Elixir Workshop

Julius Putra Tanu Setiaji

13 May 2019

Where are we?

About Erlang

- A development platform for building **scalable** and **reliable** systems.
- Built in Ericsson[1] in the 1990s
- Runs on BEAM (Björn's Erlang Abstract Machine)[2].

[1] Ericsson was and is one of the largest telecom infrastructure companies in the world.

[2] Similar idea: Java runs on the JVM (Java Virtual Machine)

High Availability

- Fault tolerance
- Scalability
- Distribution
- Responsiveness
- Live update

A tribute to Prof. Joe Armstrong

Prof. Joe Armstrong was behind the development of Erlang. He passed away recently on 20th April 2019.

Sample Erlang

Based on **Prolog**: its syntax borrows heavily from it and the first Erlang compiler[3] was written in it too.

```
-module(fact).
-export([fac/1]).

fac(0) -> 1;
fac(N) when N > 0, is_integer(N) -> N * fac(N - 1).
```

[3] https://www.erlang.se/publications/prac_appl_prolog.ps

Where are we?

About Elixir

- Targets BEAM, with full Erlang interoperability[4].
- Started by José Valim in 2012 – he was involved heavily in the Ruby on Rails coreteam before.
- Provides almost one-to-one mapping to Erlang constructs but with additions to reduce boilerplate and duplication.

[4] It means that we can use Erlang libraries and tooling

Sample Elixir

The syntax is heavily borrowed from Ruby.

```
defmodule Fact do
  def fac(0) do
    1
  end

  def fac(n) when n > 0, is_integer(n) do
    n * fac(n - 1)
  end
end
```

Phoenix Framework

- Elixir's web framework, just like RoR in Ruby, or Django in Python.
- Initially it was heavily based on Ruby on Rails.
- Over time, Phoenix has diverged from its Rails roots and developed its own unique ideas.

Ecto

- A database wrapper and language integrated query for Elixir.
- Data mapping and validation, with a SQL adapter.
- Conceptually, this is the Model in MVC architecture. Similar to ActiveRecord in Ruby on Rails.

Where are we?

Roles of Elixir in Source Academy

- Source Academy has a separate **backend** and **frontend**.
- **Backend** stores data and does the business logic.
- **Frontend** is what the user interacts with and makes requests to the backend.
- Phoenix Framework is used to write the Source Academy's backend.

Why Elixir?

- Elixir has good performance due to BEAM (compared to the alternatives, such as Ruby on Rails, Express on node.js, etc.).
- Elixir is a functional language, in line with what CS1101S and SICP taught.
- Elixir has more familiar syntax than Erlang.
- Good package manager (`hex` and `rebar`), which provides ability to use Erlang and Elixir libraries.

Where are we?

Steps of Installing Elixir

1. **Install Erlang**: I prefer using the native package manager for this (whatever the latest OTP version is)
2. **Install Elixir**: I prefer using `asdf` so I can manage more than 1 version of Elixir at the same time

Installing Erlang

On Mac: `https://is.gd/install_erlang_mac`

On Ubuntu:
`https://is.gd/install_erlang_ubuntu`

Check if you have a working Erlang/OTP 21 installation:

```
$ erl
Erlang/OTP 21 ...

Eshell ...

> io:fwrite("Hello, world!~n")
Hello, world!
ok
```

Installing asdf and Elixir

Go to `https://asdf-vm.com/`, click on "Get Started" and follow the instructions. Afterwards:

```
asdf plugin-add elixir
asdf install elixir 1.8.1-otp-21
```

