Local Declarations, Overloading

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Program Design and Data Structures

Based on notes by Tjark Weber, Lars-Henrik Eriksson, Pierre Flener, Sven-Olof Nyström

Today

- Local Declarations, Scope
- Overloading
- Revision

Local Declarations, Scope

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The identifiers declared between `let` and `in` are bound only until the end of the following expression.

Local Declarations: Example

```
Prelude> let x = 42 in x + 1
43

Prelude> x

<interactive>:...: Not in scope: `x'
```

Scope

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Different programming languages have different scoping rules.

In Haskell, the scope of a top-level declaration is typically the entire program (i.e., a name that is declared at the top level may be used anywhere in the program code). The scope of a local declaration only extends to the end of the corresponding expression.

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Prelude> (x, y)
(0,11)
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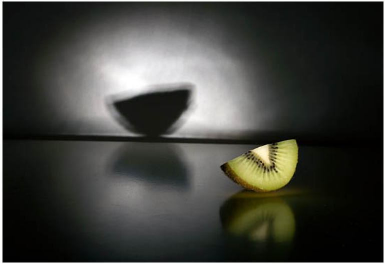

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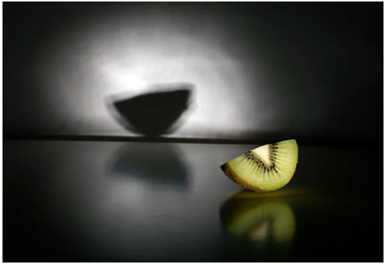

You need to know about shadowing because you should be able to read and understand realistic programs. Still, it is usually a good idea to avoid shadowing in your own code (by using distinct names).

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```
x = "shadowed"

add1 x = x + 1

Prelude> x
"shadowed"
Prelude> add1 42
43
```

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```
shadowedArgument x = let x=0 in x+1
```

```
Prelude> shadowedArgument 42
1
```

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By any other name would smell as sweet.

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Names are only interpreted by human readers of the program. They serve to **explain** the purpose of values, functions, etc.

Therefore, it is important to use **descriptive** names.

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(Of course, names that are declared outside the program, such as +, cannot be replaced in your code only.)

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We use software that can detect changed copies—even if you rename all identifiers!

Don't rename to cheat. (You won't cheat your way to a successful career anyway. Better try to pick up some effective study techniques.)

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We say that +, −, ∗, /, <, >, ==, . . . are **overloaded**.

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Another example:

```
Prelude> maxBound :: Int
9223372036854775807
Prelude> maxBound :: Char
'\1114111'
```

Overloading: Type Inference

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Here, < has type `String->String->Bool`.

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Here, < has type `String->String->Bool`.

```
Prelude> Data.Char.toUpper maxBound
'\1114111'
```

Here, `maxBound` has type `Char`.

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```
Prelude> sumOfSquares 3
18
Prelude> sumOfSquares 3.0
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```

Some Standard Type Classes

Overloaded values live in **type classes**. A type class is a collection of types that support the same operation(s).

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Overloaded values live in **type classes**. A type class is a collection of types that support the same operation(s).

- `Eq` — types having equality/inequality operator
- `Ord` — types whose values can be ordered
- `Show` — types whose values can be converted **to** strings
- `Read` — types whose values can be converted **from** strings
- `Bounded` — types with both an upper and a lower bound.
- `Num` — numbers

The Eq typeclass

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class Eq a where
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- Defined for base types, lists, tuples,...
- Used in pattern matching (value patterns).
- Using == signals that this type class is to be used—that is, that the type of its arguments must belong to class `Eq`

The Ord typeclass

```haskell
class (Eq a) => Ord a where
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- Used for sorting values.
- Assumes that values can be checked for equality: `(Eq a) => Ord a`.
    - `Ord` is a *subclass* of `Eq`.
    - `Eq` is a *superclass* of `Ord`.

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Type class `Read` is for reading values from strings, for user input, sending across network, storing in files, ...

```
class Read a where
  read :: String -> a
```

The Bounded typeclass

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class Bounded a where
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- Examples: `Bool`, `Int`, `Char`, and tuples of bounded types.

The Num Typeclass

```
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  (+),(-),(*) :: a -> a -> a
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- Examples: `Int`, `Integer`, `Double`, `Rational`, `Complex`, ...
- Can always be compared for equality (`Eq`) and printed (`Show`).
- Are not always ordered! (Why?)
- Has subclasses for standard division (/) and integral division (`mod`,`div`).

Reading Types with Class

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zero :: (Eq a, Num p) => a -> p
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Compare the logical formula

$$\forall a. \forall p. \mathrm{Eq}(a) \wedge \mathrm{Num}(p) \implies (a \implies p)$$

Revision

Basic Types in Haskell

- Integers (`Integer`): `0, 1, 2, -10, 42, ...`
- Floating point numbers (`Double`): `0.0, -10.4, 3.14159, 1.234e6, ...`
- Characters (`Char`): `'a', 'B', '1', ...`
- Strings (`String`): `"Hello", "PKD", "1", ...`
- Booleans (`Bool`): `True`, `False`
- Unit (`()`): has only one value, written `()`
- ...

