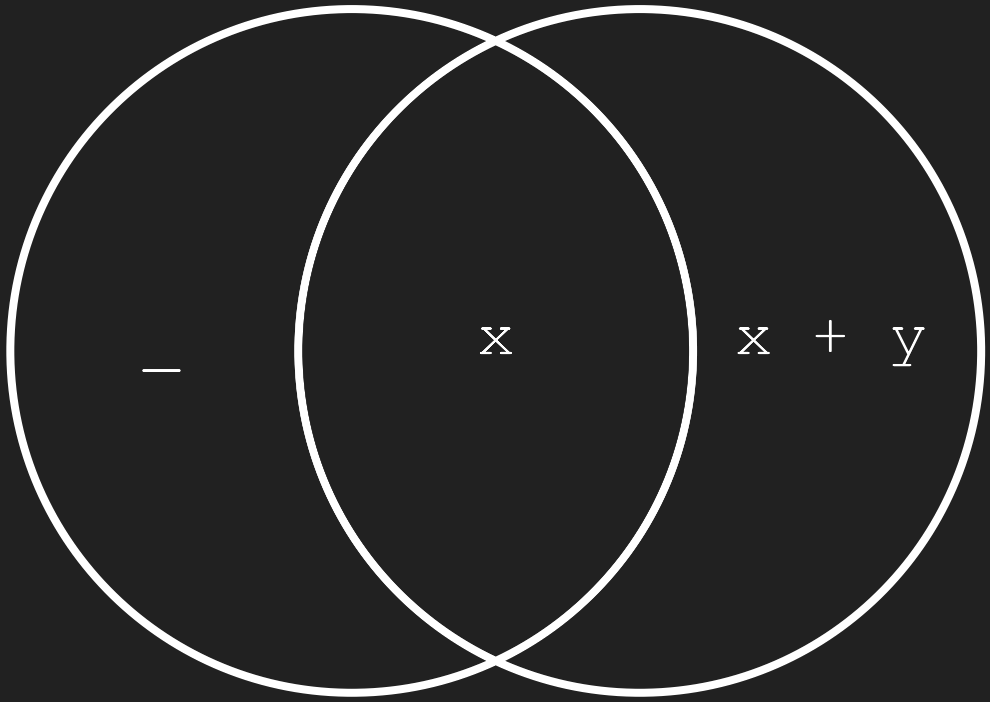
Variants

Pattern Matching Syntactic Sugar

Demo!

PATTERNS ≠ EXPRESSIONS

Patterns vs Expressions Examples



Patterns vs Expression Semantics Example

The pattern `x` *adds* a binding *to* the dynamic environment.

The expression `x` *looks up* a binding *from* the dynamic environment.

Tracing Pattern Matching