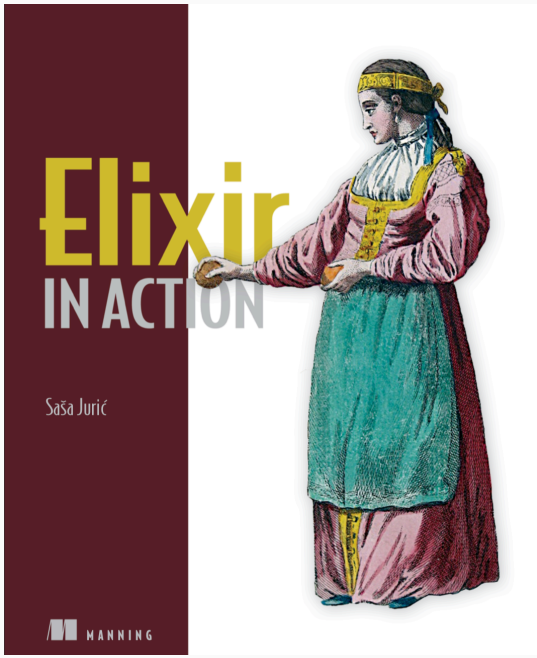
Check if you have a working Elixir 1.8.1 installation:

```
$ iex
Erlang/OTP 21 ...

Interactive Elixir (1.8.1) ...
iex(1)> IO.puts("Hello, world!")
Hello, world!
:ok
```

Recommended Reading

Elixir in Action by Sasa Juric



The first part would do (first 4 chapters)

Where are we?

Elixir Interactive Shell (REPL)

- You can enter Elixir's REPL[5] by running `iex` from terminal.
- `i`: inspect a value. Example: `i 5`
- `h`: get help about a command. Examples:

```
h Enum.reduce
h Enum.reduce/2
h Enum.reduce/3
```

- Note that in Elixir, everything is an expression and thus will return something.

[5] Read-Evaluate-Print-Loop

Where are we?

Variables

- Elixir is a *dynamic* language, thus there is no explicit type declaration.
- In Elixir, mapping a value to a variable is called **binding**.
- To do this, we use the match operator `=`
- Variable names uses snake_case style.
- Example:

```
x = 1
x
y = "a"
y
x = 2
x
```

Immutability

- Elixir is a functional language where everything is immutable.
- Re-binding a variable changes the value that a variable is pointing to but never the value itself.
- Let's test it with anonymous function:

```
x = 42
foo = fn -> IO.puts(x) end
x = 0
IO.puts(x)
foo.()
```

Where are we?

Organising Your Code

- As a functional language, Elixir relies heavily on functios.
- Due to immutable nature of data, typical Elixir program consists of many small functions.
- Multiple functions are grouped together into modules.

Module and Functions

- A collection of functions – similar to namespace in other languages.
- Every named function in Elixir must be defined inside a module.
- Syntax: `ModuleName.function_name(args)`
- Module names use CamelCase style. It can also contain the dot character to organise modules hierarchically.
- Module definition starts with the `defmodule` constuct, followed with a `do-end` block.
- Nested module or module whose names contains dot has no special relation – all modules are independent of one another (for now).

Module and Functions (cont.)

- Function names use snake_case style.
- Function name conventions: `?` suffix means the function returns a boolean, `!` suffis means the function may raise a runtime error.
- Function definition starts with the `def` constuct, followed with a `do-end` block.
- Parantheses can be omitted in definition of 0-arity functions.
- No explicit return value – instead, last expression is the return value.

Modules and Functions (cont.)

- Default argument is declared using \\ – this creates functions with the same name but different arities
- In general, ignored variable are prefixed with underscores.

Module and Functions (cont.)

Save as `Geometry.ex`, run as `iex Geometry.ex`:

```
defmodule Geometry do
  def foo, do: "Hello, world!"

  defmodule Square do
    def area(side \\ 2), do:
     ↪  Geometry.Rectangle.area(side, side)
  end
end

defmodule Geometry.Rectangle do
  def area(length, width) do
    length * width
  end
end
```

Module and Functions (cont.)

```
Geometry.Rectangle.area(2, 5)
Geometry.Square.area(3)
Geometry.foo()
```

Function visibility

- Functions defined using `def` is public (exported) and can be used by any module.
- To make a function private, define using `defp` – private functions can only be invoked inside the module where it is defined.