Note that `1`, `1.0`, `'1'` and `"1"` are all different.

Numeric Operations

For numeric types (`Num a`):

Functions	Type	Semantics
`+`, `-`, `*`	`a->a->a`	arithmetic operations
`==`, `/=`	`a->a->Bool`	equality, inequality
`<`, `<=`, `>`, `>=`	`a->a->Bool`	comparison
`-`, `negate`	`a->a`	negation (e.g., `-(2-3)` $\longrightarrow$ 1)
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For integral types (`Integral a`):

Functions	Type	Semantics
`div`, `mod`	`a->a->a`	modulo (e.g., `mod 7 3` $\longrightarrow$ 1)

String Operations

Functions	Type[1]	Semantics
`++`	`String->String->String`	concatenation
`length`	`String->Int`	length
`head`	`String->Char`	first character
`last`	`String->Char`	last character
`tail`	`String->String`	the string without its first char
`init`	`String->String`	the string without its last char
`take`	`Int->String->String`	the string's first n characters
`drop`	`Int->String->String`	the string without its first n chars
`!!`	`String->Int->Char`	the string's n^{th} character

[1] These operations actually work for lists of any type, e.g. `[Int]`.

Conversions

Function	Type
`fromInteger`	`(Num a) => Integer -> a`
`toInteger`	`(Integral a) => a -> Integer`
`round`	`(RealFrac a, Integral b) => a -> b`
`truncate`	`(RealFrac a, Integral b) => a -> b`
`floor`	`(RealFrac a, Integral b) => a -> b`
`ceiling`	`(RealFrac a, Integral b) => a -> b`
`toEnum`	`(Enum a) => Int -> a`
`fromEnum`	`(Enum a) => a -> Int`
`show`	`(Show a) => a -> String`
`read`	`(Read a) => String -> a`

Operator Precedence and Fixity

How does Haskell know that `1 + 2 * 3` should be evaluated as `1 + (2 * 3)` rather than `(1 + 2)* 3`?

Every infix operator has a **precedence**. Higher precedences bind more tightly.

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How does Haskell know that `3 - 2 - 1` should be evaluated as `(3 - 2)- 1` rather than `3 - (2 - 1)`?

Infix operators may be **left**- or **right-associative**, meaning operations are grouped from the left (or right, respectively).

Comparison operators are not associative (what should `x == y >= z` mean?).

Operator Precedence and Fixity

Prec	Left assoc	Non-assoc	Right assoc
9	!!		.
8			^, ^^, **
7	*, /, `div`, `mod`, `rem`, `quot`		
6	+, -		
5			:, ++
4		==, /=, <, <=, >, >=	
3			&&
2			||
1	>>, >>=		
0			$, $!, `seq`

Pairs and Tuples

```
("PKD", 2019) :: (String, Integer)

(1, 2, 3) :: (Integer, Integer, Integer)

(3, "three", 3.0) :: (Integer, String, Double)
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The function `(,)` takes two arguments and returns the pair (2-tuple) that consists of these arguments (in the given order).

If-Then-Else, Declarations

```
if condition then trueValue else falseValue
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Value declarations associate a value to an identifier.

```
x = 1
myPi = 3.14159
timesPi x = x * myPi

Prelude> x + x
2
Prelude> timesPi 2
6.28318
```

Functions

Function declarations consist of the name, arguments, and body.

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takeLast n str = drop (length str - n) str
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Prelude> (\n s -> drop (length s - n) s) 5 "computer"
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```

Operators are just functions written between their arguments. We can convert between operators and functions using `( )` and `` `f` ``.

```
Prelude> (+) 3 5
8
Prelude> 3 `takeLast` "PKD2019"
"019"
```

Function Specifications

In this course, our function specifications will consist of

1. Function name and arguments
2. Function type — argument(s) and result
3. Description — what is the purpose of this function?
4. What the function assumes (precondition)
5. What the function computes (return value)
6. Side effects
7. Examples of function usage

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Specifications may be given at different levels of detail.

Specifications may be given in natural language, or more formally.

Patterns

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Patterns are checked in the order they appear in the source file.

Guarded patterns are of the form `pattern | expr`. Here, `expr` must have type `Bool` and will usually refer to names from `pattern`.

Uses of Patterns

Function declarations:

```
name pattern1 = expression1
name pattern2 = expression2
...
name patternN = expressionN
```

Uses of Patterns

Function declarations:

```
name pattern1 = expression1
name pattern2 = expression2
...
name patternN = expressionN
```

Case expressions:

```
case expr of
  pattern1 -> expression1
  pattern2 -> expression2
  ...
  patternN -> expressionN
```

Haskell Sources

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- Top-level expressions are not allowed.
- Usually, each declaration is given on a separate line.
- The order of declarations doesn't matter.
- Multiple declarations of the same identifier are not allowed.