Imports and Aliases

- `import` allows calling public functions of a module without prefixing with the module name.
- `alias` allows referencing a module under a different name.
- Example:

```
import IO
puts("Hello, world!")
alias Geometry.Square
Square.area(3)
alias Geometry.Square, as: MySquare
MySquare.area(3)
```

Module Attributes

Has 3 uses:

- As annotations
- As constants at run-time
- As temporary storage at compile-time

Module Attributes: As annotation

Save as `Foo.ex`, then compile by running `elixirc Foo.ex`, then run `iex`

```
defmodule Foo do
  @moduledoc """
  This is the documentation for the Foo module.
  """

  @doc "bar/0 returns the number 5"
  def bar, do: 5
end
```

Module Attributes: As constants at run-time

```
defmodule Geometry.Circle
  @pi 3.14159

  def area(radius), do: @pi * radius * radius
end
```

Comments

- Comments start with the character #
- Block comments are not supported – instead prefix each one with #

Where are we?

Identifying functions

- Functions in Elixir are identified by their name and arity.
- The arity of a function describes the number of arguments that the function takes.
- Example: `Enum.reduce/2` identifies a function from the `Enum` module, function name is `reduce`, and the arity is 2, while `Enum.reduce/3` describes the same module, the same function name, but with arity 3.

Integer and Float

- In Elixir, just like in Erlang and Ruby, Integer has arbitrary precision, while float has 64-bit double precision.
- Predicate functions: `is_integer`/1 and `is_float`/1
- Note that the / operator always return a float.
- To get integer division, use `div`/1 instead.
- To get remainder, use `rem`/1

Integer and Float (cont.)

- Examples:

```
1 + 2
5 * 5
10 / 2
div(10, 2)
rem(10, 3)
rem 10, 3
```

- Note that in Elixir, you can drop parantheses when invoking named functions, just like Ruby (generally discouraged)

Integer and Float (cont.)

- Elixir also provides shortcut notation to enter binary, octal, and hexadecimal numbers:

```
0b1010
0o777
0x1F
```

- Float requires a dot followed by at least 1 digit.
- It also supports `e` for scientific notation.
- You can use `floor/1`, `ceil/1`, `trunc/1`, `round/1`.

```
1.0
1.0e-10
round(-1.5)
trunc(-1.5)
floor(-1.5)
ceil(-1.5)
```

Boolean

- Either the value `true` or `false`
- Predicate function: `is_boolean/1`
- Examples:

```
is_boolean(true)
is_boolean(false)
is_boolean(5)
```

Atom

- A constant whose name is its own value. Similar to Symbols in Ruby or Lisp.
- Comparison is $O(1)$, while keeping the value named instead of an integer constant.
- Syntactically, written with a colon `:` prefix (like Ruby)
- Predicate function: `is_atom/1`
- Example:

```
:test
is_atom(:test)
```

Atom (cont.)

- Note that in Elixir (and Erlang), booleans are implemented as atoms `:true` and `:false`, and `nil` as `:nil` too.
- Module names are atoms too.
- You can also specify atom name that contains special characters (such as dot or colon) by delimiting them with double-quotes.

```
is_atom(true)
is_atom(Tuple)
:"Elixir.Tuple"
:"asd:a.sdd"
```

String

- Delimited by double quotes, encoded in UTF-8
- Represented internally by binaries (sequence of bytes). Binaries are delimited with << and >>
- Predicate function: `is_binary/1`
- Examples:

```
"Hello, world!"
<<104, 101, 108, 108, 111>>
is_binary("Hi!")
```

- Elixir supports string interpolation:

```
"Hello, #{:world}"
```

String (cont.)

- Get number of bytes in a string using `byte_size/1`
- Get length of string using `String.length/1`
- However, they might not be the same as the length of the string due to UTF-8 encoding:

```
byte_size("hellö")
String.length("hellö")
```

- `String` module contains helpful functions to manipulate string:

```
String.upcase("hellö")
```

Anonymous functions (lambda)

- Delimited by keywords `fn` and `end`
- Functions are first-class citizens: they can be passed as arguments to other functions.
- Note that a dot between the variable and parantheses is required to invoke an anonymous function.
- Predicate functions: `is_function/1`, `is_function/2`
- Examples:

```
add = fn a, b -> a + b end
add.(1, 2)
is_function(add)
is_function(add, 2)
is_function(add, 1)
Enum.each('hello', fn x -> IO.puts(x) end)
```

The Capture Operator

- Ampersand `&` is the capture operator.
- It can be used to create anonymous function
- Examples:

```
Enum.each('hello', &IO.puts/1)
Enum.each('hello', &IO.puts(&1))
(&IO.puts(&1)) == &IO.puts(&1)
```

(Linked) Lists

- Dynamic, variable-sized collections of data.
- The syntax might look like an array, but it actually is a linked list with $O(n)$ complexity for most functions.
- It uses Lisp-y list (SICP list): the lists are built from pairs
- Syntax for pair: `[head | tail]`
- To get head and tail, use `hd`/`1` and `tl`/`1` respectively.
- Predicate functions: `is_list`/`1`

(Linked) Lists

- Examples:

```
[1 | 2]
[1 | [2 | []]]
[1, 2]
is_list([1, 2, 3, 4])
length([1, 2, 3, 4])
```

- Concatenate using the `++/2` operator, subtract using the `--/2` operator:

```
[1, 2, 3] ++ [4, 5, 6]
[1, true, 2, false, 3, true] -- [true, false]
```

(Linked) Lists (cont.)

- Note that in Erlang, strings are usually represented as charlist (list of characters) instead of binaries.
- Charlist is written in Elixir delimited single quote.
- Examples:

```
'hello'
[104, 101, 108, 108, 111]
"hello"
<<104, 101, 108, 108, 111>>
'hello' == "hello"
```

Tuple

- Delimited by curly braces.
- Group a fixed number of elements, stored contiguously in memory. Thus, most operations are $O(1)$
- Examples:

```
tuple = {:ok, "world"}
tuple_size({:ok, "world"})
elem(tuple, 1)
put_elem(tuple, 1, "world")
```

List vs Tuple

- Appending lists is $O(n)$
- Tuples are stored contiguously in memory, thus updating a value in tuple is expensive as a new tuple has to be created.
- Tuples are typically used to return more than 1 data from a function: `{:ok, data}`, `{:error, :reason}`
- Usually, Elixir will guide you to do the right thing: `elem/1` exists but no built-in equivalent for lists.
- When counting elements, in Elixir, `size` signifies $O(1)$, while `length` signifies $O(n)$
- E.g. `byte_size/1`, `tuple_size/1` vs `length/1`, `String.length/1`

Operators

- **Arithmetic**: `+`, `-`, `*`, `/`, `div`, `rem`
- **List**: `++`, `--`
- **Binary (String)**: concatenate `<>`
- **Boolean**: `and`, `or`, `not`
- **Truthy/Falsey**: `||` return the first truthy value or the last element, `&&` return the first falsey value or the last element, `!` returns `true` except for `false` and `nil`
- **Comparison**: `==`, `!=`, `<=`, `>=`, `>`, `<`, `===` strict compare integer and float, `!==`
- Different types can be compared with total order[6].

[6] number < atom < reference < function < port < pid < tuple < map < list < bitstring

Maps

- A key-value store, implemented using Hash Array Mapped Trie (HAMT).
- Examples:

```
%{a: 1, b: 2}
%{:a => 1, :b => 2}
map = %{"a"=> %{"b" => [true, false, nil]}, 5
 ↪  => "boo", :z => 100}
map["a"]
map["a"]["b"]
map[:z]
map.z
%{map | 5 => "honhonhon"}
```

Keyword List

- Older way to create a key-value store is having a list of 2-item tuple.
- If the first item of the tuple is an atom, then this is a keyword list.
- Example:
  ```
  [{:a, 1}, {:b, 2}]
  [a: 1, b: 2]
  ```
- Important properties:
  - Keys must be atoms
  - Keys are ordered
  - Keys can be given more than once.
- Beware of the $O(n)$ performance characteristics.

Range

- Represents a range of numbers (like Ruby)
- Example:

```
range = 1..2
1 in range
-1 in range
Enum.each(1..3, &IO.puts/1)
```

Macros

- Advanced feature – we will not go into much detail.
- A very lisp-y feature.
- Elixir metaprogramming feature: code that receives AST and manipulates them.
- Note that many of the constructs in Elixir are actually implemented as macros on the standard library: `def`, `defp`, etc.

Where are we?

Pattern Matching

- One of the most powerful features of functional languages.
- Similar to destructuring in Ruby or JavaScript.
- Recall the match operator `=`
- So far we have just done simple bindings from the RHS to LHS:

```
x = 1
x
```

Pattern Matching (cont.)

- However, we can also do:

  ```
  1 = x
  ```

- This is because LHS and RHS are both `1`.
- The value in the RHS, namely the value bound to `x` (i.e. `1`) is being pattern-matched against the value in the LHS, namely `1`
- However, doing `2 = x` will result in **`MatchError`**

Pattern Matching on More Complex Data Types

```
{name, age} = {"Bob", 25}
{_, {hour, _, _}} = :calendar.local_time()
# Mimicking Prolog's unification. Suck it Haskell!
{amount, amount, amount} = {127, 127, 127}
{amount, amount, amount} = {127, 127, 1}

[first, second, third] = [1, 2, 3]
[head | tail] = [1, 2, 3]

%{name: name, age: age} = %{name: "Bob", age: 25}
%{age: age} = %{name: "Bob", age: 25}

"Hello" <> rest = "Hello, world!"
```

Pin Operator ^

- Variables in Elixir can be rebound.
- To pattern match against an existing variable's value rather rebinding, use the pin operator ^:

```
x = 1
^x = 2
```

Where are we?

Pattern Matching on Function Arguments and Multi-clausal Functions

In functional languages, you can pattern match on function arguments too, and provide multiple clauses!

```
defmodule Fact do
  def fac(0), do: 1
  def fac(n), do: n * fac(n - 1)
end
```

For a function, each clause will be attempted based on the order of definition.

Function Guards

- For a factorial function, only non-negative integers are valid input.
- Using predicate functions and simple comparison expressions, we can provide constraints more than just the pattern match on each function clause:

```
defmodule Fact do
  def fac(0) do: 1
  def fac(n) when is_integer(n) and n > 0, do:
  ↪   n * fac(n - 1)
end
```

Function Guards (cont.)

- The set of operators and functions that can be called is very limited, the full list is at `https://hexdocs.pm/elixir/guards.html`
- Note that error raised in the guard expression will simply result in match failure, and Elixir will move on to the next clause, e.g. applying `length/1` on a non-list.

Multi-clausal lambdas

Anonymous functions (lambdas) may also consist of multiple clauses:

```
test_num = fn
  0 -> :zero
  x when is_number(x) and x < 0 -> :negative
  x when is_number(x) and x > 0 -> :positive
end
Enum.map(-2..2, test_num)
```

case

- `case` allows us to compare a value against many patterns until we find a matching one.
- Guards can be used also.
- If none of the clauses match, `CaseClauseError` is raised.
- Example:

```
case {1, 2, 3} do
  {4, 5, 6} -> :no_match
  {1, x, 3} when x > 0 -> :match
  _ -> :match_anything
end
x
```

case (cont.)

In fact, we can reimplement our factorial function using `case`:

```
defmodule Fact do
  def fac(n) do
    case n do
      0 ->
        1

      x when is_integer(x) and x > 0 ->
        n * fac(n - 1)
    end
  end
end
```

cond

- Used to check for different conditions and find the first clause that is truthy.
- Similar to if-else if-else clauses in imperative languages.
- Note that idiomatic Elixir uses `cond` very sparingly.
- Example:

```
cond do
  2 + 2 == 5 -> :never_true
  1 + 1 == 2 -> :should_match_this
  true -> :will_match_this_if_all_fail
end
```

`if` and `unless`

- To check for only 1 condition, Elixir provides `if` and `unless` (if not). They are implemented as macros.
- If no block is specified, an implicit `nil` is returned.
- Example:

```
if nil do
  "This won't be seen"
else
  "This will"
end

unless true do
  "This will never be seen"
end
```

Where are we?

Our Old Friend Recursion!

```
defmodule Fact do
  def fac(0), do: 1
  def fac(n) when is_integer(n) and n > 0, do: n *
  ↪  fac(n - 1)
end
```

And Tail Call Recursions!

```
defmodule Fact do
  def fac(n, acc \\ 1) when is_integer(n) and
  ↪  is_integer(acc) and acc > 0 do
    case n do
      0 -> acc
      n when n > 0 -> fac(n - 1, acc * n)
    end
  end
end
```

Where are we?

Enumerable

- Elixir provides the concept of enumerables and the `Enum` module (`https://hexdocs.pm/elixir/Enum.html`) to work with them using higher order functions.
- Example:

```
# Allow us to use macros in Integer module
require Integer
Enum.reduce(Enum.filter(Enum.map(1..100_000,
↪  &(&1 * 3)), &Integer.is_even/1), 0, &+/2)
Enum.sum(Enum.filter(Enum.map(1..100_000, &(&1
↪  * 3)), &Integer.is_even/1))
```

The Pipe Operator

- In my opinion, the best feature that Elixir has!
- The pipe operator `|>` takes the output from the left side and passes it as the first argument to the function call on the right side.
- Similar to Unix shell `|` operator.
- Clear pipeline of transformation of data.
- Example:

```
require Integer
1..100_000
|> Enum.map(&(&1 * 3))
|> Enum.filter(&Integer.is_even/1)
|> Enum.sum()
```

Where are we?

Streams

- Enumerables are eager. Elixir provides a lazy alternative: the `Stream` module (`https://hexdocs.pm/elixir/Stream.html`)
- They are composable too.
- Examples:

```
stream = Stream.cycle([1, 2, 3])
stream |> Stream.take(4) |> Enum.to_list()
require Integer
1..100_000 |> Stream.map(&(&1 * 3)) |>
↪  Stream.filter(&Integer.is_odd/1)
```

Where are we?

Comprehension

- Similar concept to Python's list comprehension, but on steroids (with pattern matching)
- Example:

```
values = [good: 1, good: "a", bad: 3, good: 4]
for {:good, n} when is_number(n) <- values, do:
↪   n * n
```

- Besides pattern matching and guards, filter expression can be used too:

```
multiple_of_3? = fn n -> rem(n, 3) == 0 end
for n <- 0..5, multiple_of_3?.(n), do: n * n
```

Comprehension (cont.)

- Comprehensions also allow multiple generators and filters:

```
dirs = ['/tmp/', '/usr/lib']
for dir <- dirs,
    file <- File.ls!(dir),
    path = Path.join(dir, file),
    File.regular?(path) do
  File.stat!(path).size
end
```

Comprehension (cont.)

- Using `:into`, result of a comprehension can be inserted into different data structures:

```
for <<c <- " hello world ">>, c != ?\s, into:
↪   "", do: <<c>>

for {key, val} <- %{"a" => 1, "b" => 2}, into:
↪   %{}, do: {key, val * val}
```

Comprehension (cont.)

Using comprehension, we can even implement quicksort!

```
defmodule Sort do
  def qsort([]) do
    []
  end

  def qsort([x | xs]) do
    qsort(for a <- xs when a < x) ++ [x] ++
    ↪  qsort(for a <- xs when a >= x)
  end
end
```

Where are we?

Struct

- Extensions built on top of maps that provide compile-time checks and default values.
- Defined using **defstruct** construct:

```
defmodule User do
  defstruct name: "John", age: 27
end

%User{}
%User{oops: :field}
jane = %User{age: 10, name: "Jane"}
%{jane | age: 11}
%{name: name} = jane
name
jane.name
is_map(jane)
```

Struct (cont.)

- In Phoenix Framework, ecto data are abstracted as a struct.
- However, ecto provides us with special constructs (using macros) to specify the struct fields, so typically in using the Phoenix Framework, we rarely need to use `defstruct`
- However, other syntaxes such as initialising a struct, updating a field, etc. are still used extensively.

Where are we?

Protocol

- A mechanism in Elixir to achieve polymorphism.
- Dispatching on a protocol is available to any data type as long as it implements the protocol.
- Defined using **`defprotocol`**
- Example:

```
defprotocol Size do
  @doc "Calculates the size (not the length!)
   ↪  of a data structure"
  def size(data)
end
```

- the `Size` protocol expects a 1-arity function called `size` to be implemented.

Protocol (cont.)

- Implementation is defined using `defimpl`

```
defimpl Size, for: BitString do
  def size(string), do: byte_size(string)
end

defimpl Size, for: Map do
  def size(map), do: map_size(map)
end

defimpl Size, for: Tuple do
  def size(tuple), do: tuple_size(tuple)
end
```

Protocol (cont.)

- With the protocol and implementation defined, we can start using it.
- Passing a data type that doesn't implement the protocol raises **`Protocol.UndefinedError`**.

```
Size.size("foo")
Size.size({:ok, "Hello"})
Size.size(%{label: "some label"})
Size.size([1, 2, 3])
Size.size(%User{})
```

- Protocols can be implemented for all Elixir data types, as well as user-defined structs:

```
defimpl Size, for: User do
  def size(_user), do: 2
end
```

Protocol (cont.)

- Elixir ships with some built-in protocols.
- For example, `Enum` module provides functions that work with any data structure that implements the `Enumerable` protocol.

Where are we?

Sigils

- Like Perl and Ruby, Elixir has sigils too.
- Strings are delimited by double-quotes. Double-quotes inside a string must be escaped.
- These kinds of representation problems is what sigils try to solve.
- Unlike Perl and Ruby, Elixir only allows a limited set of delimiters: `//`, `||`, `""`, `''`, `()`, `[]`, `{}`, `<>`

String, Charlist, Word List Sigils

- `s` sigil is used to generate string
- `c` sigil is used to generate char lists
- `w` sigil is used to generate lists of words (separated by whitespace).
- The `w` sigil also accepts the `c`, `s`, `a` modifiers (for char lists, strings and atoms respectively) to specify the data type of the elements of the resulting list.

String, Charlist, Word List Sigils (cont.)

```
~s(a string with "double quotes")
~c|a charlist with 'single quotes' and
 ↪  (parantheses)|
~w(foo bar bat)
~w(ok error)a
```

Regular Expressions

- Elixir provides Perl-compatible regexes, as implemented by the PCRE library.
- **A word of caution**: "Some people, when confronted with a problem, think I know, I'll use regular expressions. Now they have two problems" (Zawinski, 1997)[7]
- There exists a `Regex` module in Elixir, as well as the regex match operator `=~`, and the `~r` sigil to specify precompiled regex.

[7] There is also an interesting read at `https://blog.codinghorror.com/regular-expressions-now-you-have-two-problems/`

Regular Expressions

```
regex = ~r/foo|bar/
"foo" =~ regex
"bar" =~ regex
"bat" =~ regex
```

Where are we?

Typespec

- One advantage of using Elixir is that we can use tooling for Erlang, a 30 years old language.
- This includes type specs, a system of notating types in Erlang/Elixir.
- The Elixir compiler doesn't do type check, but one can use the `dialyzer` tool to perform type check.
- Owing to its age, `dialyzer` is more mature than, say, `mypy`, especially in terms of type inference[8]

[8] More information on Erlang type inference in `https://it.uu.se/research/group/hipe/papers/succ_types.pdf`

Typespec (cont.)

- Not compulsory, but being able to read type spec helps a lot in reading documentation.
- Some code that I wrote in Source Academy have type specs.
- In source code, typically notated using module attribute `@spec`
- More information in `https://hexdocs.pm/elixir/typespecs.html`

Where are we?

Structure

- Phoenix Framework:
  - Router
  - Plugs
- MVC
  - Model
    - Contexts: inside `lib/cadet/`
    - Migrations: inside `priv/repo/migrations/`
    - Seeds: inside `priv/repo/seeds.exs`
  - View: `lib/cadet_web/views/` – renders json
  - Controller: inside `lib/cadet_web/controllers/`

Structure (Cont.)

- Jobs: inside `lib/cadet/jobs/`
  - Updater, XML Parser
  - Autograder
- Mix tasks for convenience: inside `lib/mix/tasks/`
- Config files: inside `config/`
- Tests: 98% test coverage. Every feature are tested.